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3D Modeling of Urban Groundwater Recharge from Stormwater Infiltration basins

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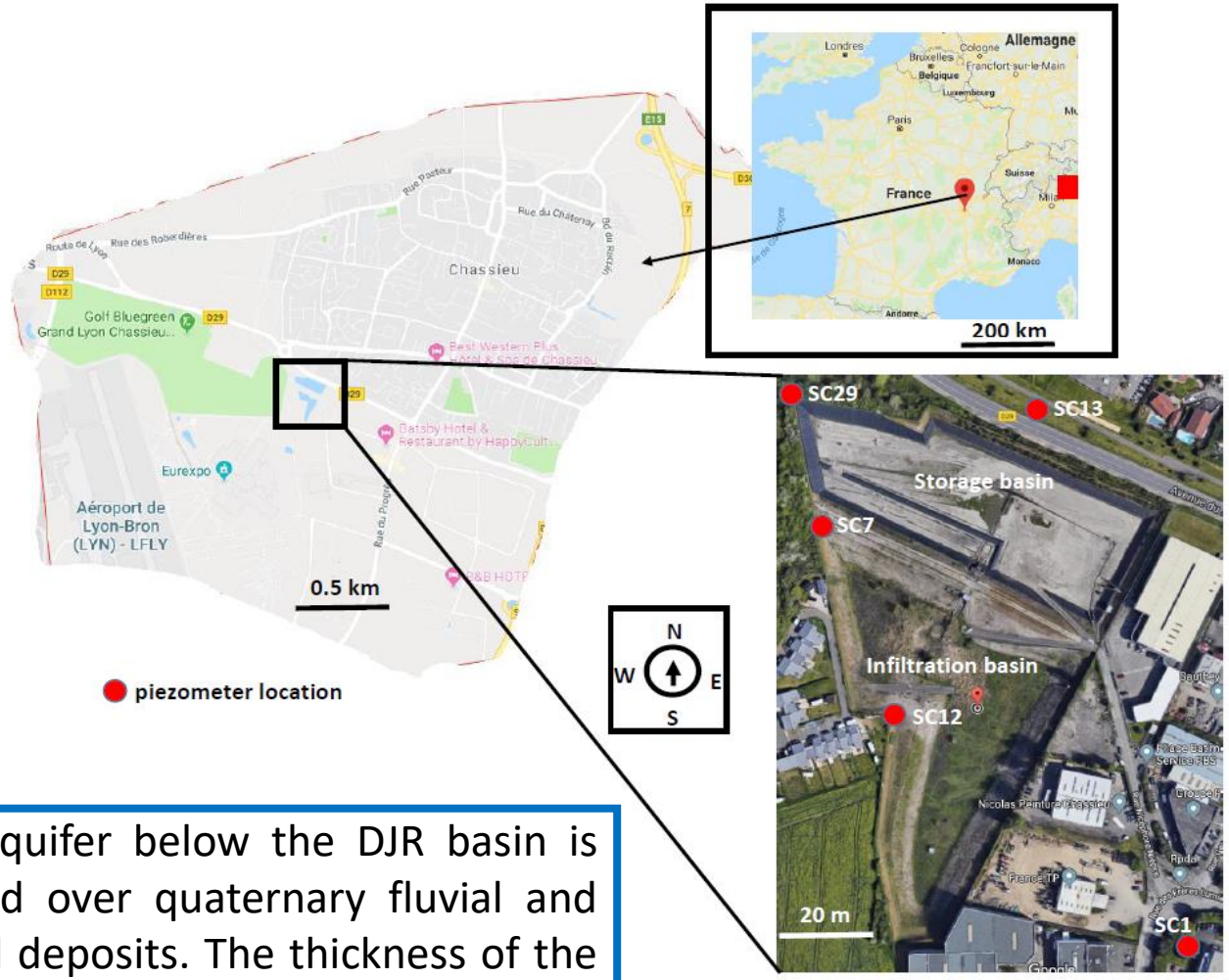
Objective

- Simulate the operation of MAR in terms of water transfers and contaminants in a realistic 3D geometry: Example of the **Django-Reinhardt** basin (Chassieu, France)
- To study the effect of the control **piezometers** location on the estimation of water and pollutant fluxes:

What is the significance of concentrations estimated using punctual integrative samplers (chemcatcher) implemented in piezometer?

Django Reinhard infiltration basin (experimental site of OTHU)

Presentation of study site: The Django Reinhard (DjR) infiltration basin (Chassieu, France)



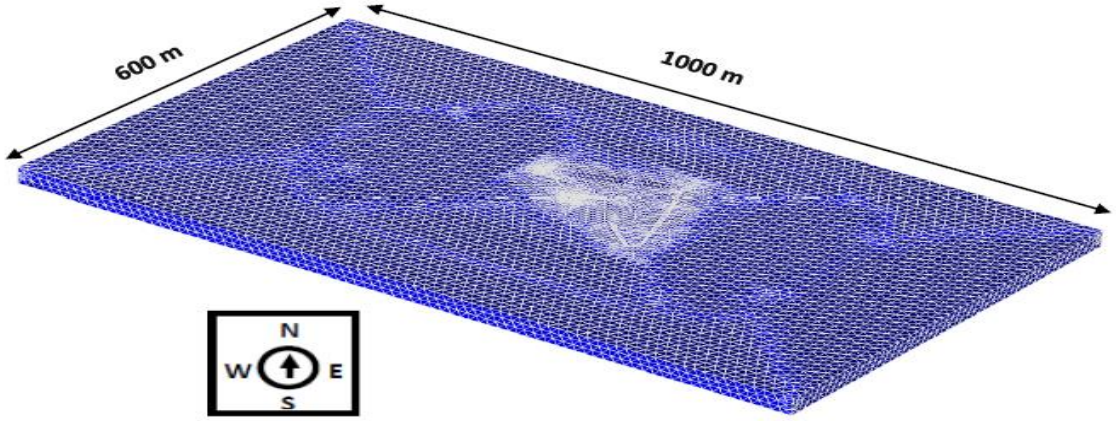
The aquifer below the DJR basin is located over quaternary fluvial and glacial deposits. The thickness of the deposits is 30 m

This site is well instrumented by the OTHU (Field Observatory for Urban Hydrology) and measurements of the flow and environmental parameters (turbidity, PH, conductivity, temperature) in the basin are available (every 2 minutes)

Groundwater level, electrical conductivity (EC) and groundwater temperature are measured continuously (every hour) using multiparameter probes

Presentation of the 3D numerical model

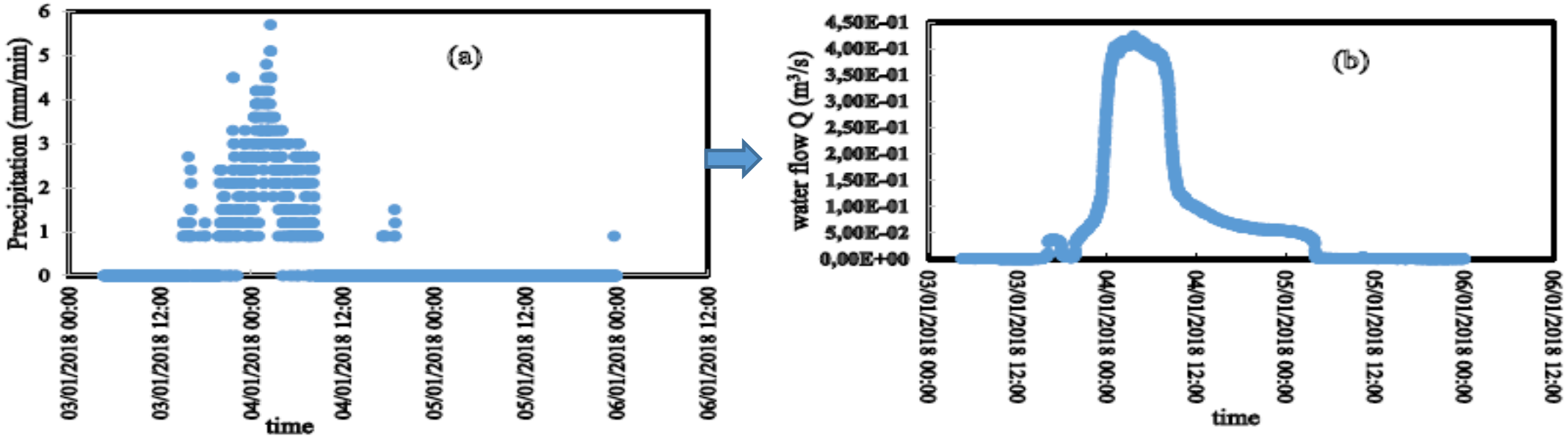
- The geometry of the basin was built from the DEM data of the National Geographic Institute (resolution of the digital elevation model is 1 m)
- The well-known Richard model is used to simulate the flow in the saturated and unsaturated zone of the study site
- Imposed flow applied on the basin surface calculated through the mass balance based on surface data (Q, H, topography)
- The transfer of solutes in the basin/aquifer system is modelled by the advection-dispersion equation (ADE) - 1st step, ADE calibration using EC data – 2nd step transport of a tracer



three dimensional model of the Django Reinhardt experimental site including the infiltration basin and aquifer domain

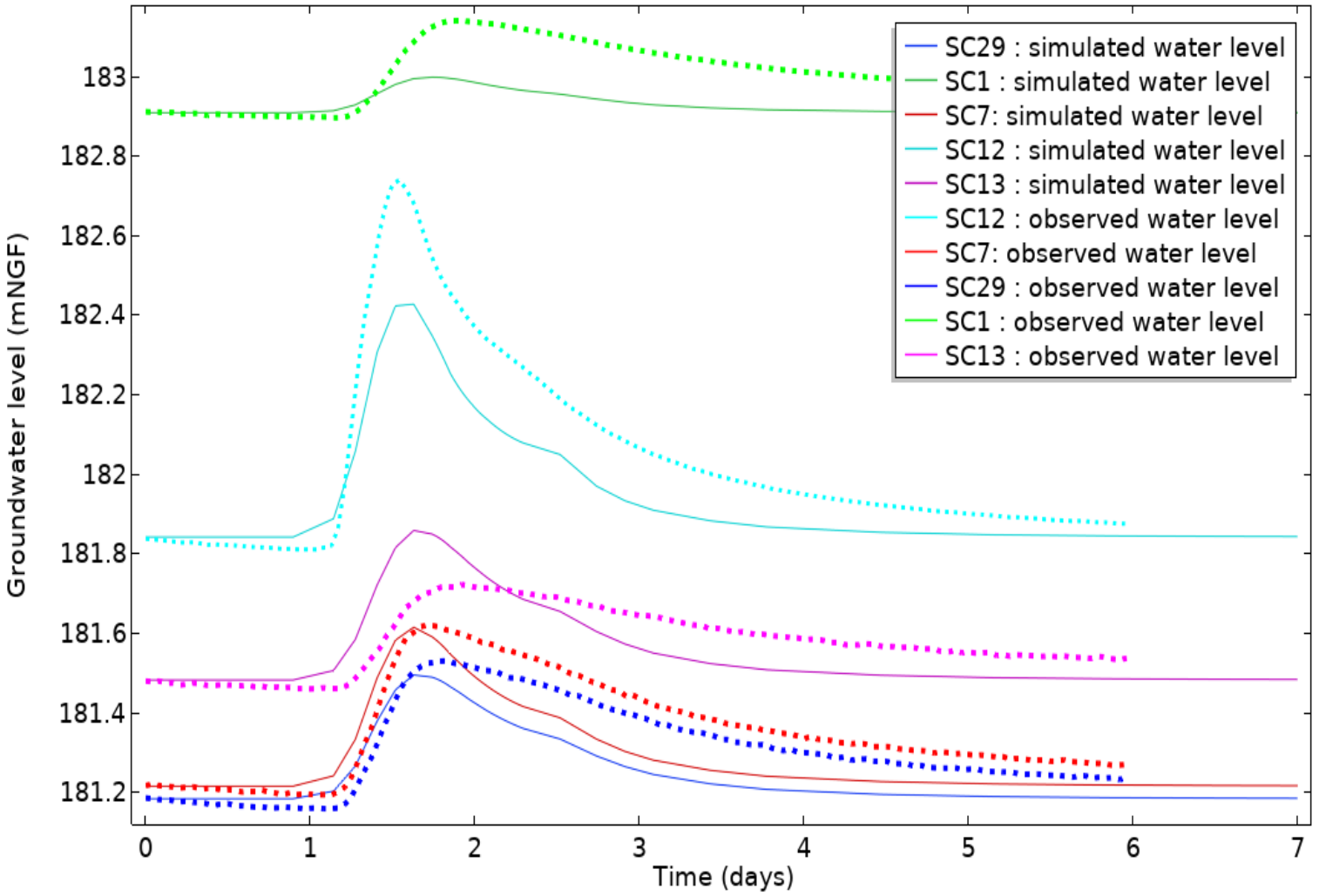
Selection of the reference rainy episode

- The reference rainy episode was chosen from the data measured by the OTHU around Django Reinhardt's site over the period 2016-2018
- The choice of the rainy event was made according to its intensity and its duration to influence significantly the aquifer in terms of recharge



(a) intensity of rain during the rainy episode (b) water flow at the inlet of the basin

Calibration of 3D groundwater flow model: comparison between observed and simulated piezometric levels



- the simulations are carried out over 7 days: 1.8 days for the rainy episode and the rest to observe the relaxation of the system after the rain
- Main parameters of the flow model to be calibrated are the horizontal and vertical permeability and the effective porosity

Kh (m^2)	$9x10^{-10}$
Kv (m^2)	$8x10^{-11}$
ε_{eff}	0.13

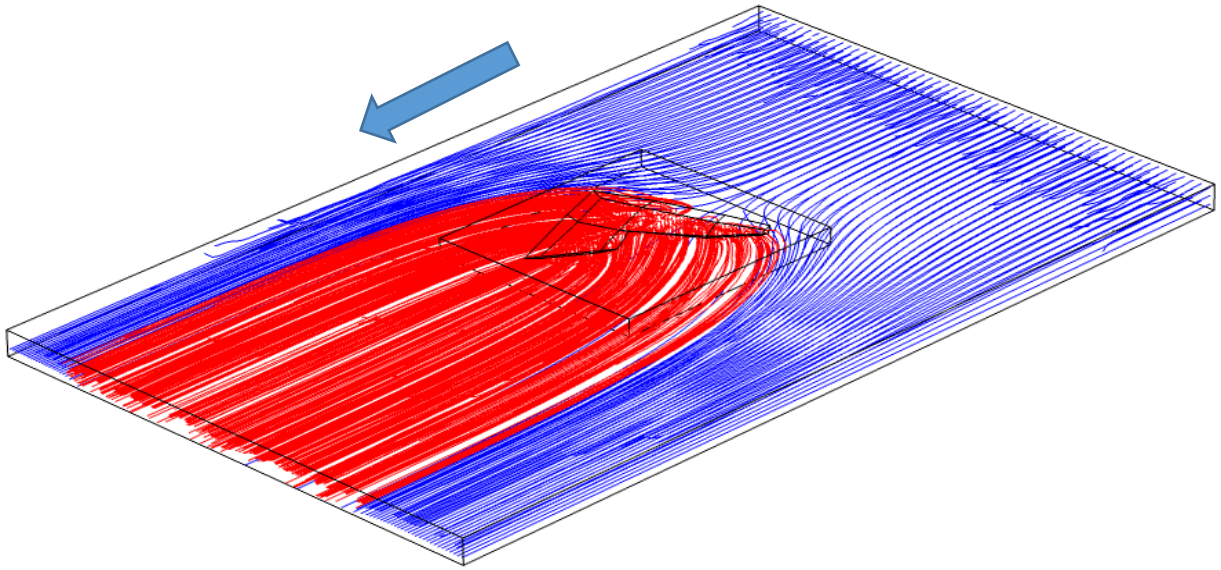
- Reasonable restitution of the measured data in view to the complexity of the real system

3D water flow distribution during the infiltration process

current line from aquifer

current line from basin

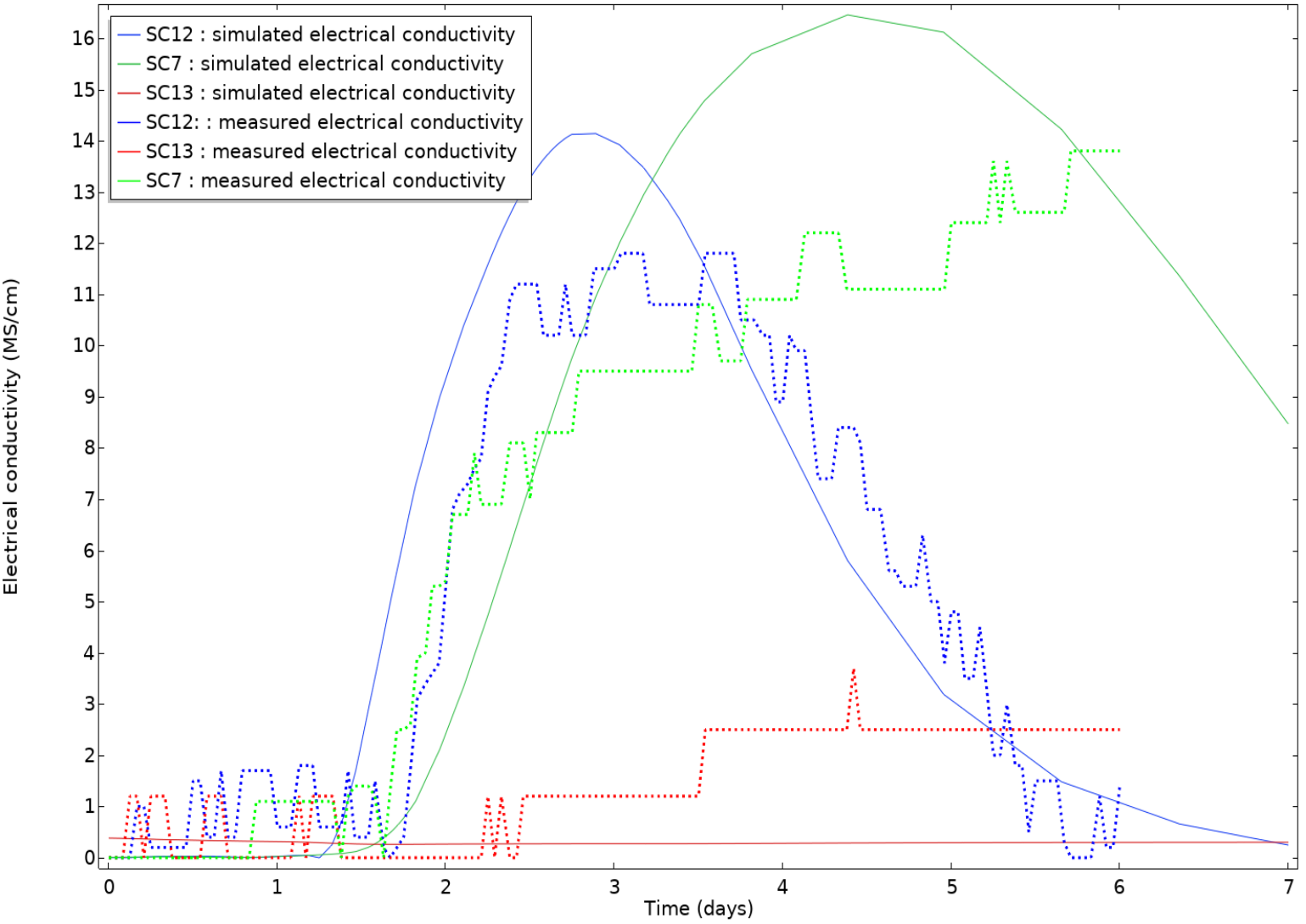
Flow direction



this image including the current lines coming from the basin and the aquifer show the 3D flow profile at the maximum of recharge (recharge after time of 1.5 days)

at the maximum of recharge, it is observed that the flow profile under the basin is the result of the impact of the geometric shape of the basin

Calibration of 3D transport model: comparison between observed and simulated electrical conductivity



- Calibration of the ADE model on the reference rainy episode
- Electrical conductivity was used to calibrate the transport properties (Approximate method)
- Main parameters of the transport model to be calibrated are the longitudinal dispersivity and the transversal dispersivity

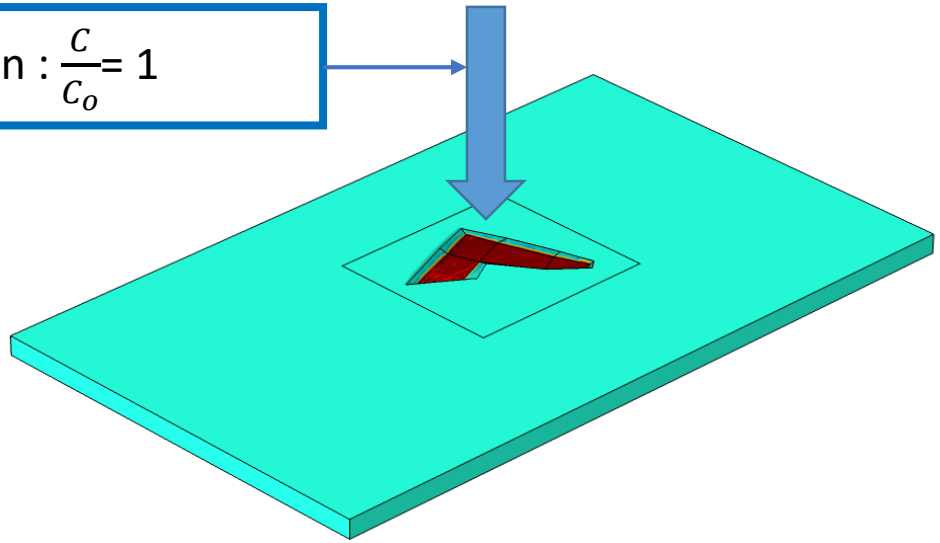
Longitudinal dispersivity α_L	2 m
Transverse dispersivity α_T	0.03 m

Simulations reproduce fairly well the electrical conductivity (intensity and dynamics) observed in control piezometers

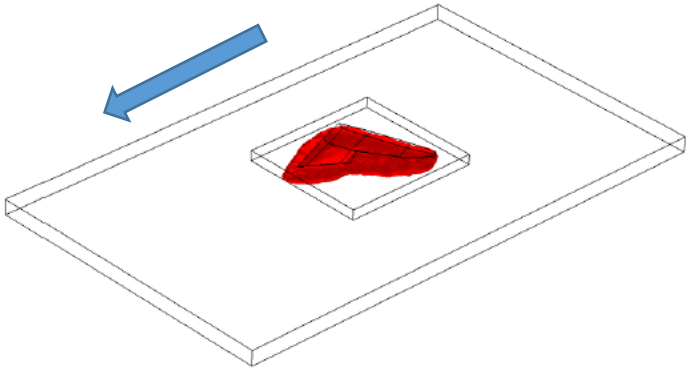
Simulation and analysis of the fate of a tracer infiltrated in the aquifer via the basin: case of the DjR experimental site

- The fate of a pollutant considered as a tracer (most critical case) was simulated during the reference rainy episode
- The 3D simulations make it possible to highlight the effect of the observation points location and the representativity of the measurements made in the field
- Computation of concentration averaged on 10 days (C_m) to mimic punctual integrative samplers located in piezometers

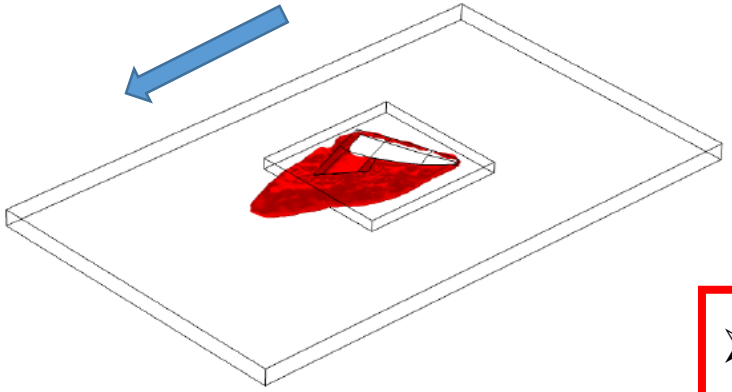
Injected concentration during the rain : $\frac{C}{C_o} = 1$



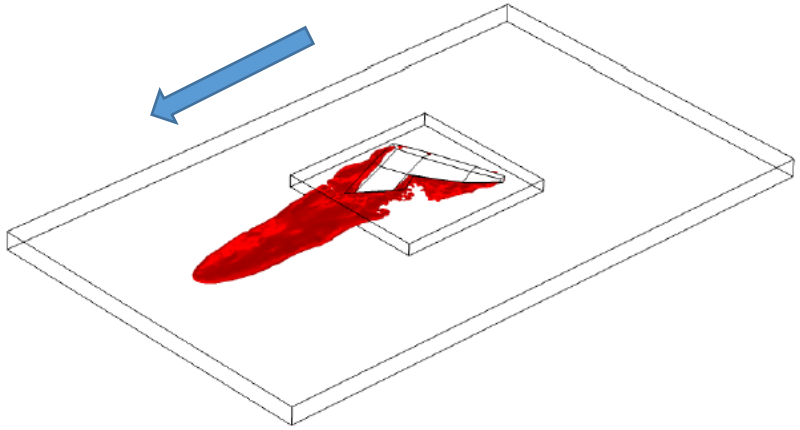
Evolution of the pollutant plume during the infiltration-drainage process



Pollutant plume, after time = 2 day



Pollutant plume, after time = 5 day

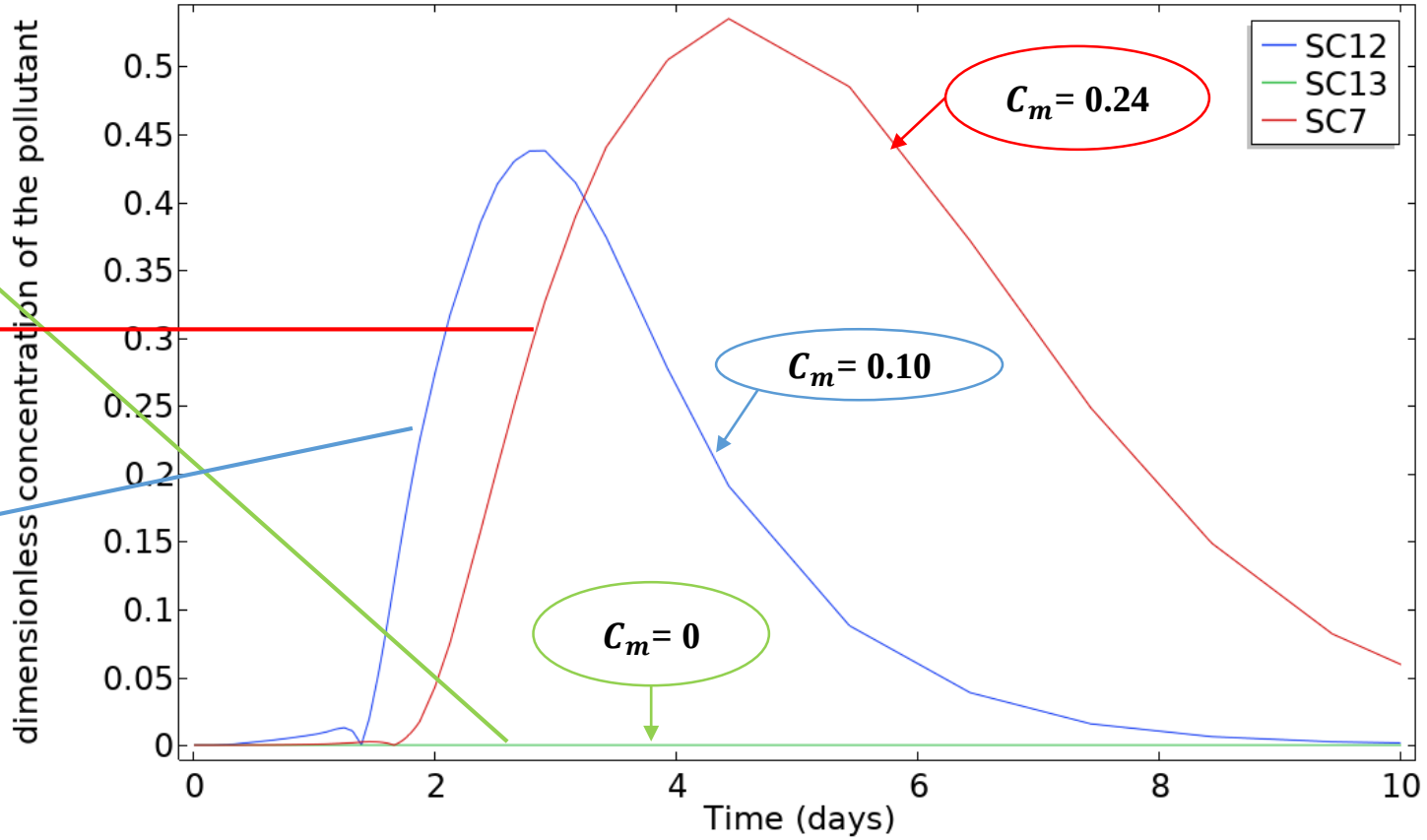


Pollutant plume, after time = 10 day

- Influence of the basin shape on the pollutant plume
- Progressive transport and dilution of the plume downstream the basin
- Prediction of pollutant entrapment in the vadose zone due to flow slow down at the end of the drainage (capillary entrapment)

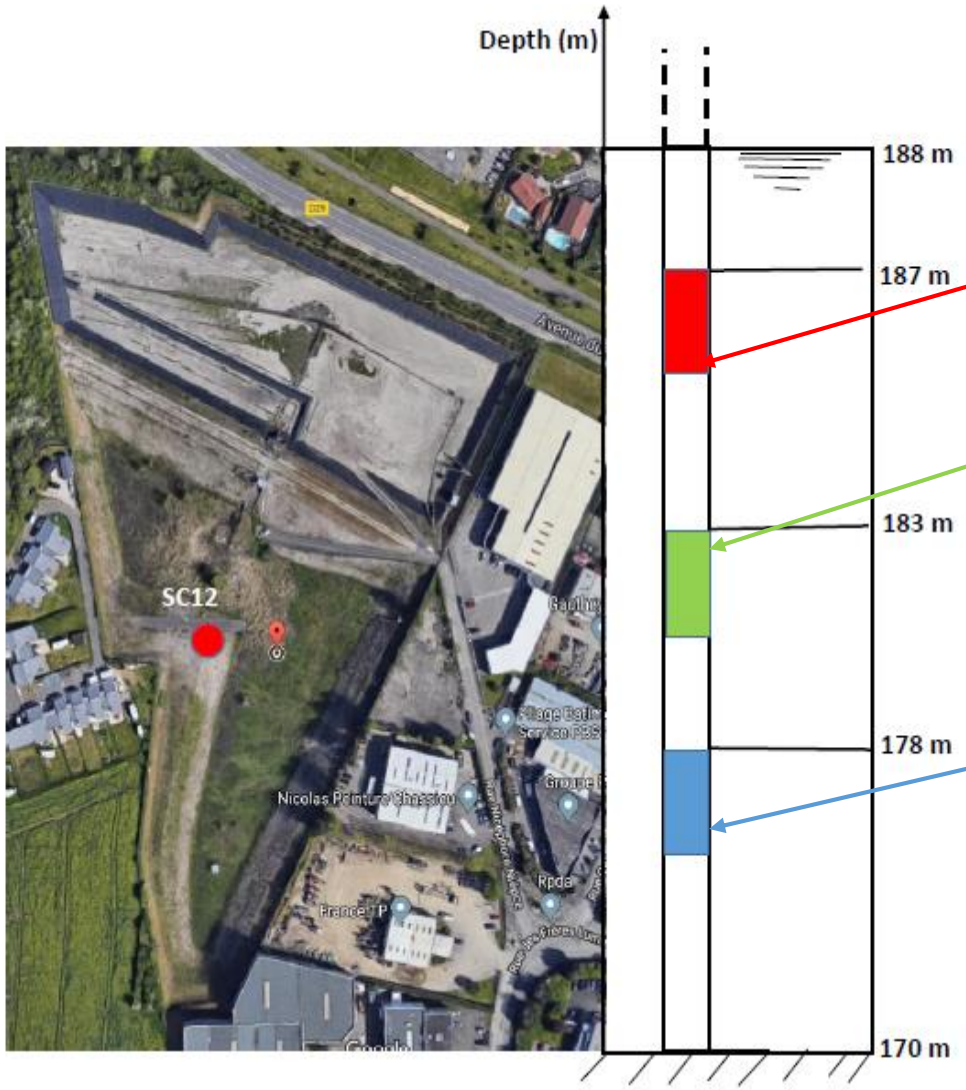
Evolution of isovalues at C = 0.2 during the rain event

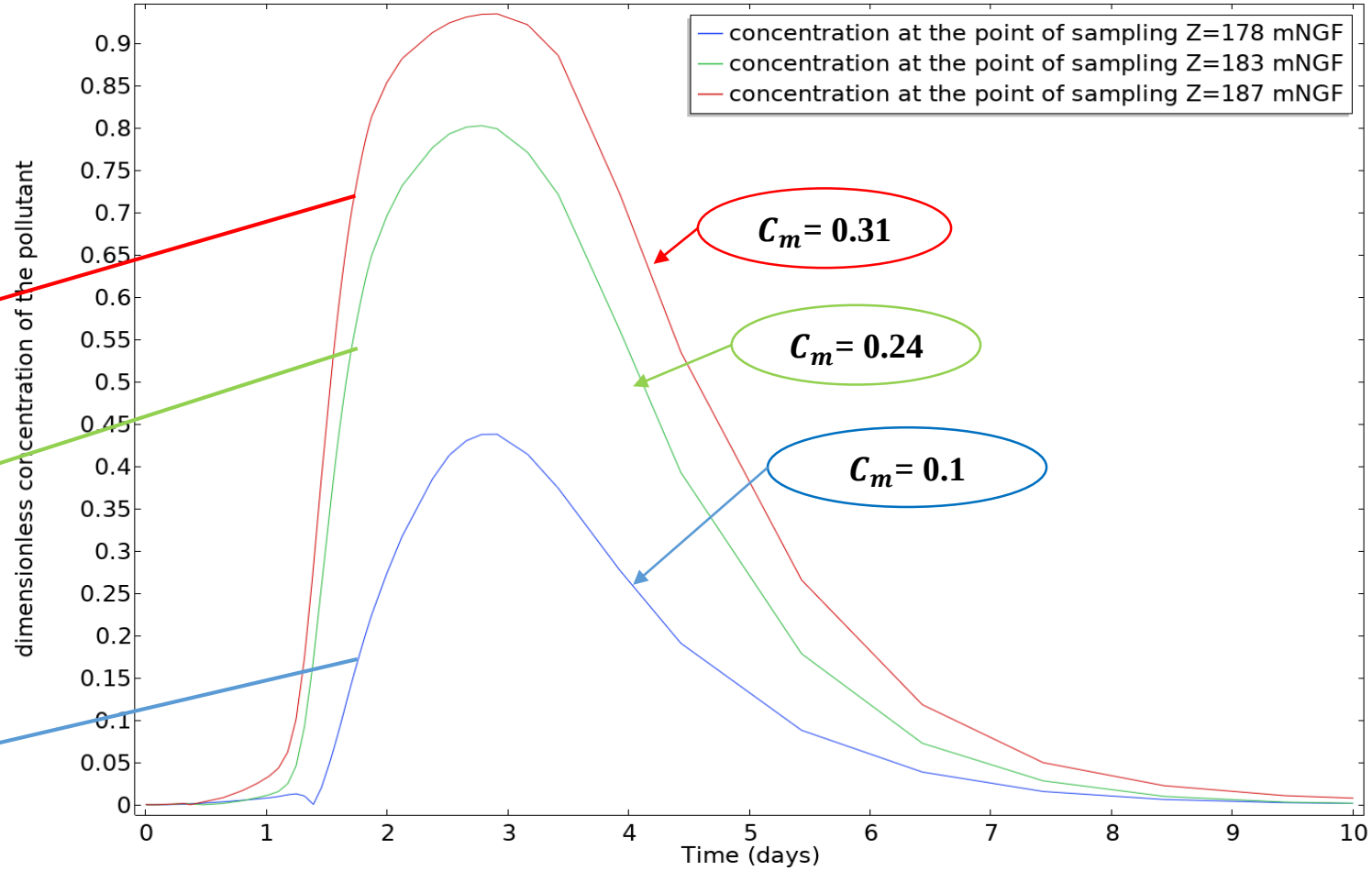
Effect of piezometer locations on the estimate of pollutant fluxes



A spatial variation of C_m between 0 and 24% of the injected concentration is observed depending on the location of the piezometers ➡ information of interest to interpret punctual measurements carried out in the field

Effect of the probe depth on the control of pollutant flows





An average variation of 40% of C_m is observed by varying the depth of the probe of ± 5 m ➡ information of interest to positioning the multiparameter probe in the site

Conclusions

- A 3D model of the vadose zone/aquifer system is implemented to simulate the fate of water and pollutant in stormwater infiltration basins located in Chassieu (Lyon area, France).
- The 3D flow and transport model developed was calibrated according to field measurements (piezometric levels and electrical conductivity)
- A Characterization of the flows and concentrations in the control piezometers is carried out by post-treatment of the 3D calculation

➡ Effect of piezometer location : 0 to 24% of the injection concentration could be recovered depending on the orientation of the basin with the main aquifer flow direction

➡ Effect of the probe depth: Cm decreases by 40% if the measuring probe is lowered by 5 m

Perspectives

- The proposed 3D model could be extended to take into account pollutant sorption and biodegradation in order to compare with data on chemical concentration observed in the aquifer
- Such a modeling approach could be useful to design infiltration basin with respect to the type of soil and aquifer (depth, permeability, thickness)
- The ADE model developed could be considered while analyzing measurements obtained from punctual integrative chemical sensors (chemcatcher) implemented in control piezometer because it provides additional quantitative information on the quantity of pollutant fluxes

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Thank you for your kind attention