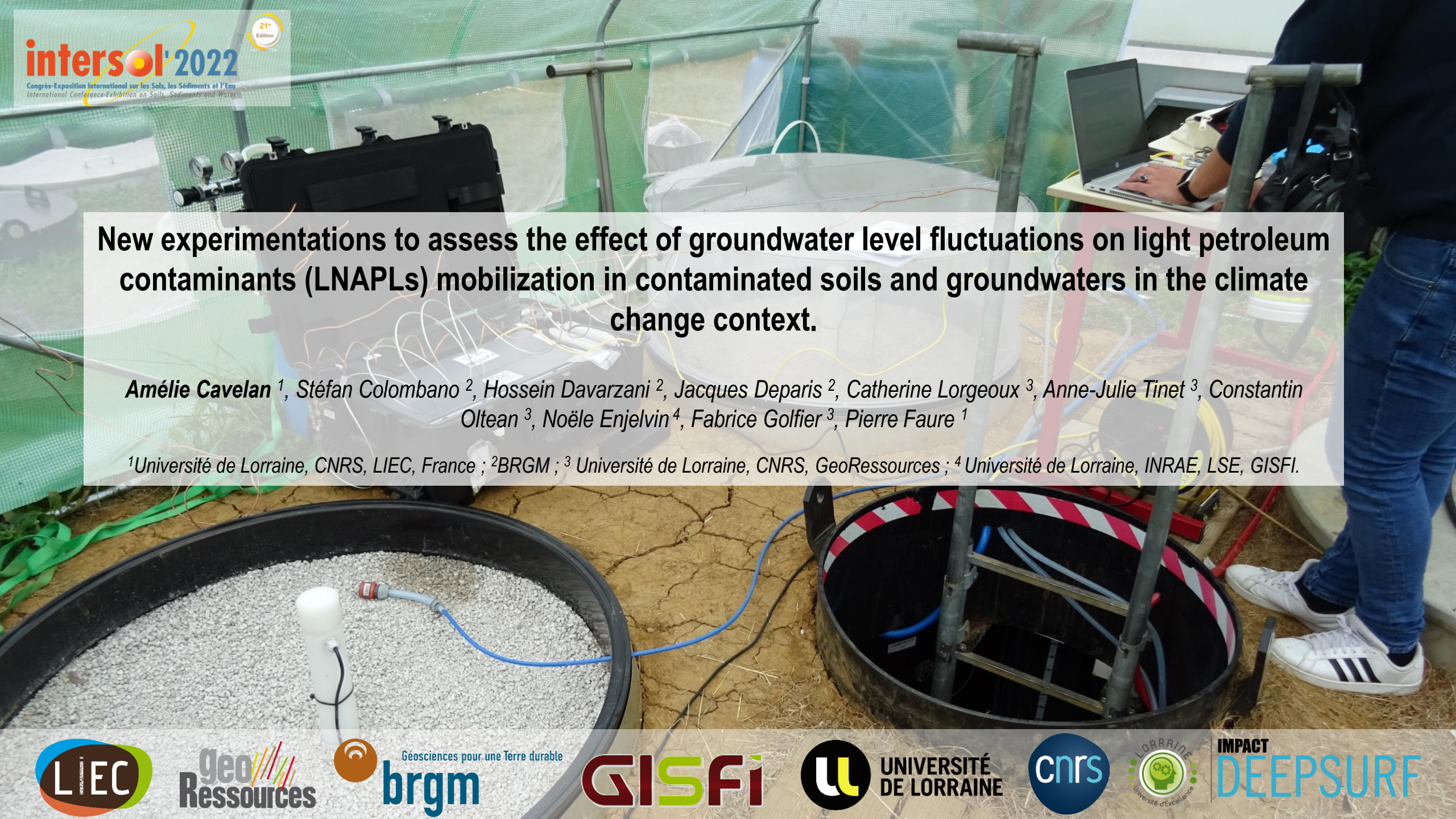


intersol 2022
21e Edition
Congrès-Exposition International sur les Sols, les Sédiments et l'Eau
International Conference-Exhibition on Soils, Sediments and Water

New experimentations to assess the effect of groundwater level fluctuations on light petroleum contaminants (LNAPLs) mobilization in contaminated soils and groundwaters in the climate change context.

Amélie Cavelan [1], *Stéfan Colombano* [2], *Hossein Davarzani* [2], *Jacques Deparis* [2], *Catherine Lorgeoux* [3], *Anne-Julie Tinet* [3], *Constantin Oltean* [3], *Noële Enjelvin* [4], *Fabrice Golfier* [3], *Pierre Faure* [1]

[1]*Université de Lorraine, CNRS, LIEC, France ;* [2]*BRGM ;* [3] *Université de Lorraine, CNRS, GeoRessources ;* [4] *Université de Lorraine, INRAE, LSE, GISFI.*

LIEC · GeoRessources · Géosciences pour une Terre durable brgm · GISFI · Université de Lorraine · cnrs · Lorraine Université d'Excellence · IMPACT DEEPSURF

Light Non-Aqueous Phase Liquids (LNAPLs)

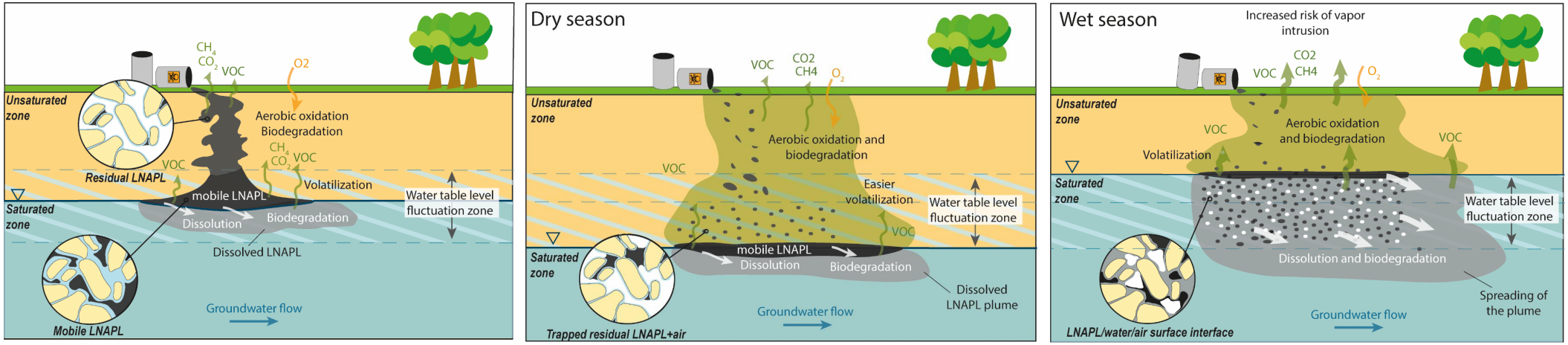
- 37% of soil and groundwater contaminations (EEA, 2019)
- Accidental release of fuel, diesel oil, crude oil, etc.
- Hydrophobic, non-ionic and low density than water

Contamination of water by fuel

Diesel + water

Groundwater table fluctuations and climate change

- Groundwater table fluctuations affect the LNAPL remobilization



Cavelan et al., 2022

Effect of groundwater table fluctuation intensity?

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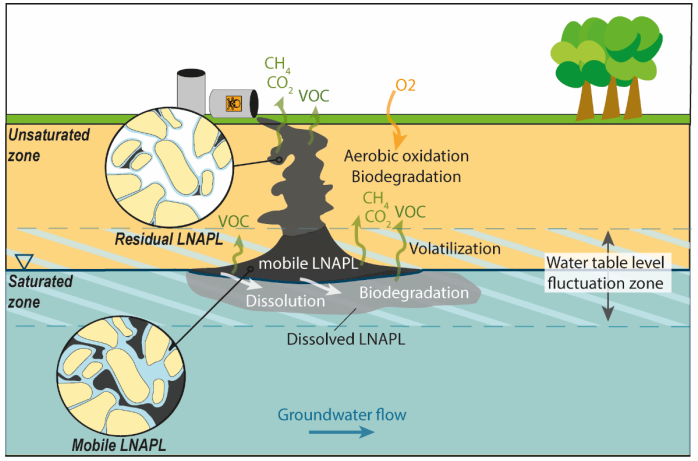
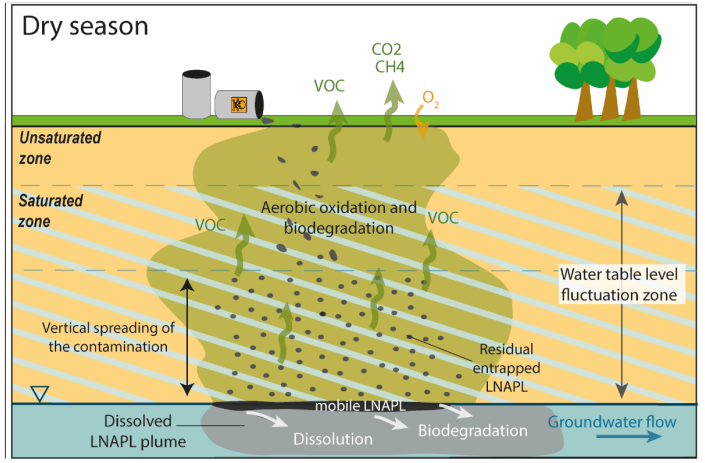
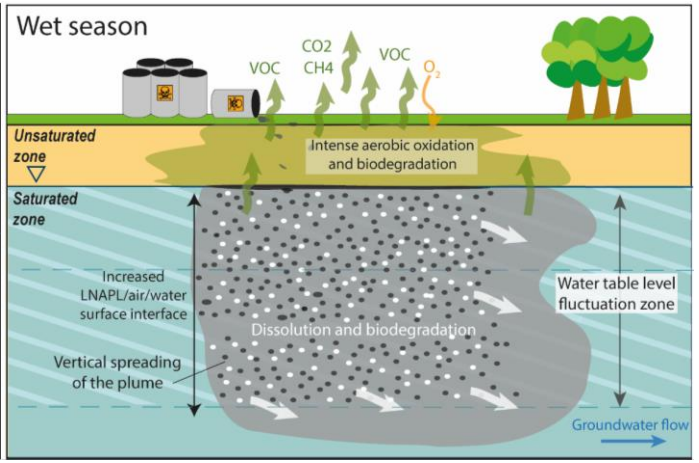






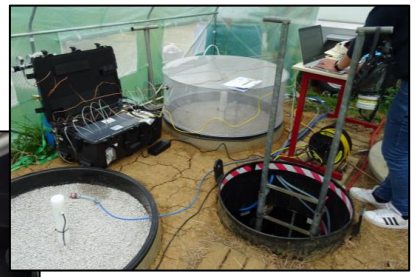
Cavelan et al., 2022

Effect of groundwater table fluctuation intensity?

Our objectives:

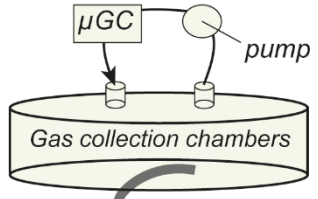
- Understanding the impact of groundwater table fluctuations intensity on LNAPL remobilization processes
- Improve in situ monitoring methods

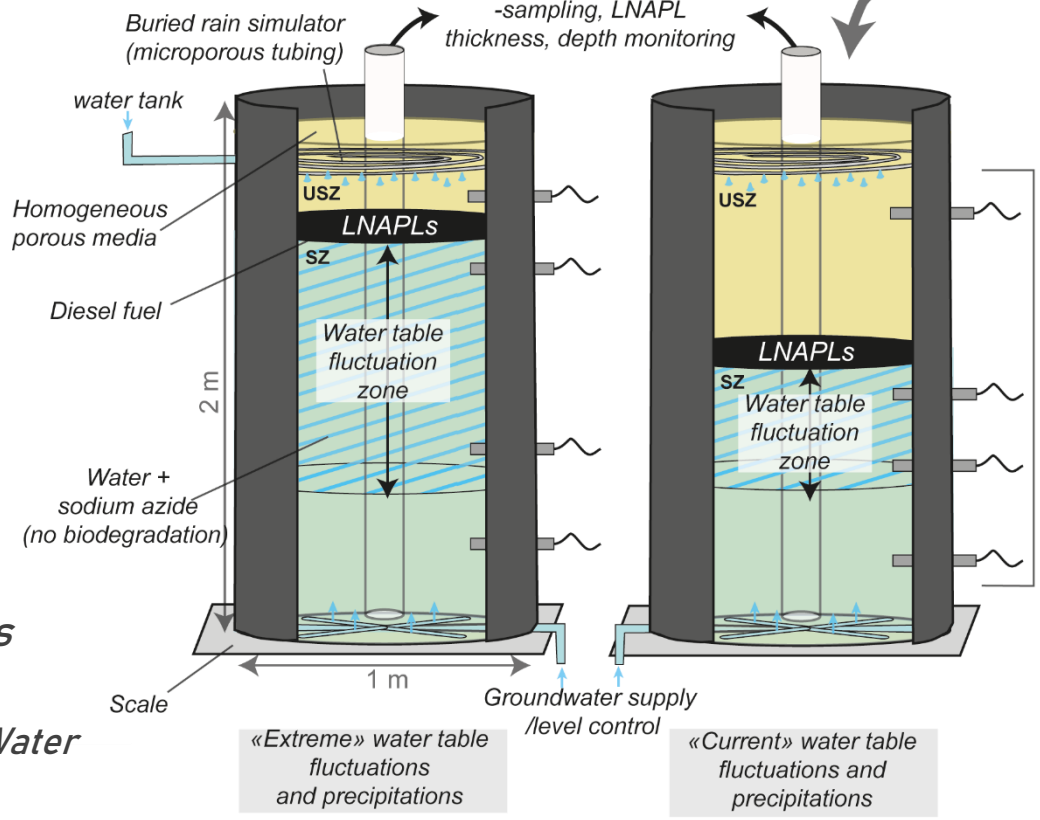
THE SCIENTIFIC APPROACH/The experimental system



Gases

Gas fluxes and composition
(O_2, CO_2, CH_4, hydrocarbons)

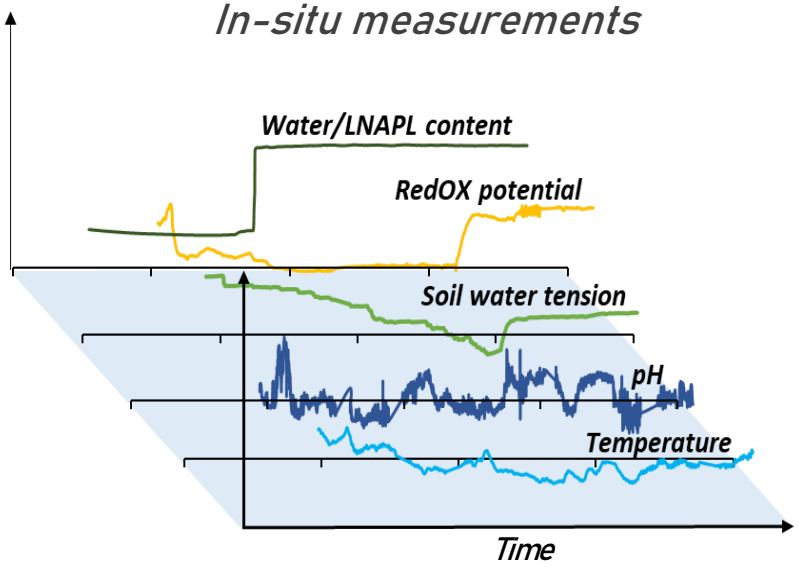




Sensors:
- pH, Redox
-Temperature
-Tensiometers
-Permittivity
-Electrical conductivity

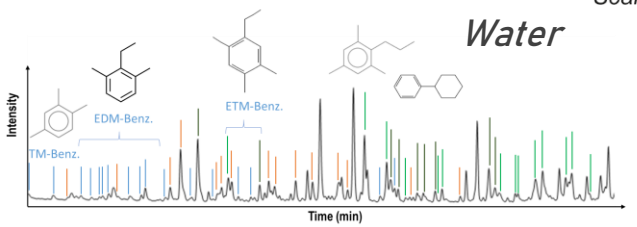
Suction cups:
- Dissolved organic carbon
-Hydrocarbons (SPE, GC-MS, FTIR)

In-situ measurements

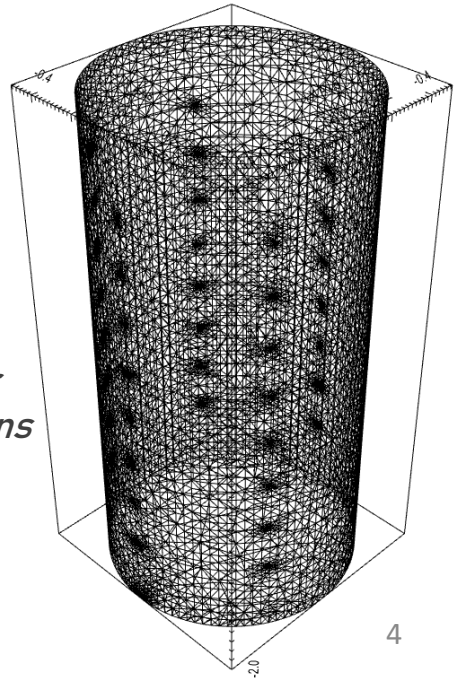


Ex-situ measurements

Water

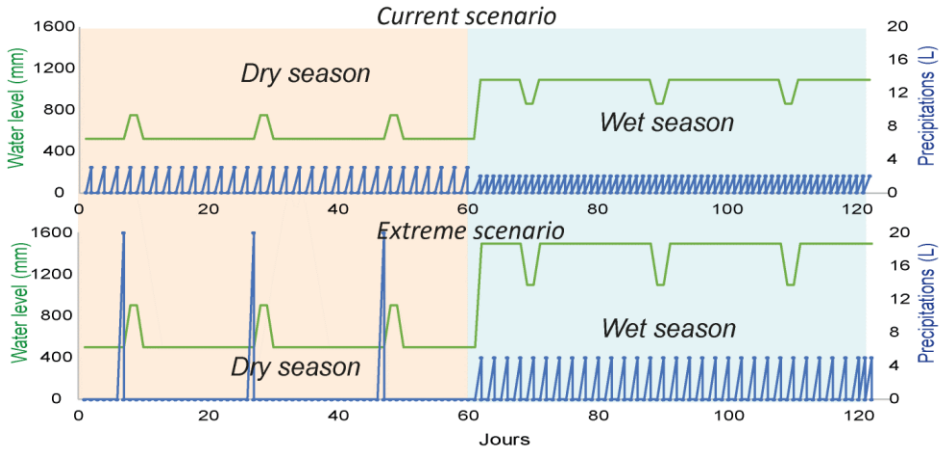


LNAPL/water soil saturations

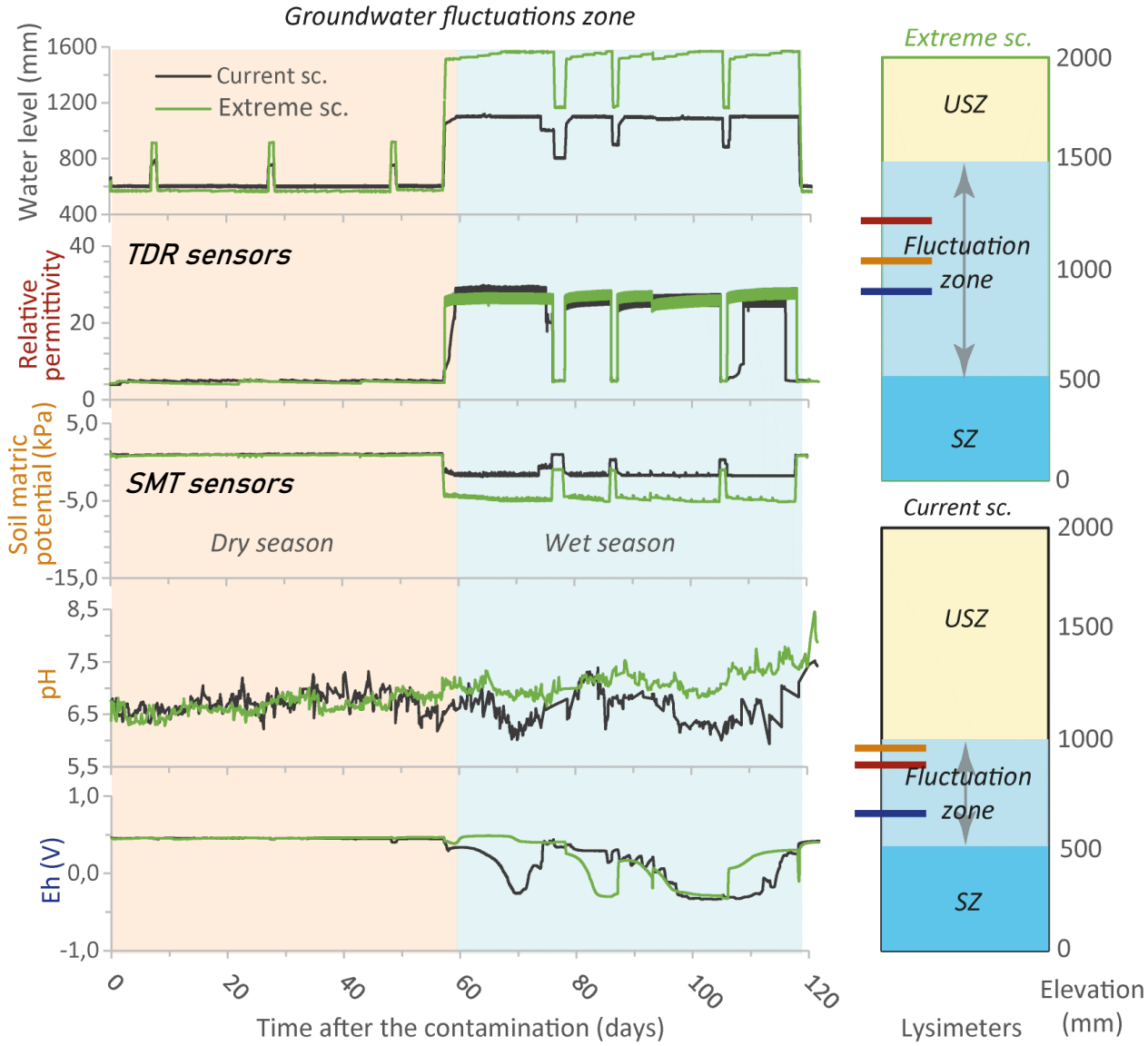


14-months-long monitoring
2 scenarios of water table fluctuations and precipitations

FIRST RESULTS/ Sensors efficiency and calibrations



Variations of the soil properties during the two scenarios



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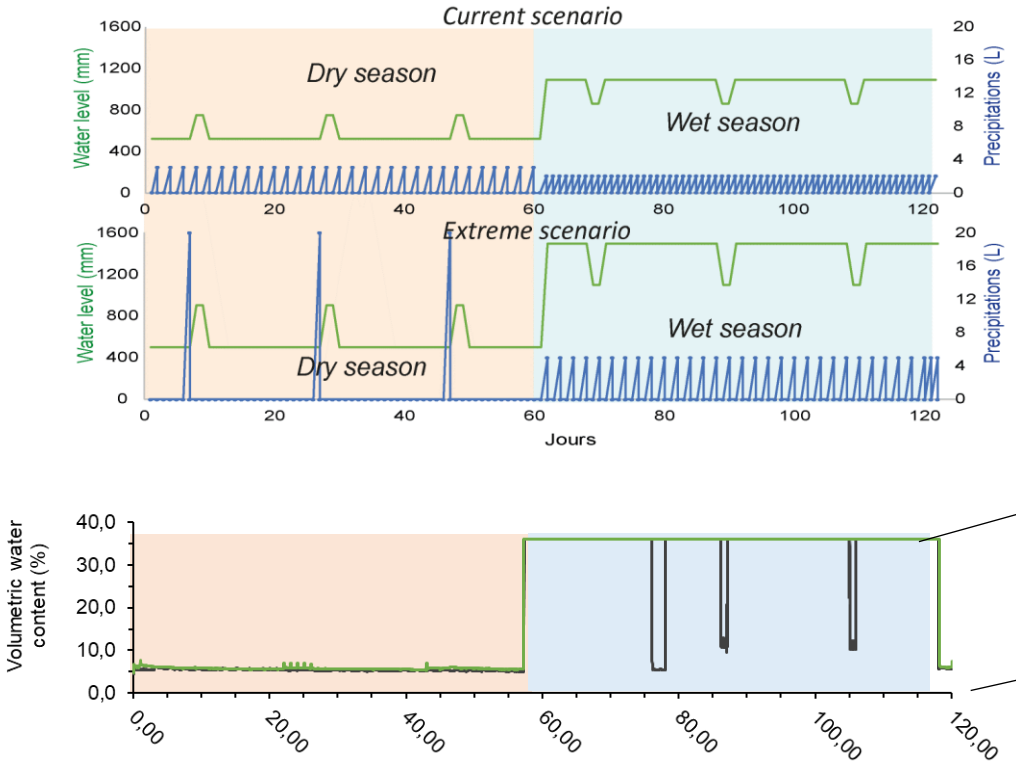
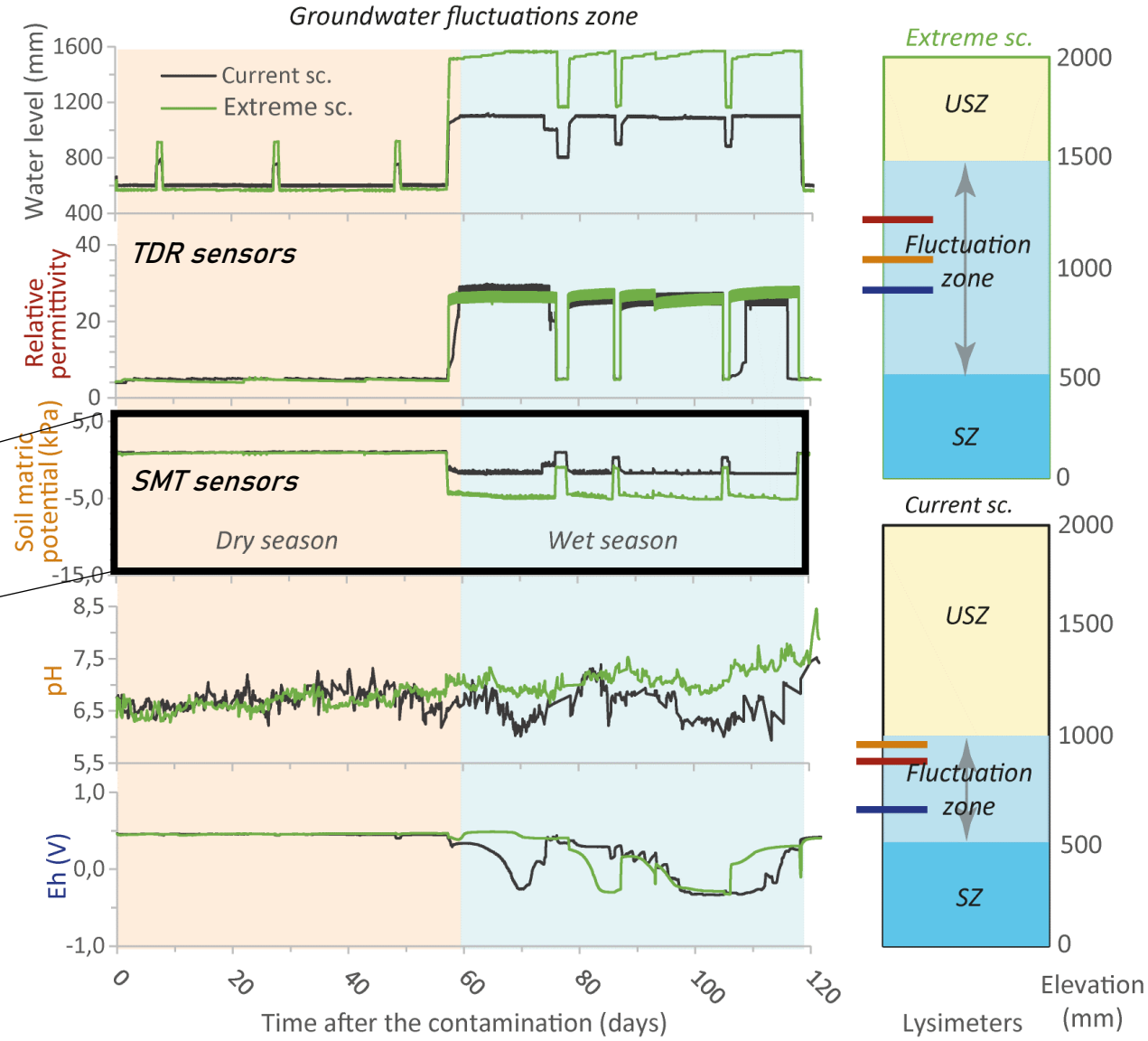


Volumetric water content (%)

Variations of the soil properties during the two scenarios



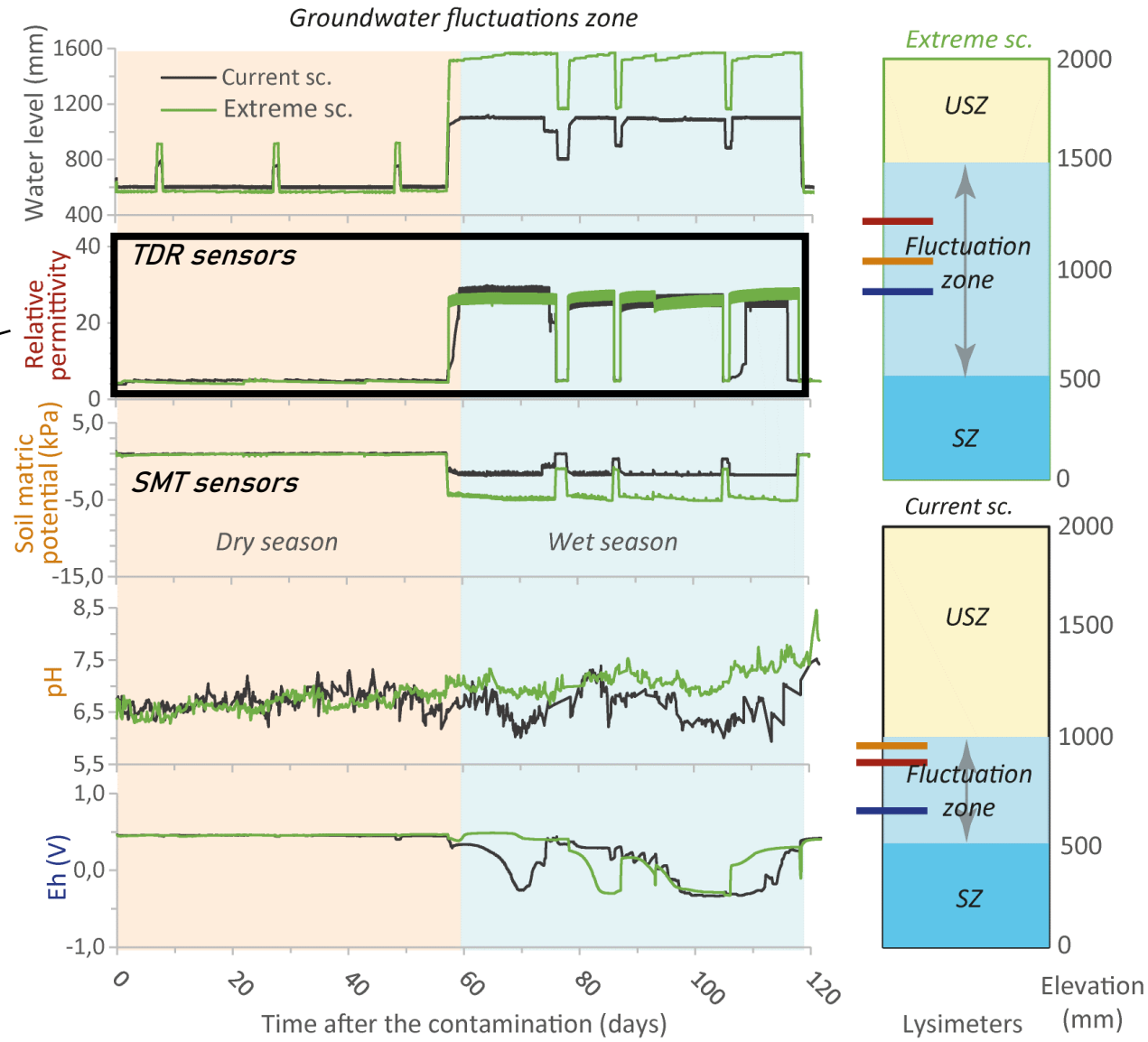
FIRST RESULTS/ Sensors efficiency and calibrations

Relative permittivity

$$\theta = -0{,}053 + 0{,}029.\varepsilon - 5{,}5.10^{-4}.\varepsilon^2 + 4{,}3.10^{-6}.\varepsilon^3$$

(Topp et al., 1980)

Volumetric water content

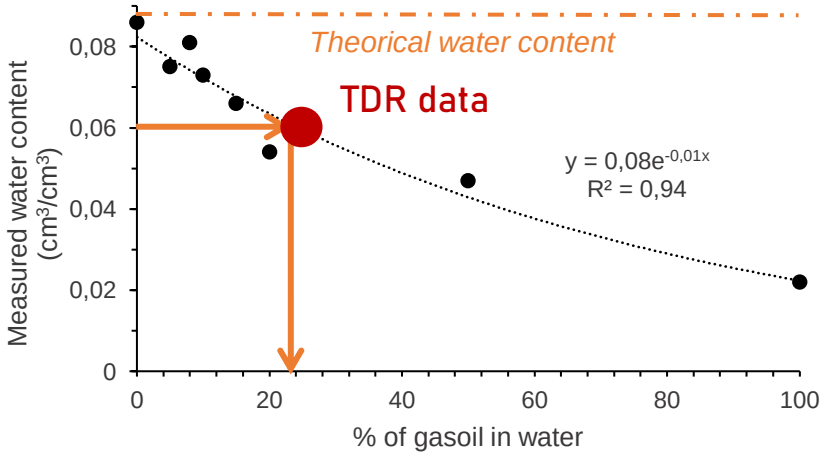


Variations of the soil properties during the two scenarios

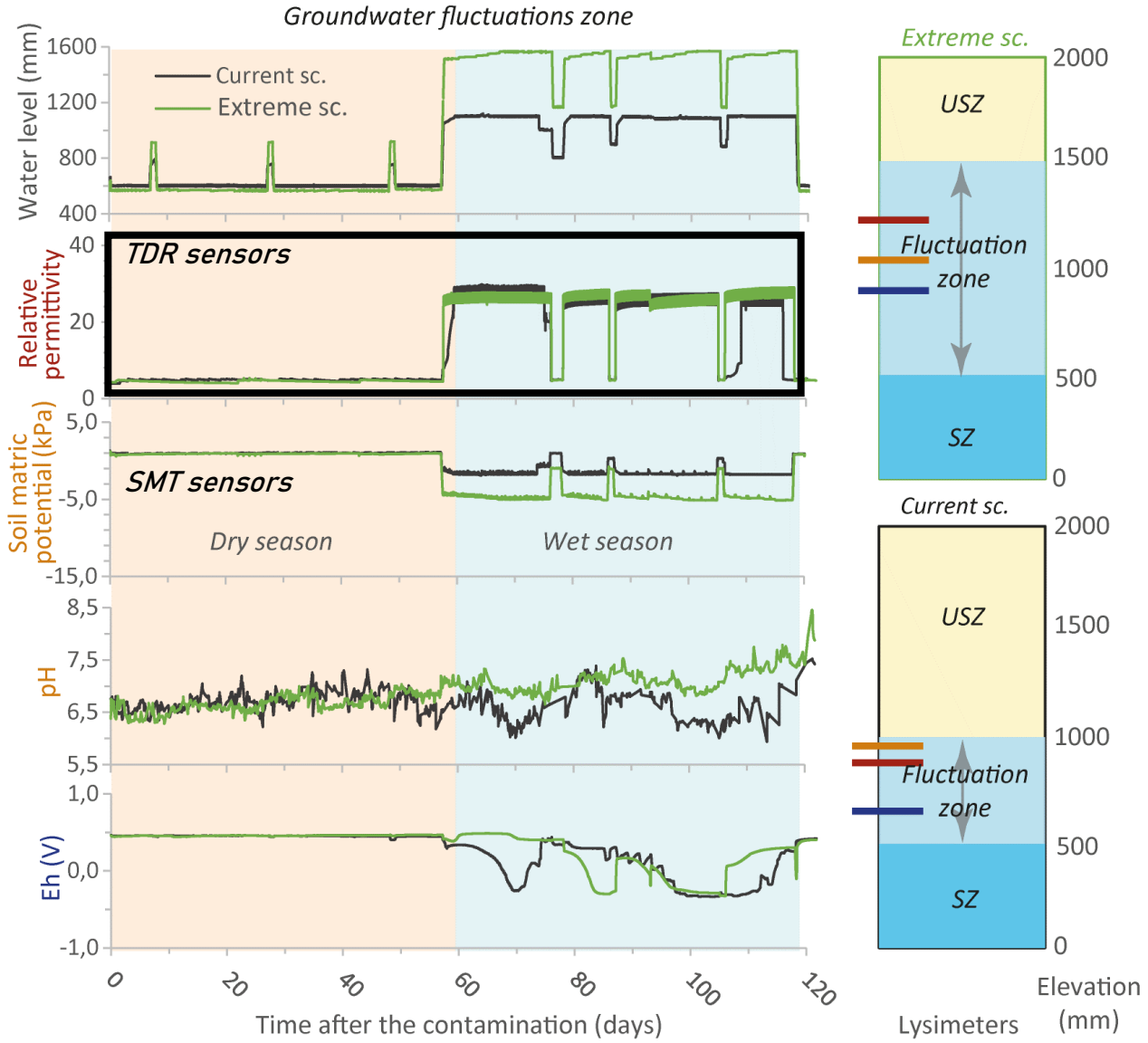
FIRST RESULTS/ Sensors efficiency and calibrations

Calibration of TDR measurements as a function of the LNAPL/water saturation of the soil

SMT data



Soil volumetric LNAPL content



- 3 depths of sensors

FIRST RESULTS/ Sensors efficiency and calibrations

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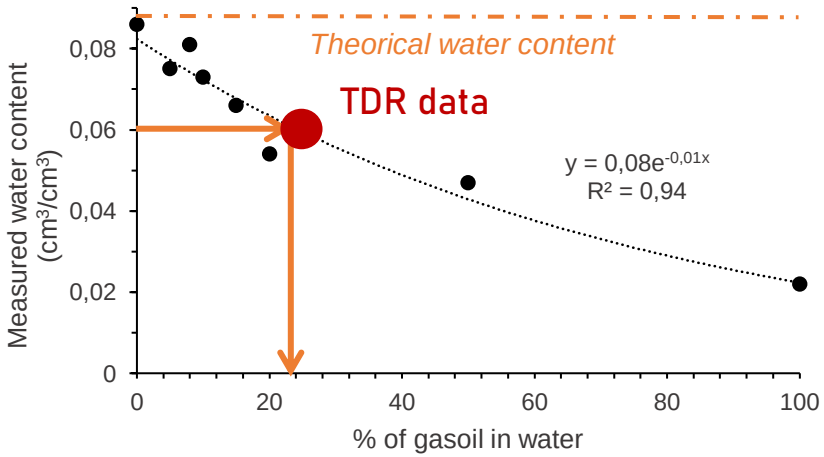

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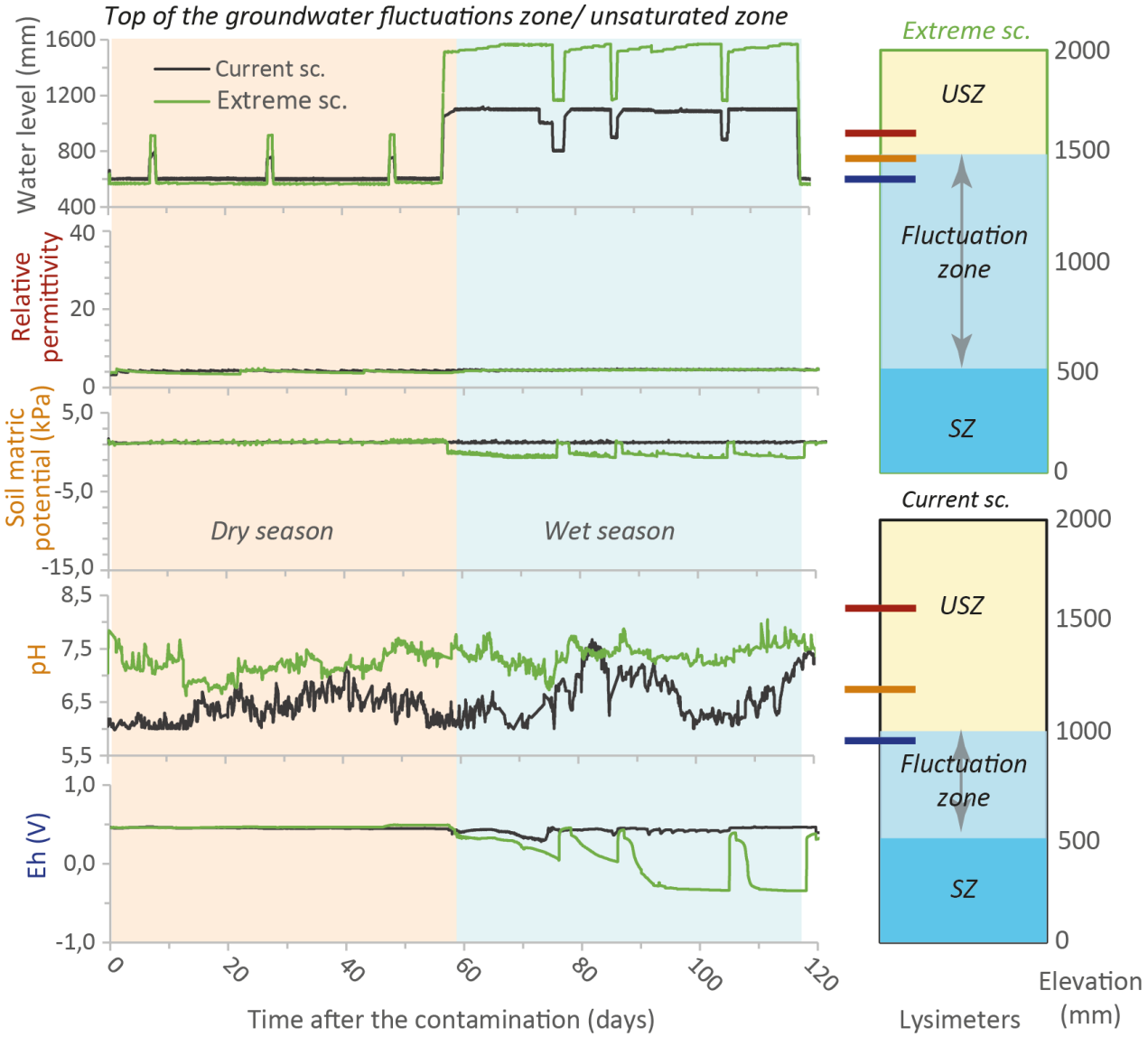

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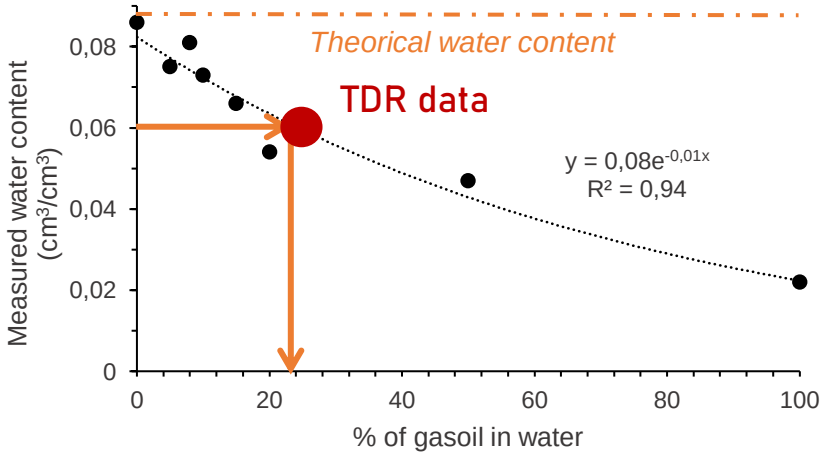

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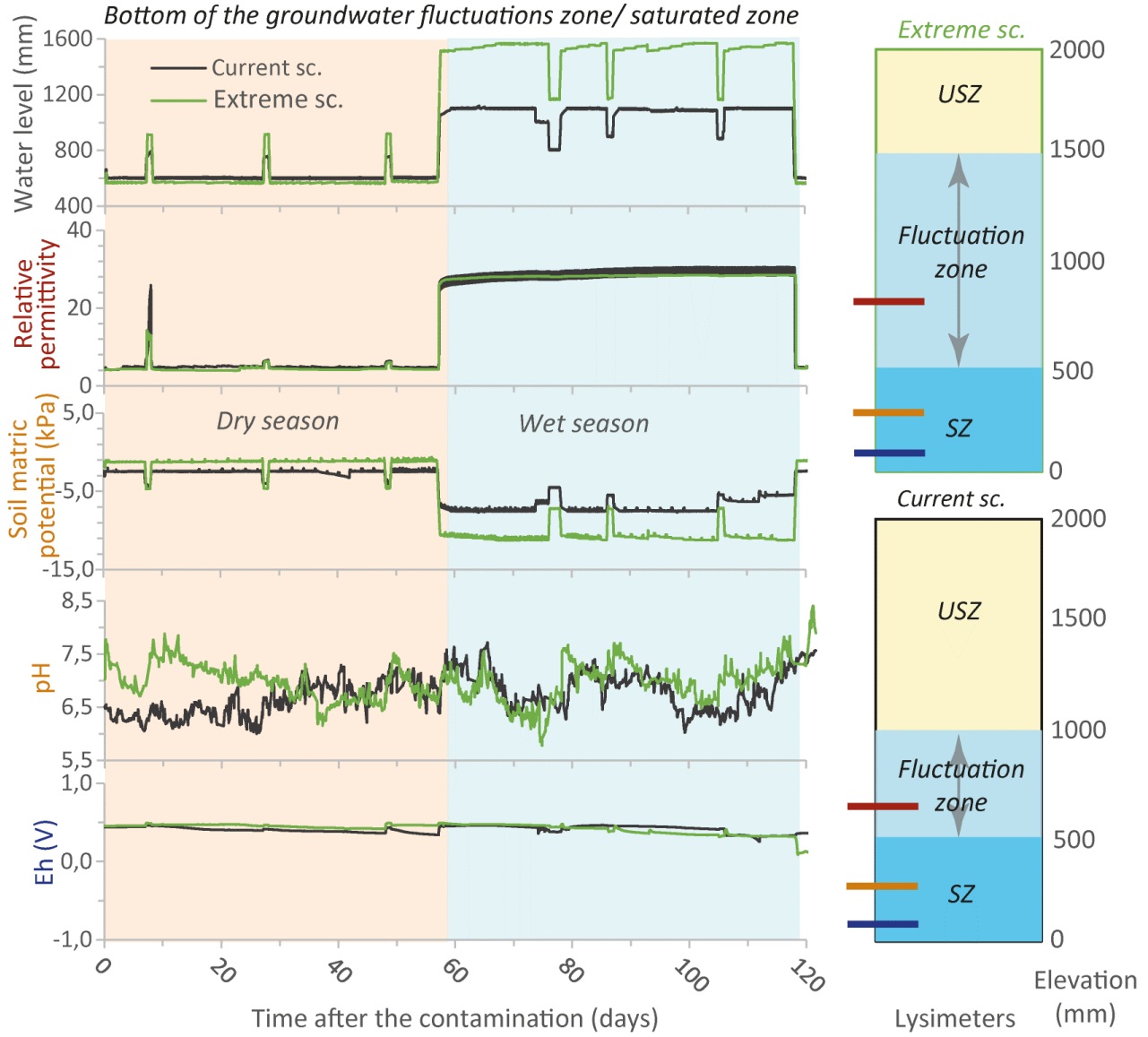
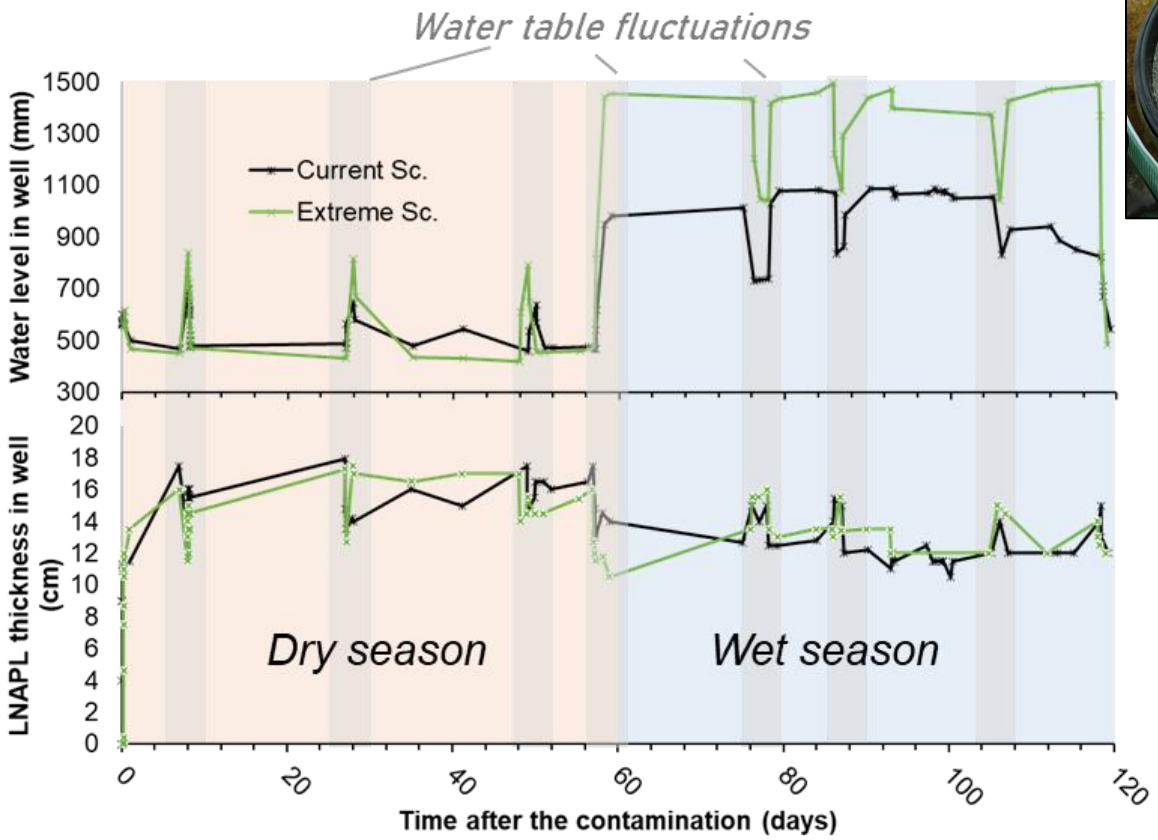


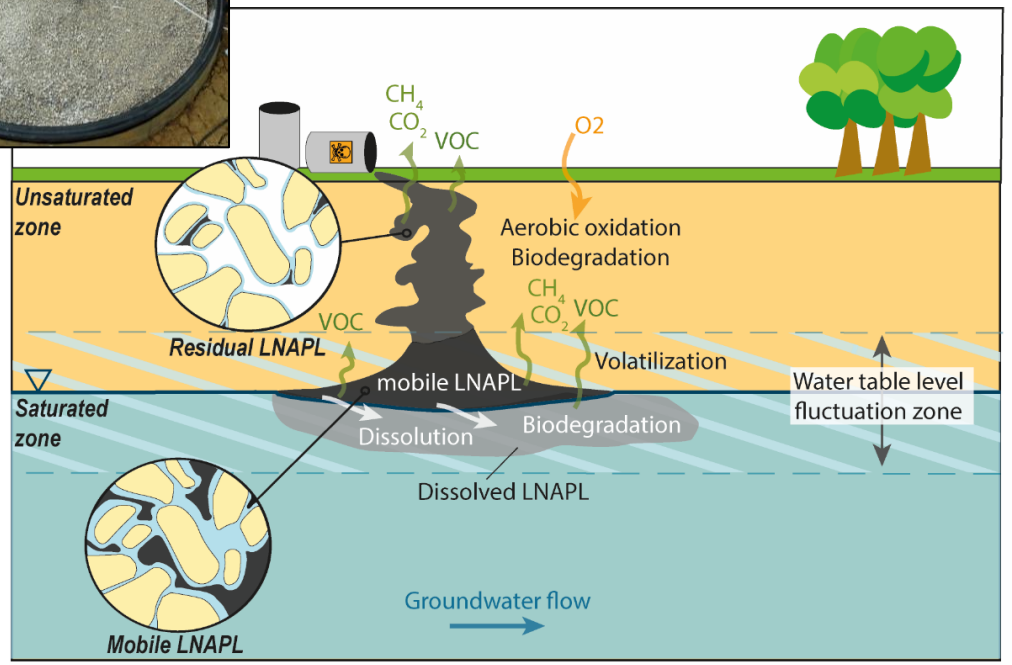
- 3 depths of sensors

FIRST RESULTS/ Evolution of the pure floating LNAPL phase (piezometer)



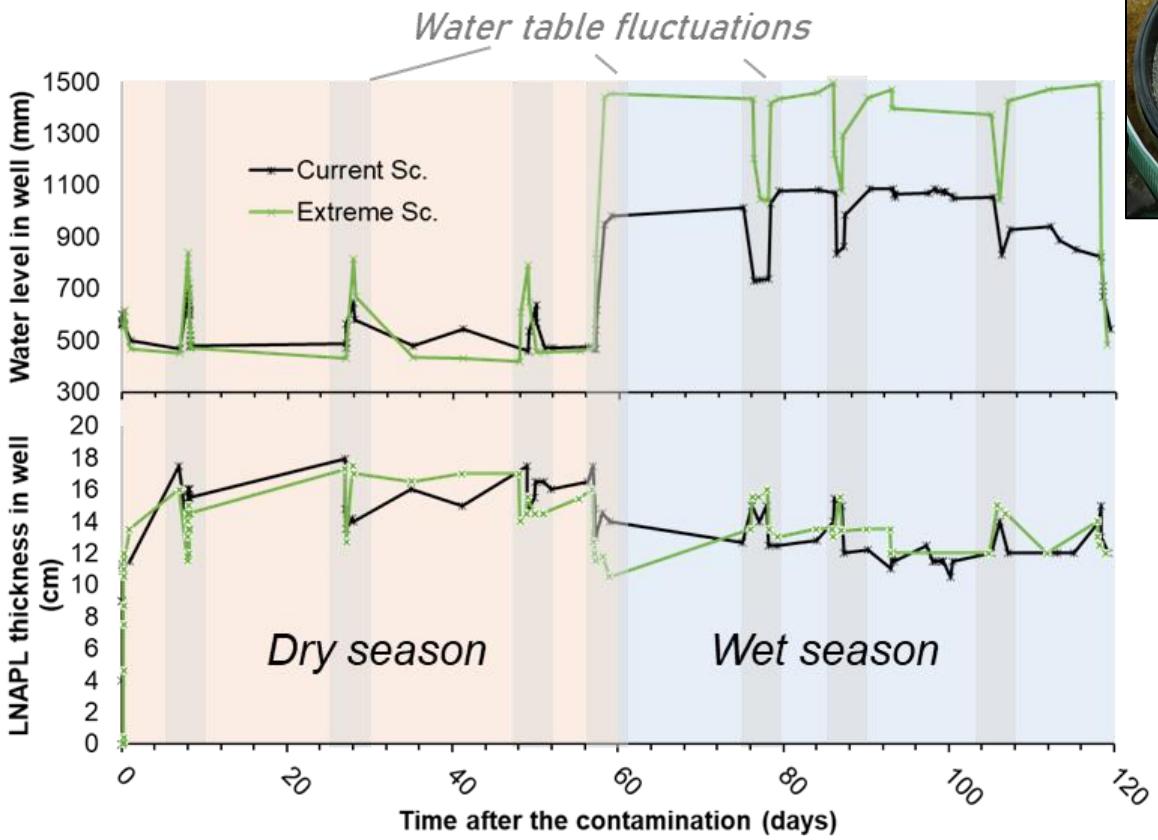
- Water table fluctuations = LNAPL remobilization across the fluctuation zone

Cavelan et al., 2022



- Increase of the water level = decrease of the LNAPL thickness in wells => Spreading of the LNAPL in the saturated zone.

FIRST RESULTS/ Evolution of the pure floating LNAPL phase (piezometer)



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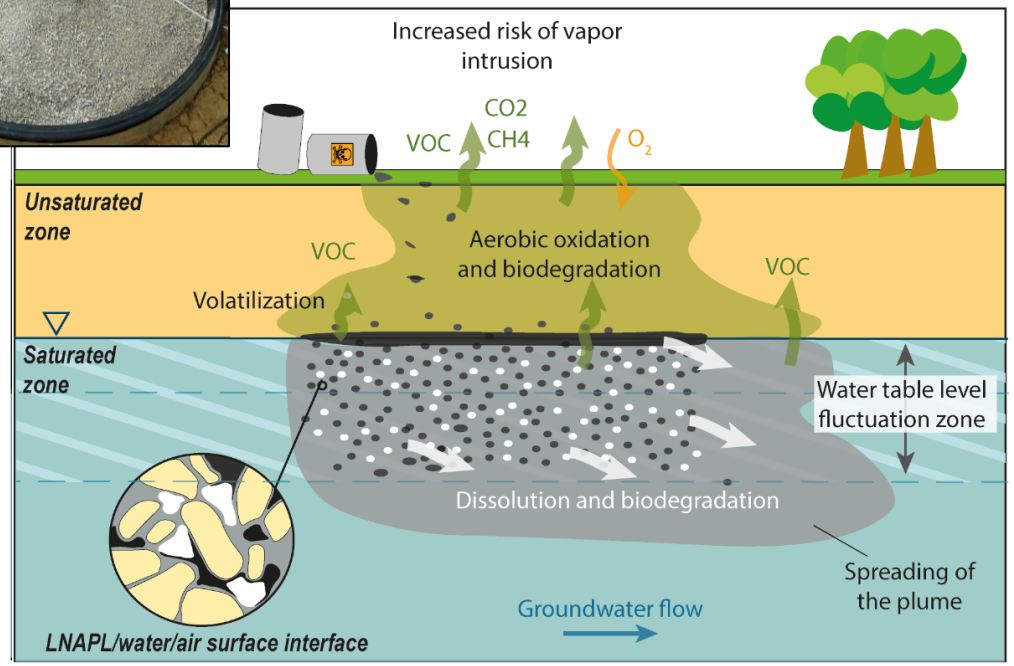

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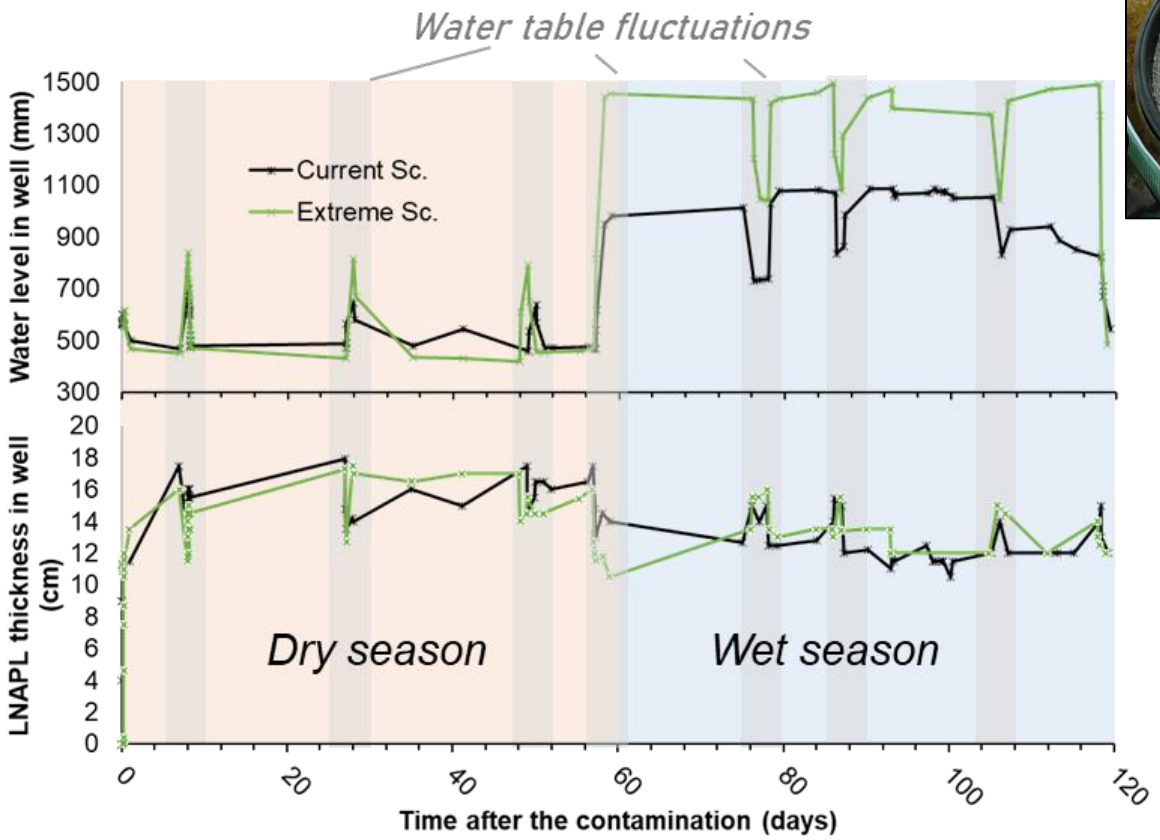

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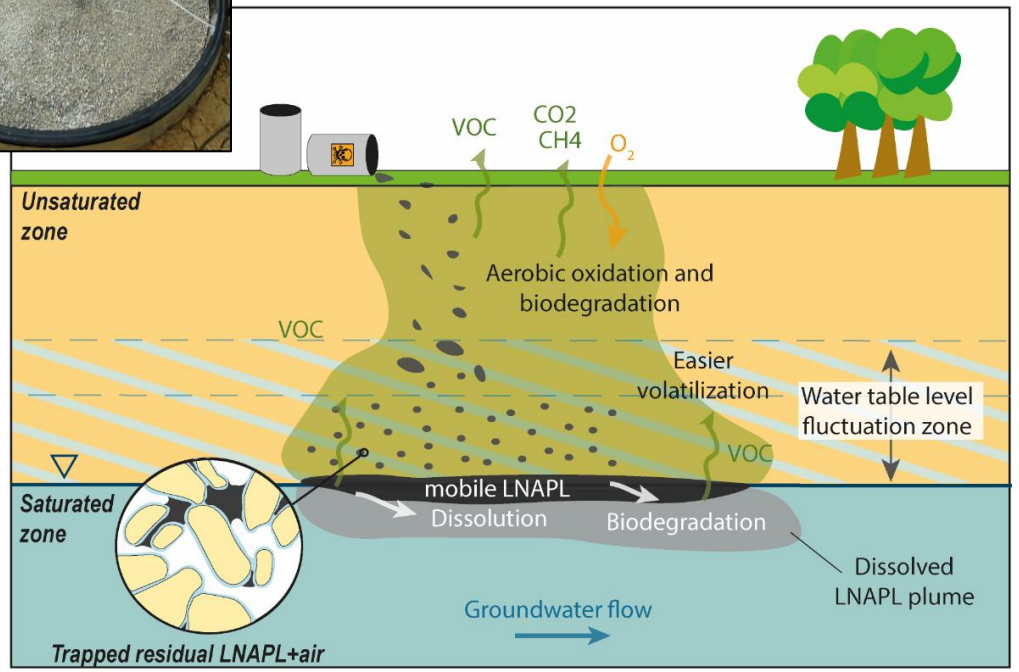
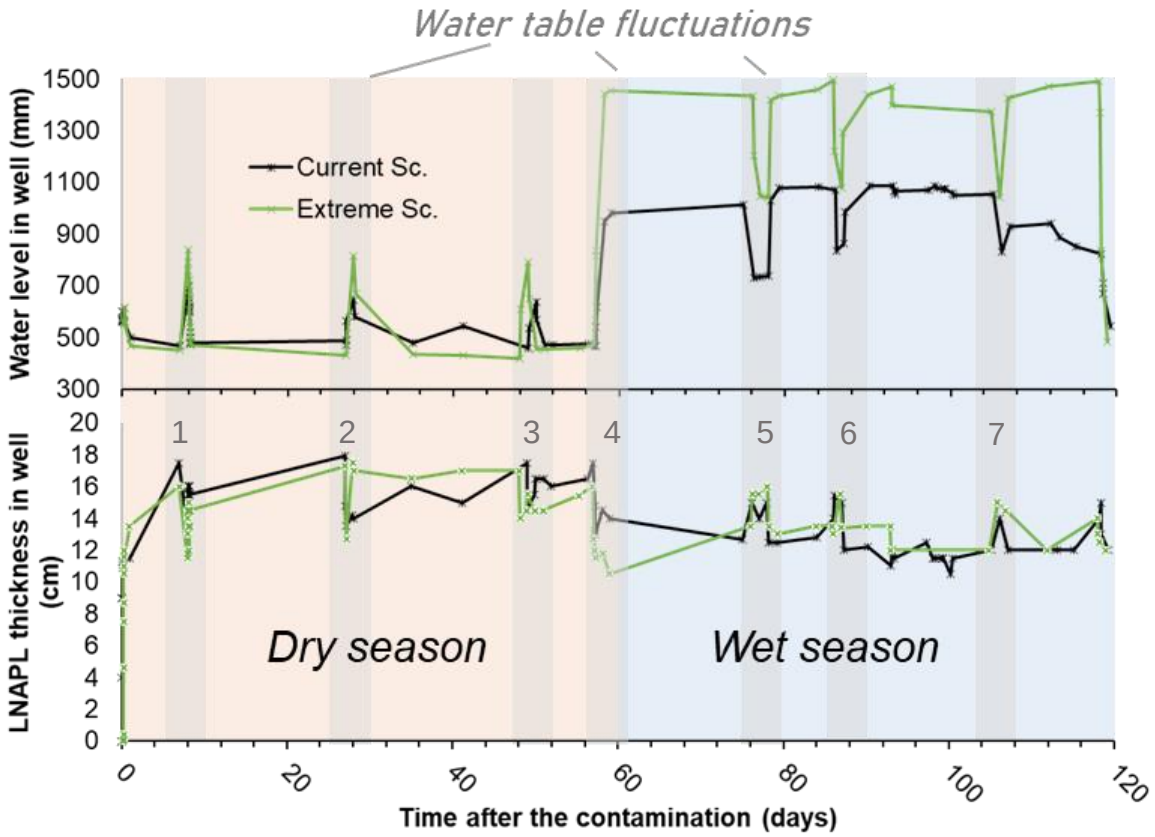
Cavelan et al., 2022

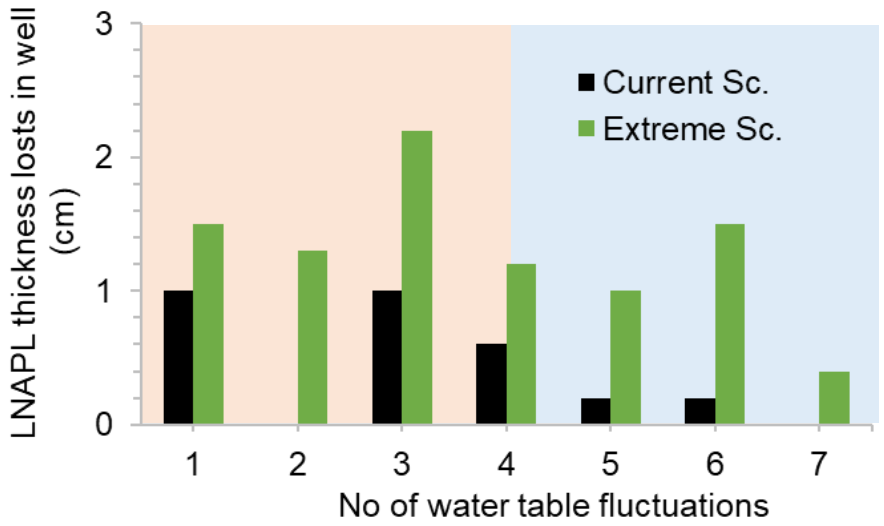


- Increase of the water level = decrease of the LNAPL thickness in wells => Spreading of the LNAPL in the saturated zone.
- Decrease of the water level = increase of the LNAPL thickness => Recovery of a part of the residual LNAPL.

FIRST RESULTS/ Evolution of the pure floating LNAPL phase (piezometer)



- Water table fluctuations = LNAPL remobilization across the fluctuation zone



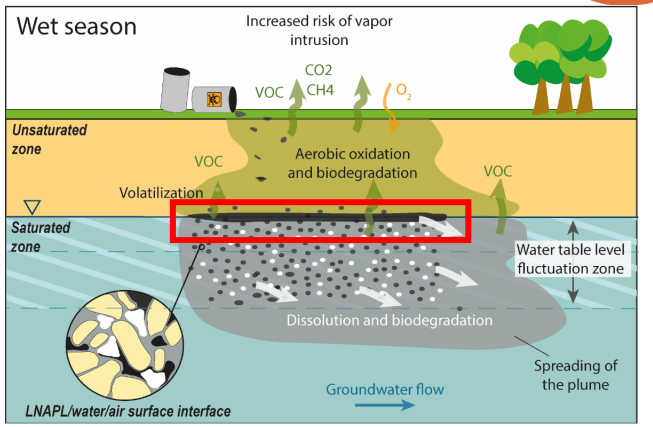
- Greater spreading of the pure LNAPL phase during the extreme water table fluctuations.
- Progressive re-equilibration the following days

Greater spreading = greater remobilization for the extreme scenario ?

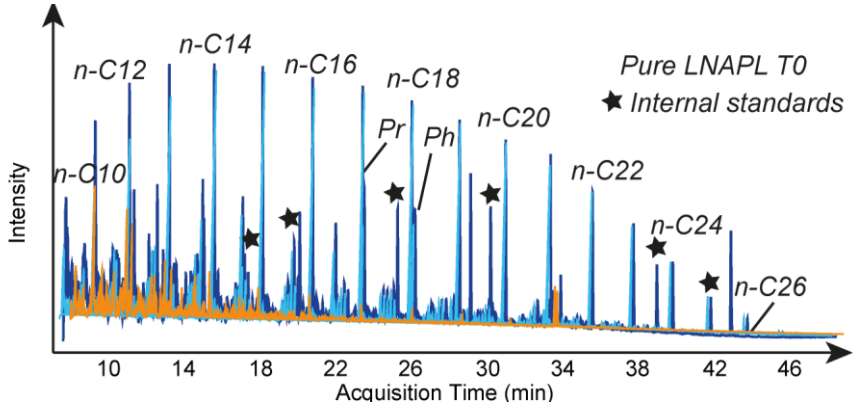
FIRST RESULTS/ Chemical data

Pure LNAPL phase composition (gasoil):

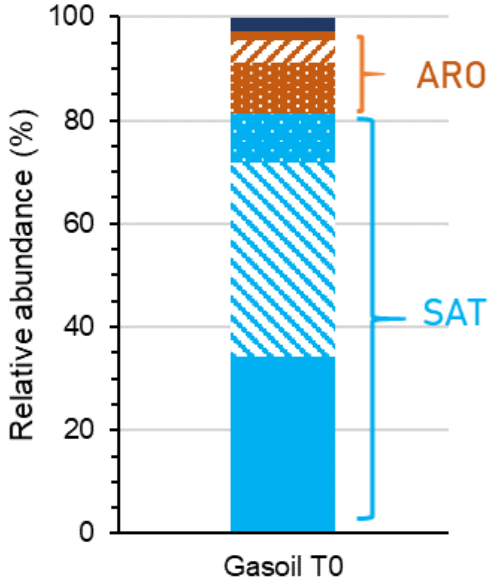
- Sampled in monitoring wells at 0 and 90 days after the contamination.
- Analyzed by GC/MS (TQD and TORION)

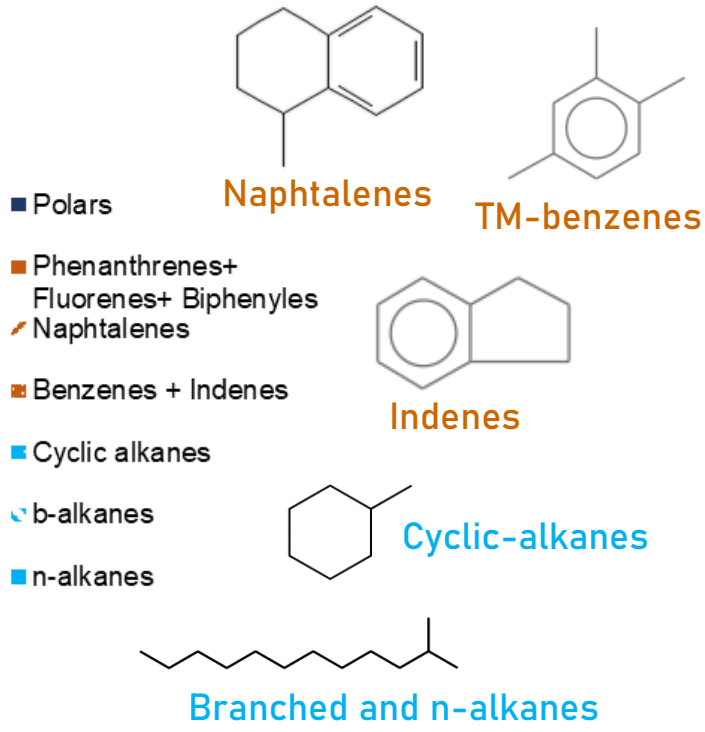


Initial composition (T0)



Chromatogram of the gasoil at T0





Pure LNAPL phase composition (gasoil):

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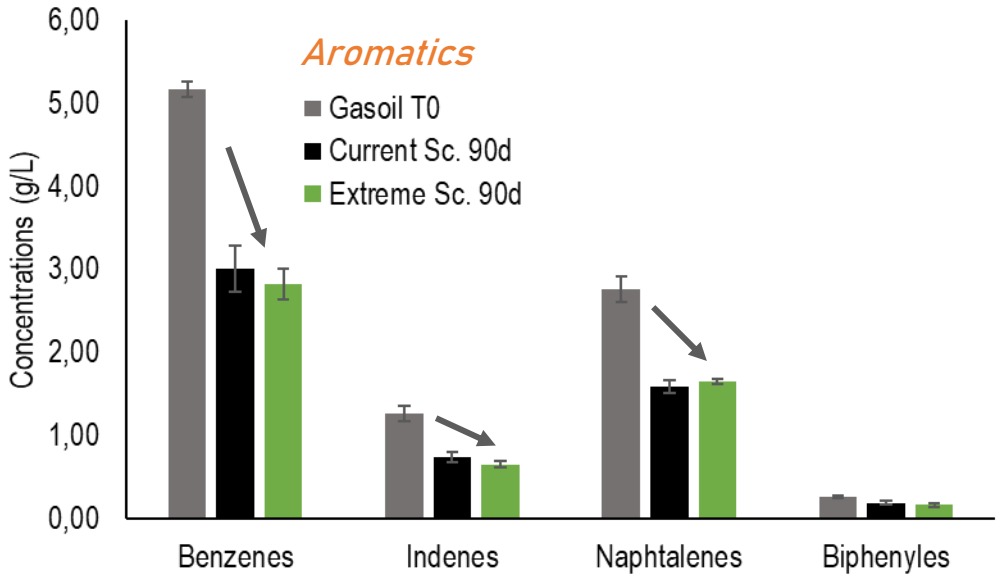
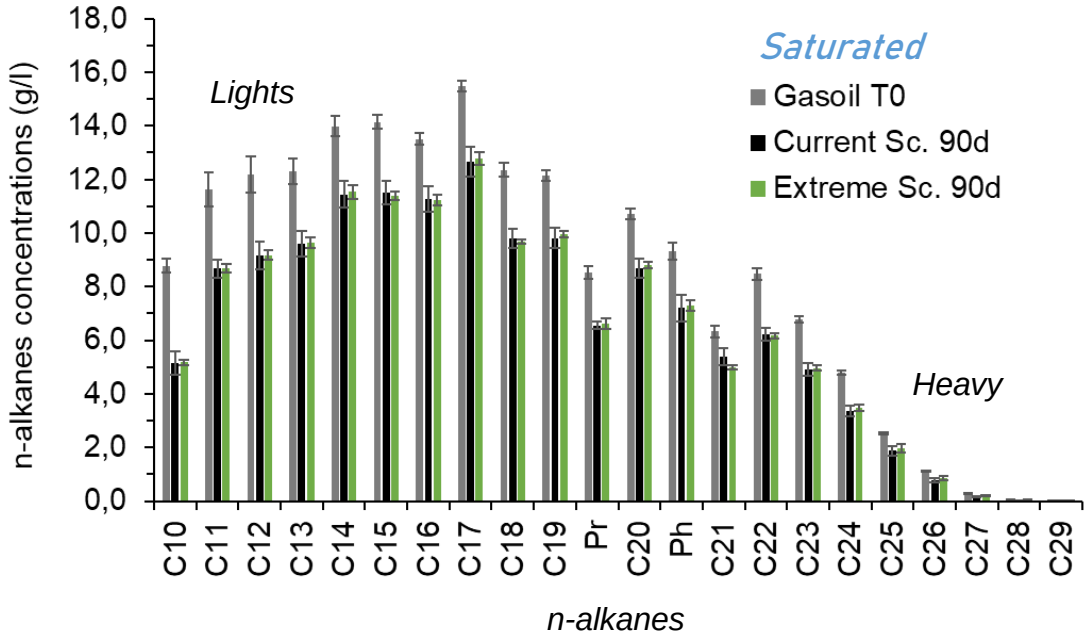
- Analyzed by GC/MS (TQD and TORION)

Evolution of the composition after 90 days





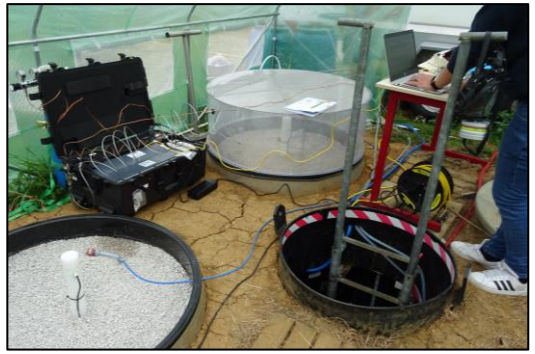
- Decrease of the concentrations of the most soluble and volatile n-alkanes and aromatics for the two scenarios.
  - ➢ No clear difference between the scenarios

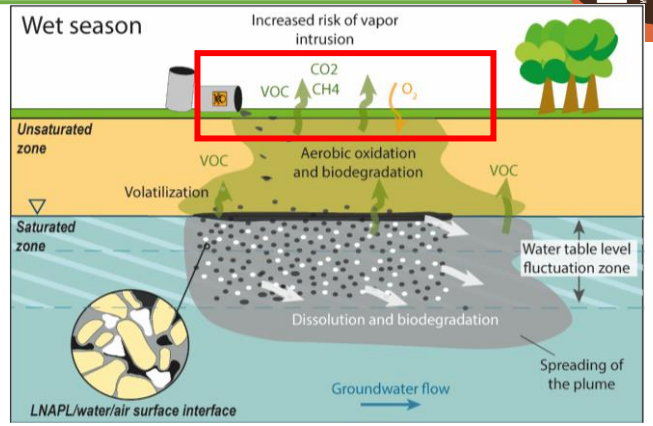
Volatilization and dissolution?

FIRST RESULTS/ Chemical data

Gaseous phase:

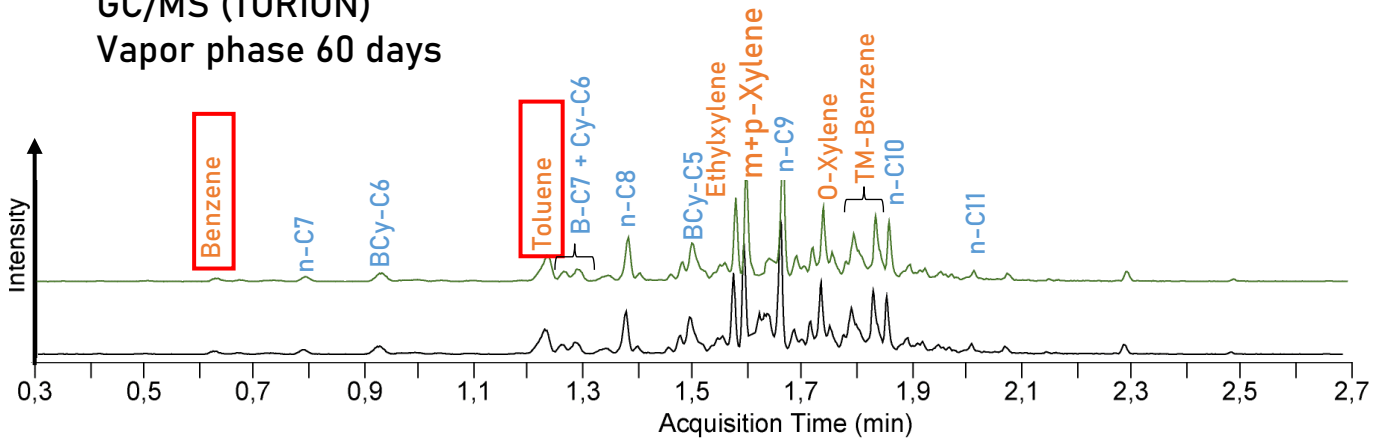
- Analyzed at the surface of each lysimeter by µGC in gas chambers.
- Sampled in tedlar bags for GC/MS analyses (TORION)

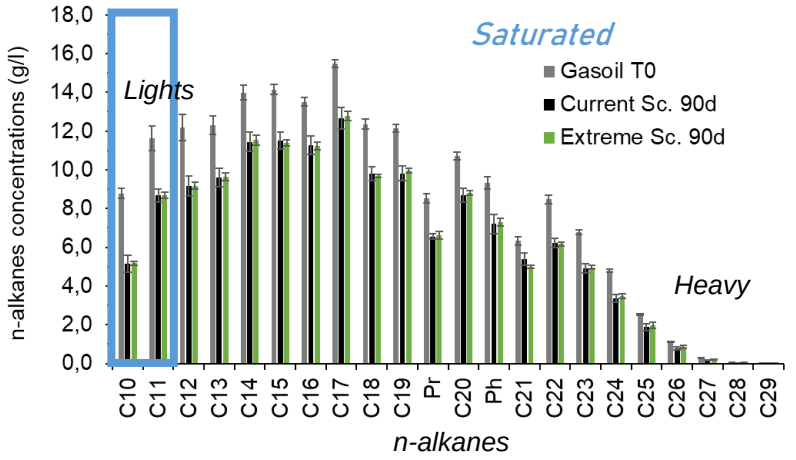


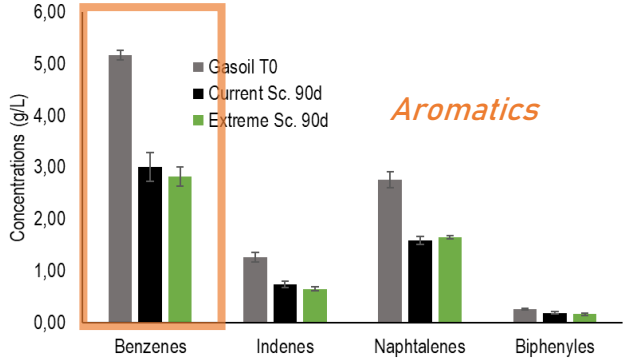


Gaseous phase composition

GC/MS (TORION)
Vapor phase 60 days







Gaseous phase:

- Analyzed at the surface of each lysimeter by µGC in gas chambers.
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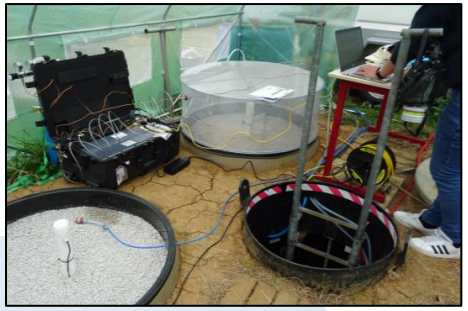
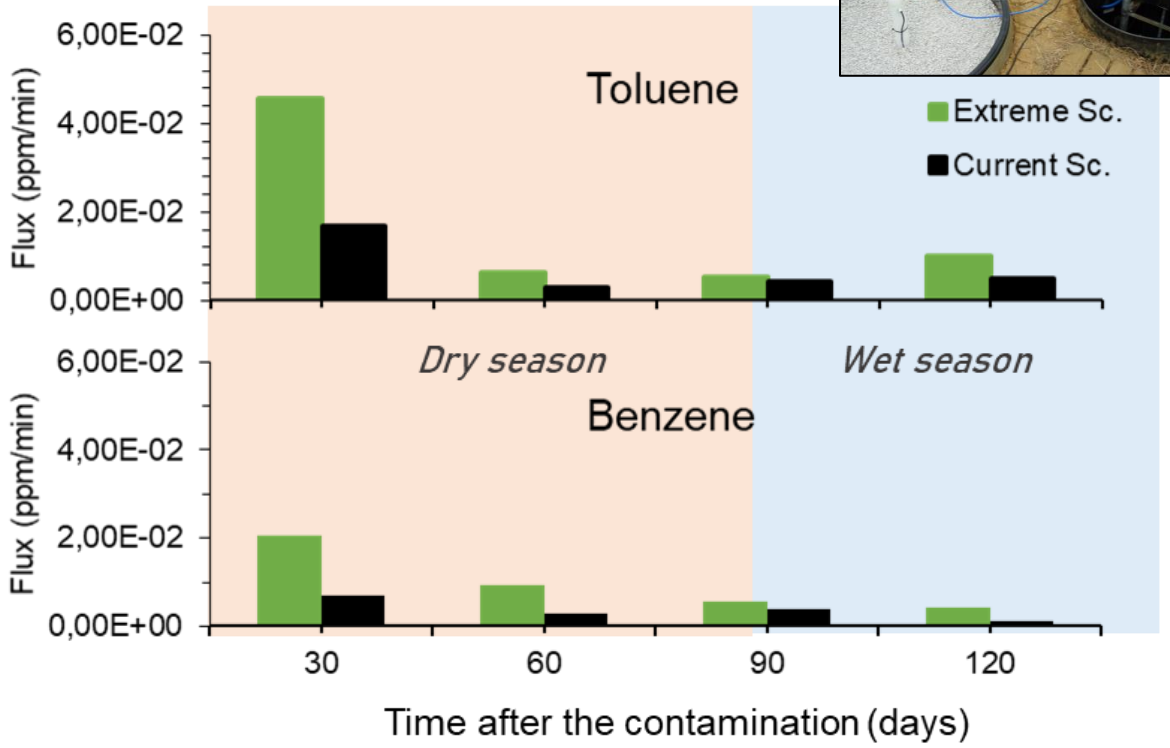
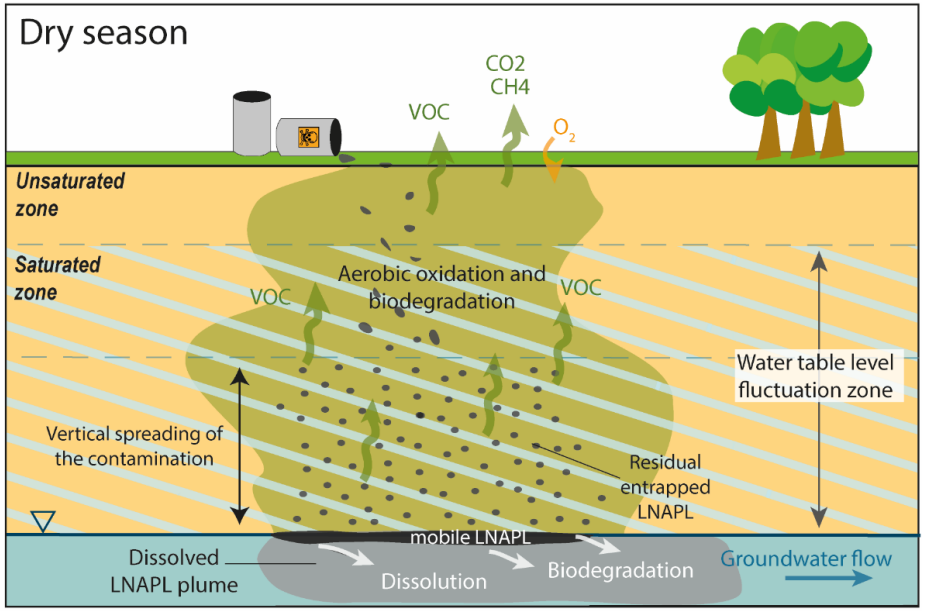


Evolution of fluxes (µGC):





- Decrease in gas flux mobilized by each water level fluctuation with increasing time.
- Surface mobilized gas fluxes are higher for the extreme scenario.

Gaseous phase:

- Analyzed at the surface of each lysimeter by µGC in gas chambers.
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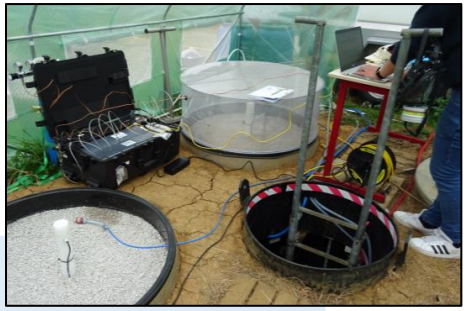
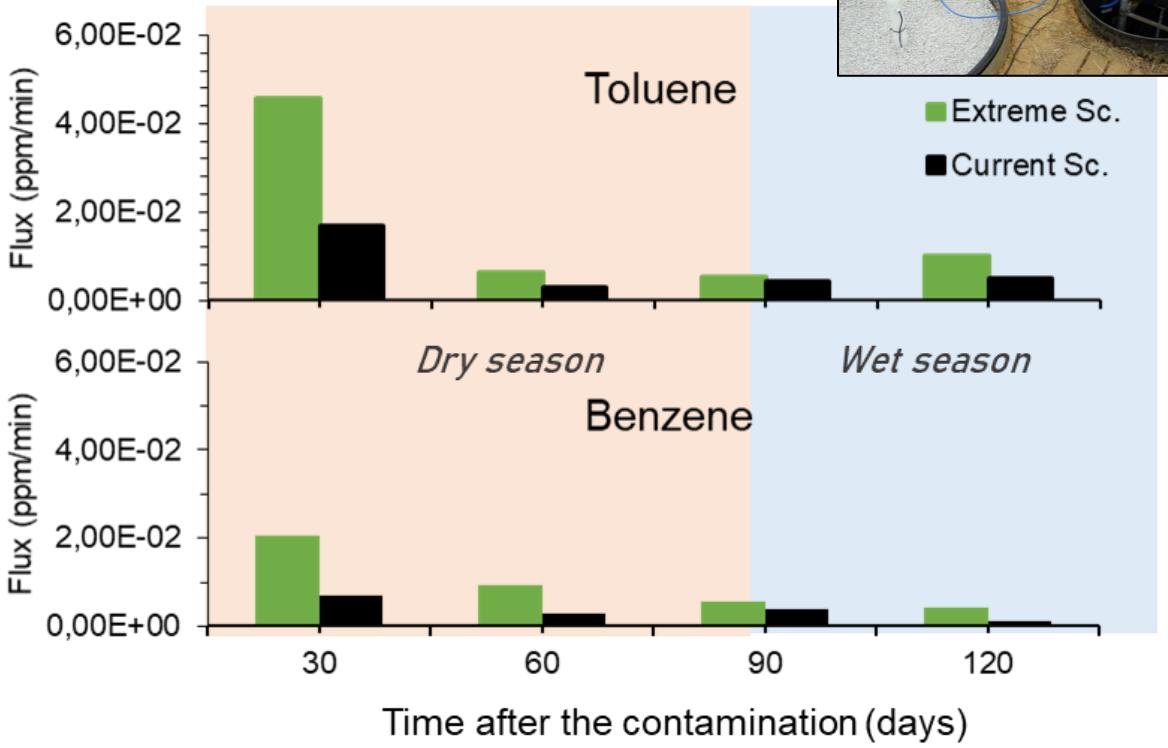
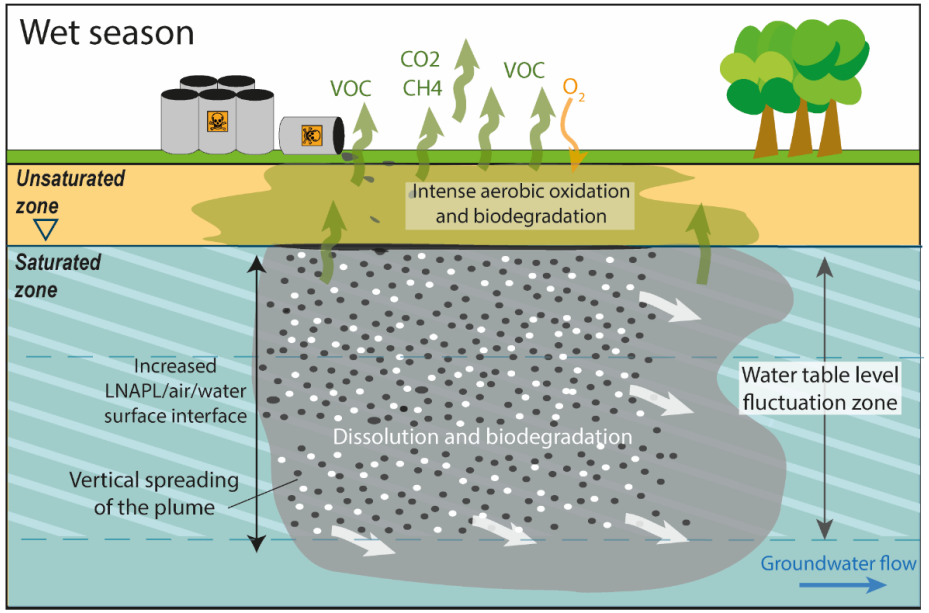
Evolution of fluxes (µGC):







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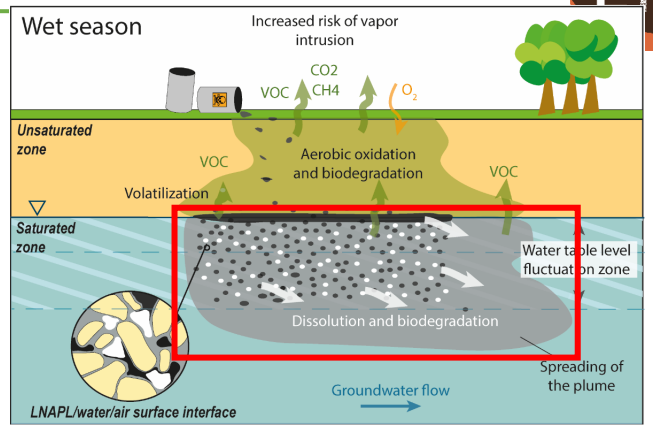
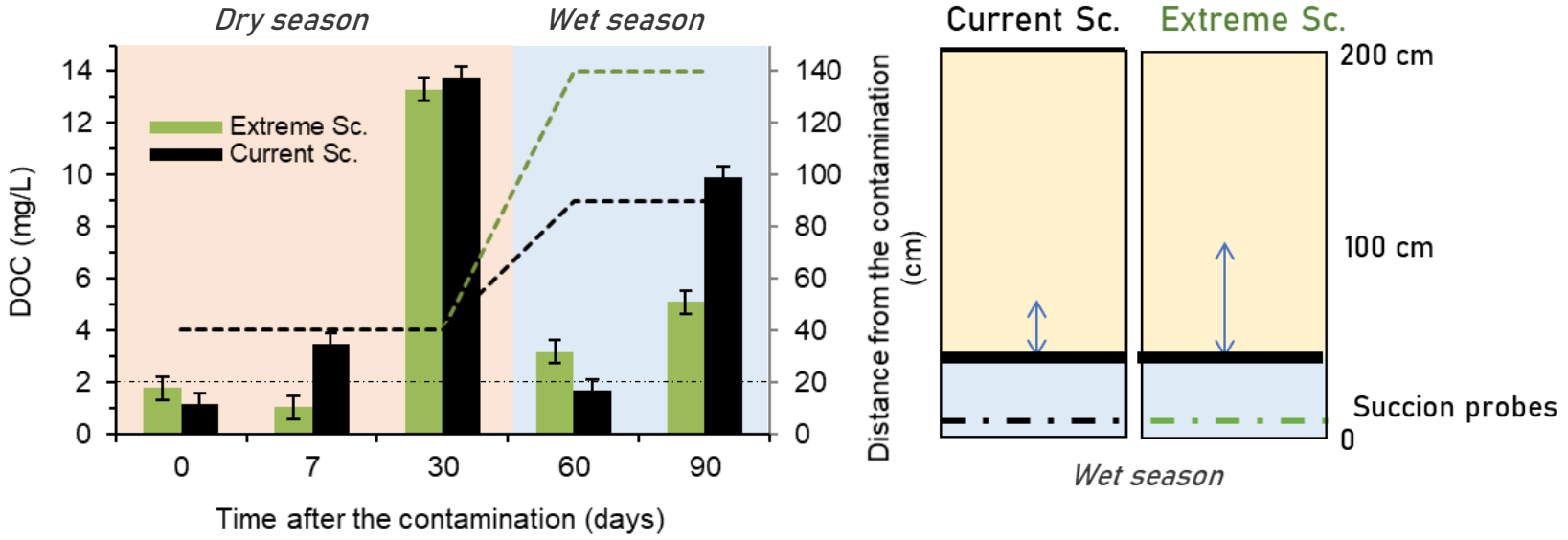
FIRST RESULTS/ Chemical data

Aqueous phase:

- Sampling by suction probes
- Analysis: DOC, GC/MS (TORION, TQD)



Evolution of the composition with time:

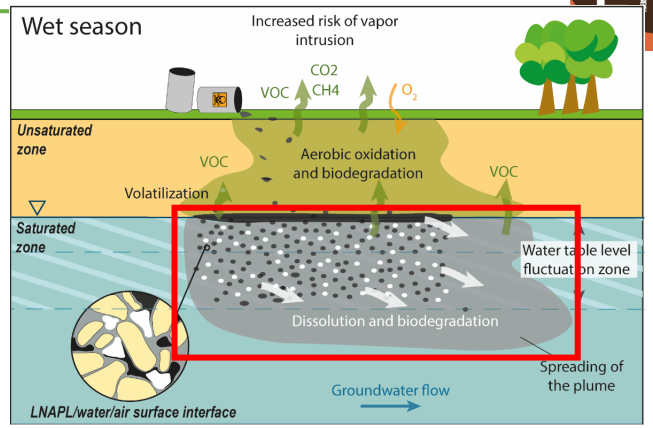


- No clear difference between the scenarios at this time of the monitoring.

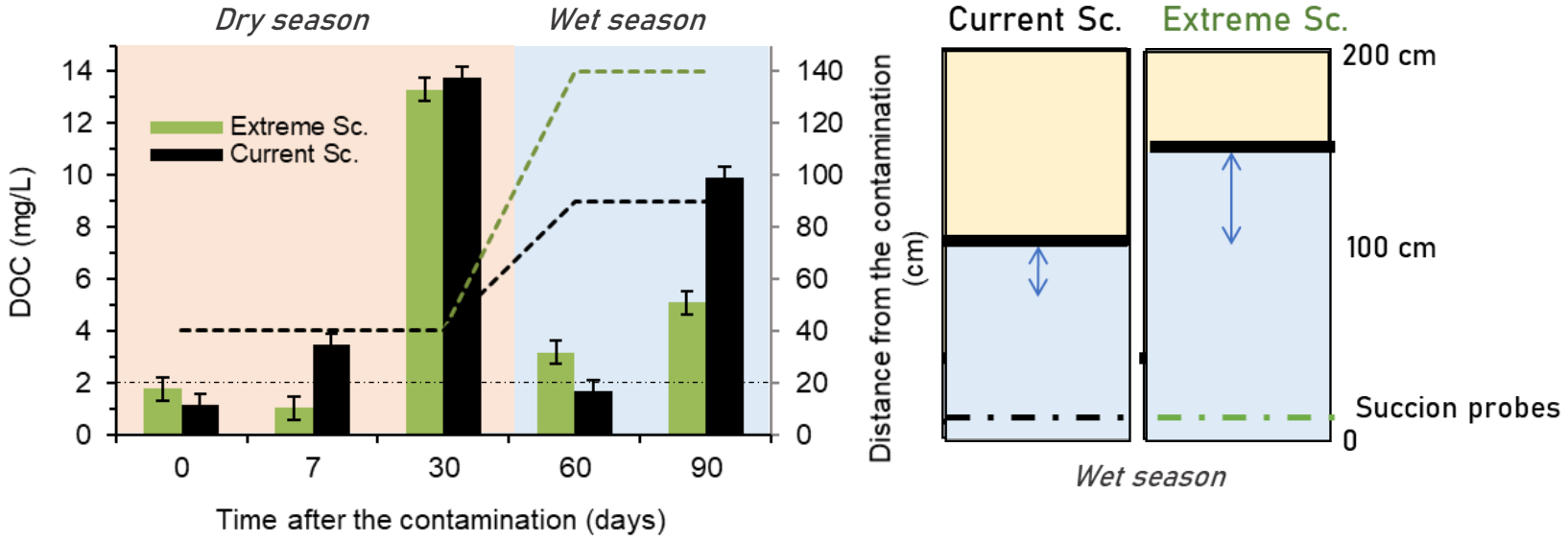
FIRST RESULTS/ Chemical data

Aqueous phase:

- Sampling by suction probes
- Analysis: DOC, GC/MS (TORION, TQD)



Evolution of the composition with time:



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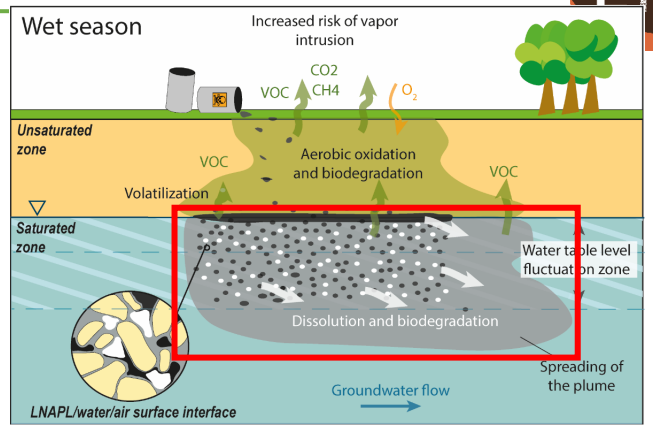
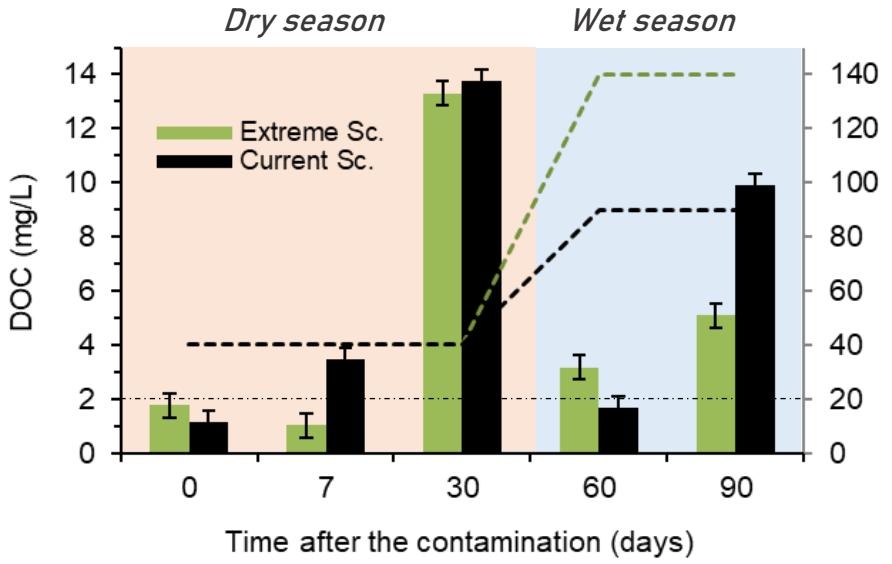
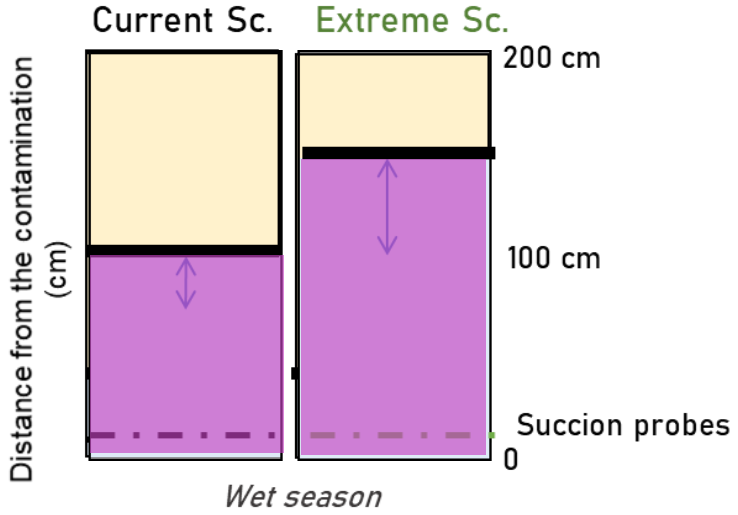


Evolution of the composition with time:





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FIRST RESULTS/ Chemical data

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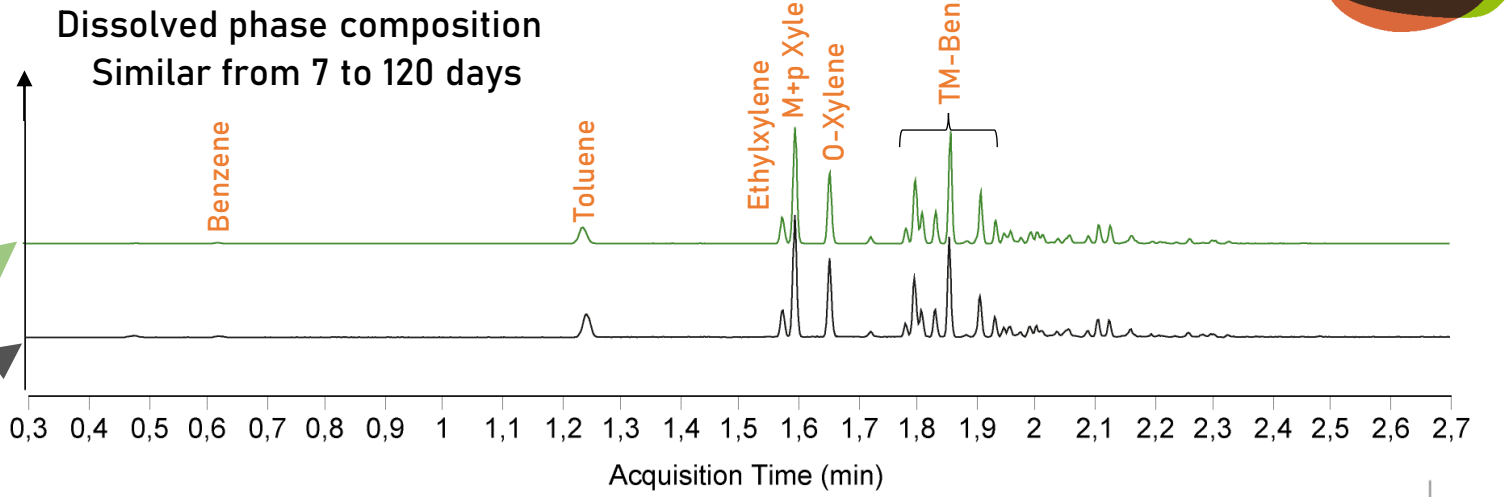
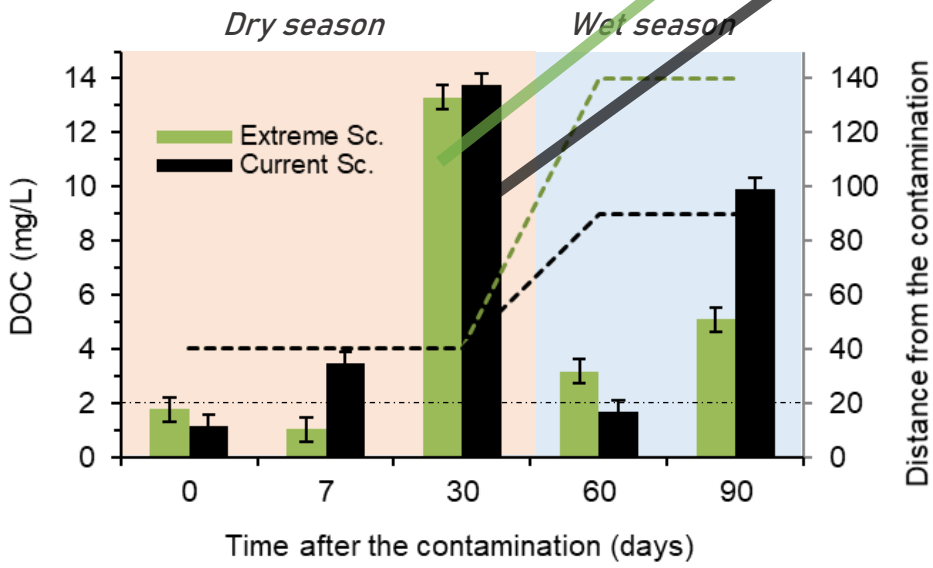
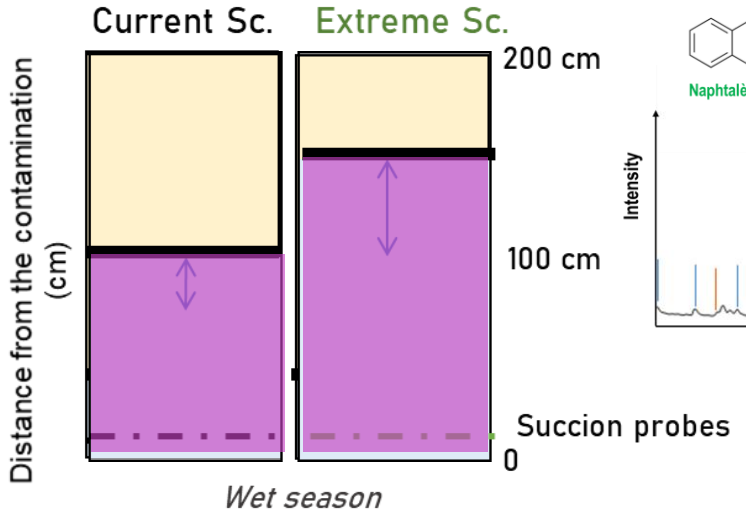
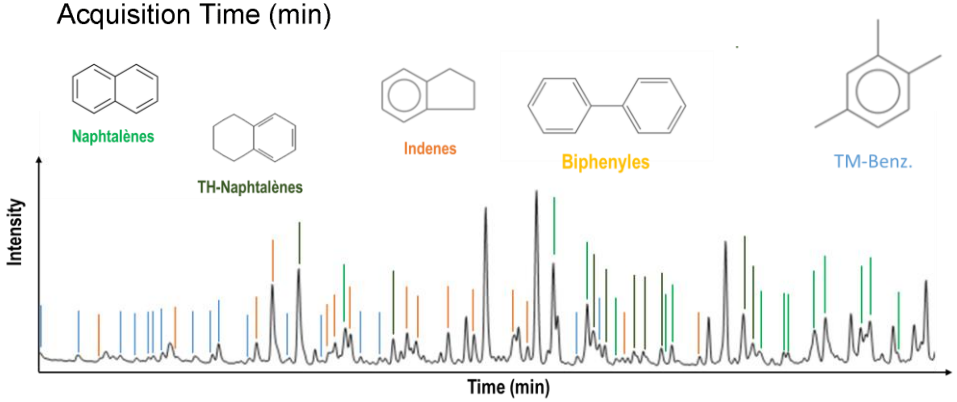
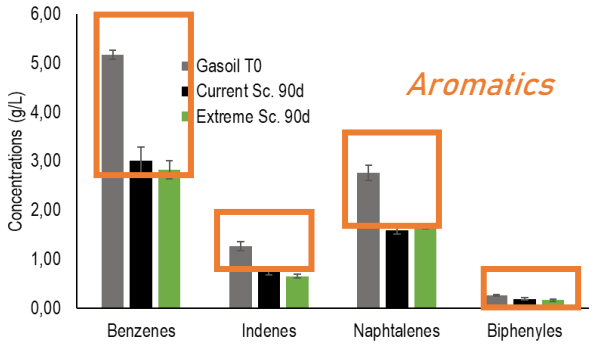
Evolution of the composition with time:











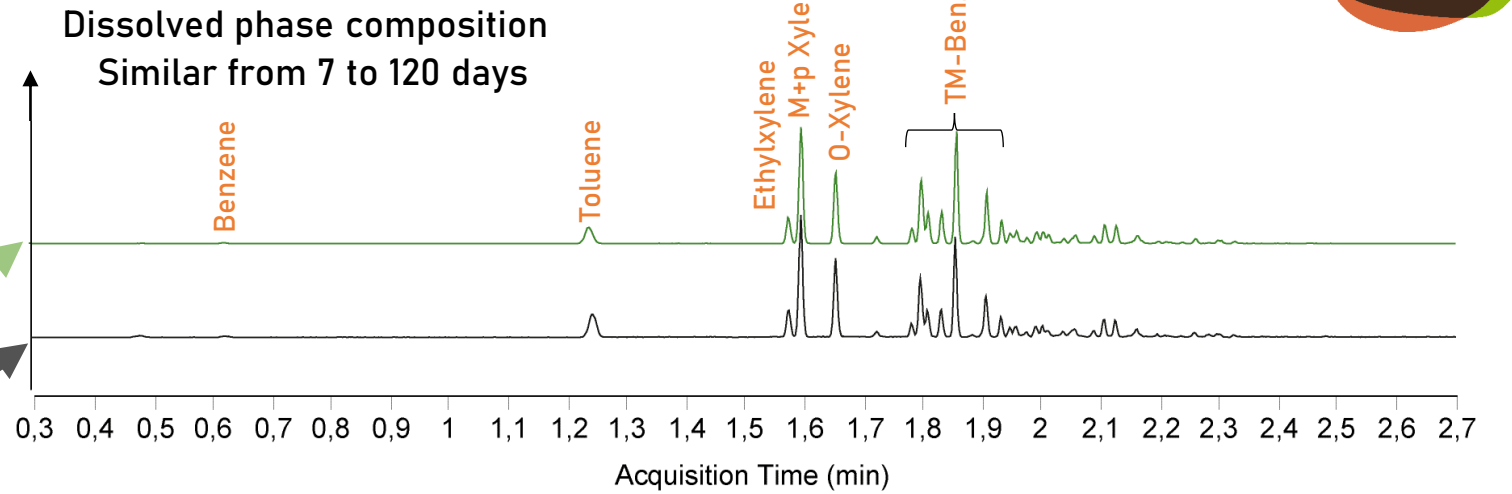
- No clear difference between the scenarios at this time of the monitoring.
- The aqueous phase is only composed of aromatics, no alkanes can be found.

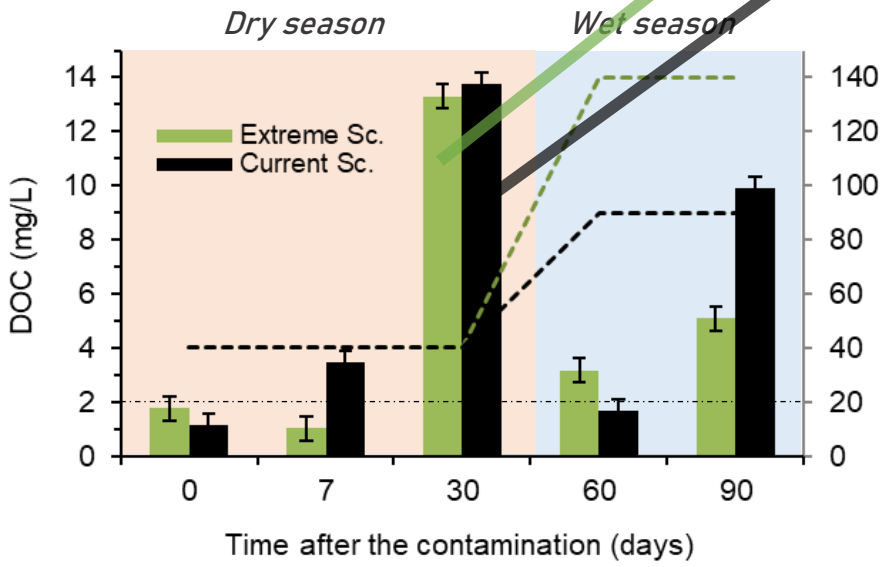
FIRST RESULTS/ Chemical data

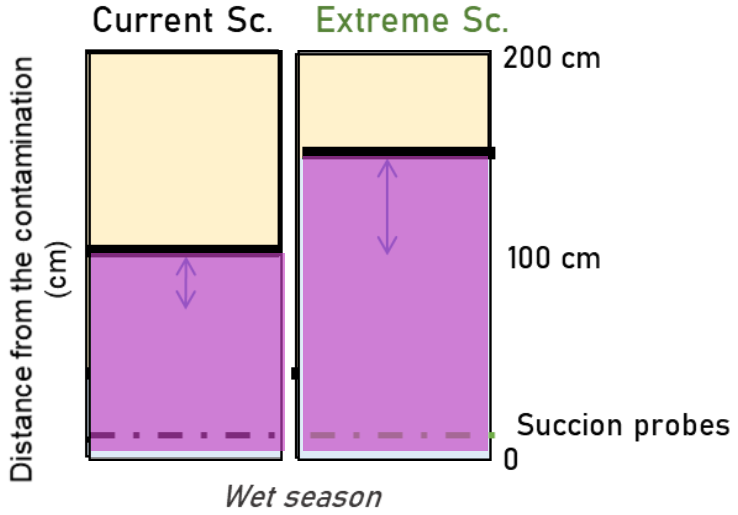
Aqueous phase:

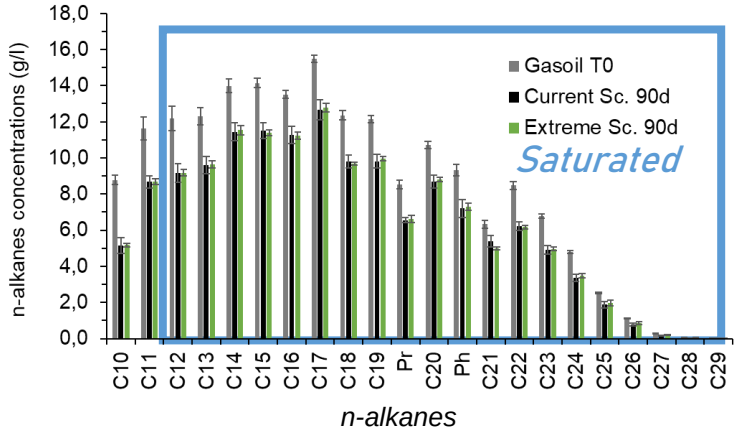
- Sampling by suction probes
- Analysis: DOC, GC/MS (TORION, TQD)

Evolution of the composition with time:







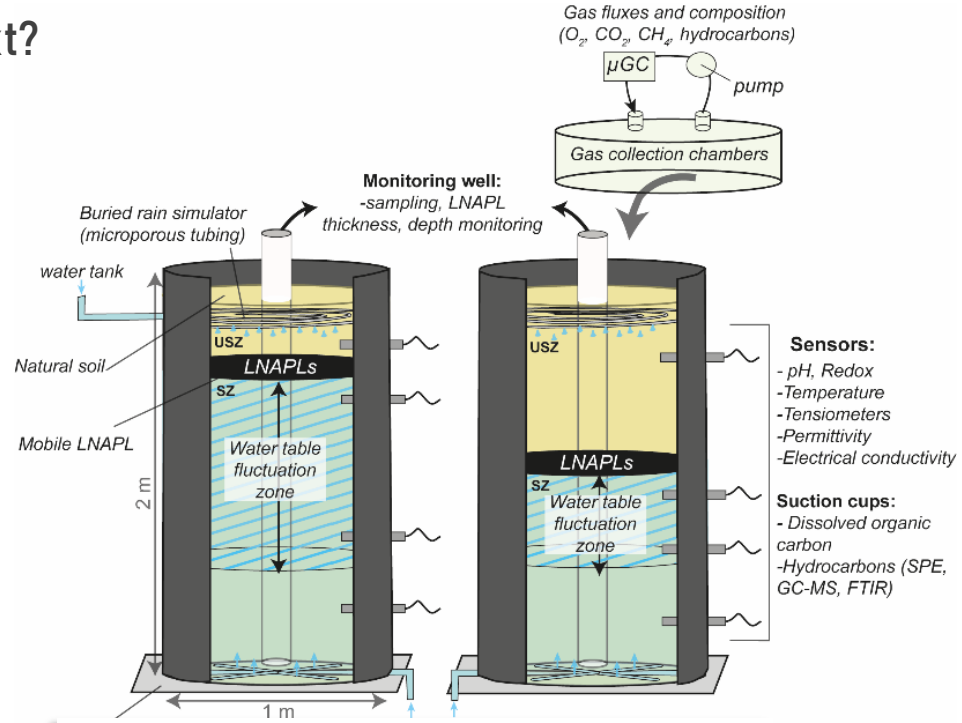


(Bio)degradation?

- No clear difference between the scenarios at this time of the monitoring.
- The aqueous phase is only composed of aromatics, no alkanes can be found.

- The experimental device allows to follow the effect of climatic scenarios on LNAPL contaminations.
- Increase of the intensity of groundwater table fluctuations =
  - a greater LNAPL spreading across the soil.
  - greater gas fluxes at the surface.
  - a greater thickness of the dissolved plume.

What next?



Lysimeters in "natural conditions"
Natural soil, LNAPL taken from a contaminated site, active biodegradation

The "BatMobile" project

Applications for LNAPL monitoring in natural conditions

Monitoring of a LNAPL contaminated site by coupling *in-situ* and *ex-situ* monitoring techniques

Thanks for your attention !

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amelie.cavelan@univ-lorraine.fr

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