Dynamics of greenhouse gases in the aquifers of two agricultural catchments of Belgium

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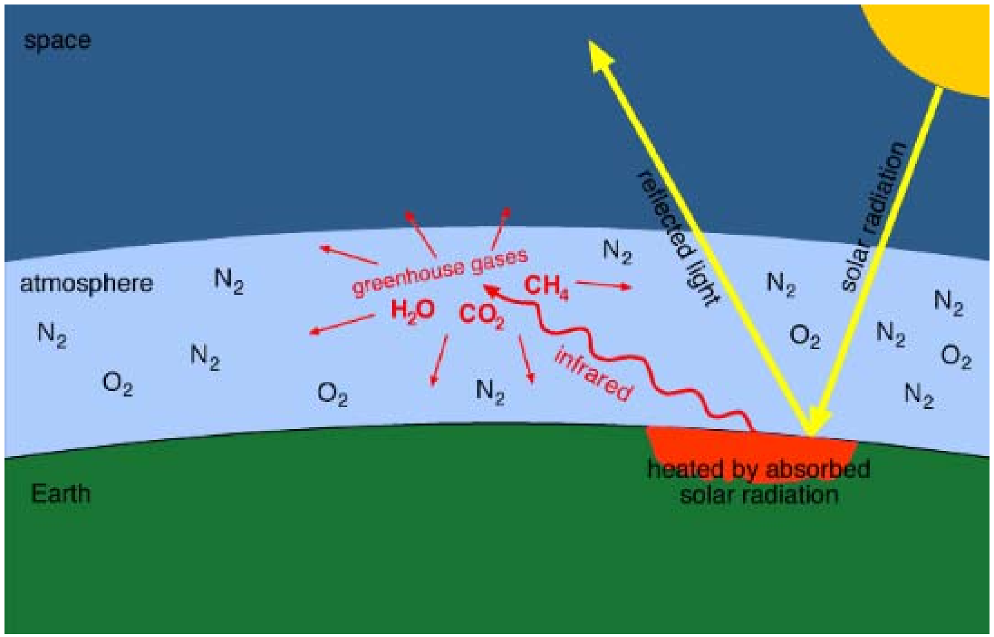
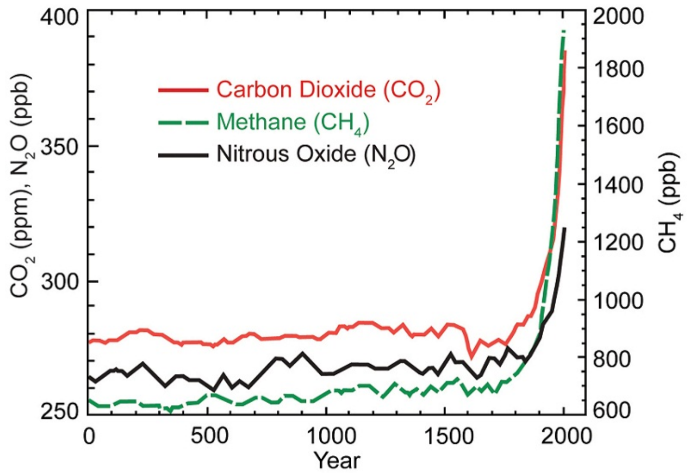
Context of the study : Greenhouse gases emissions and climate change

However, groundwater flows are complex in space and time …



Source: http://www.ehso.com/climatechange/climatechangecauses-greenhouseeffect.php



CO_2

CH_4

N_2O

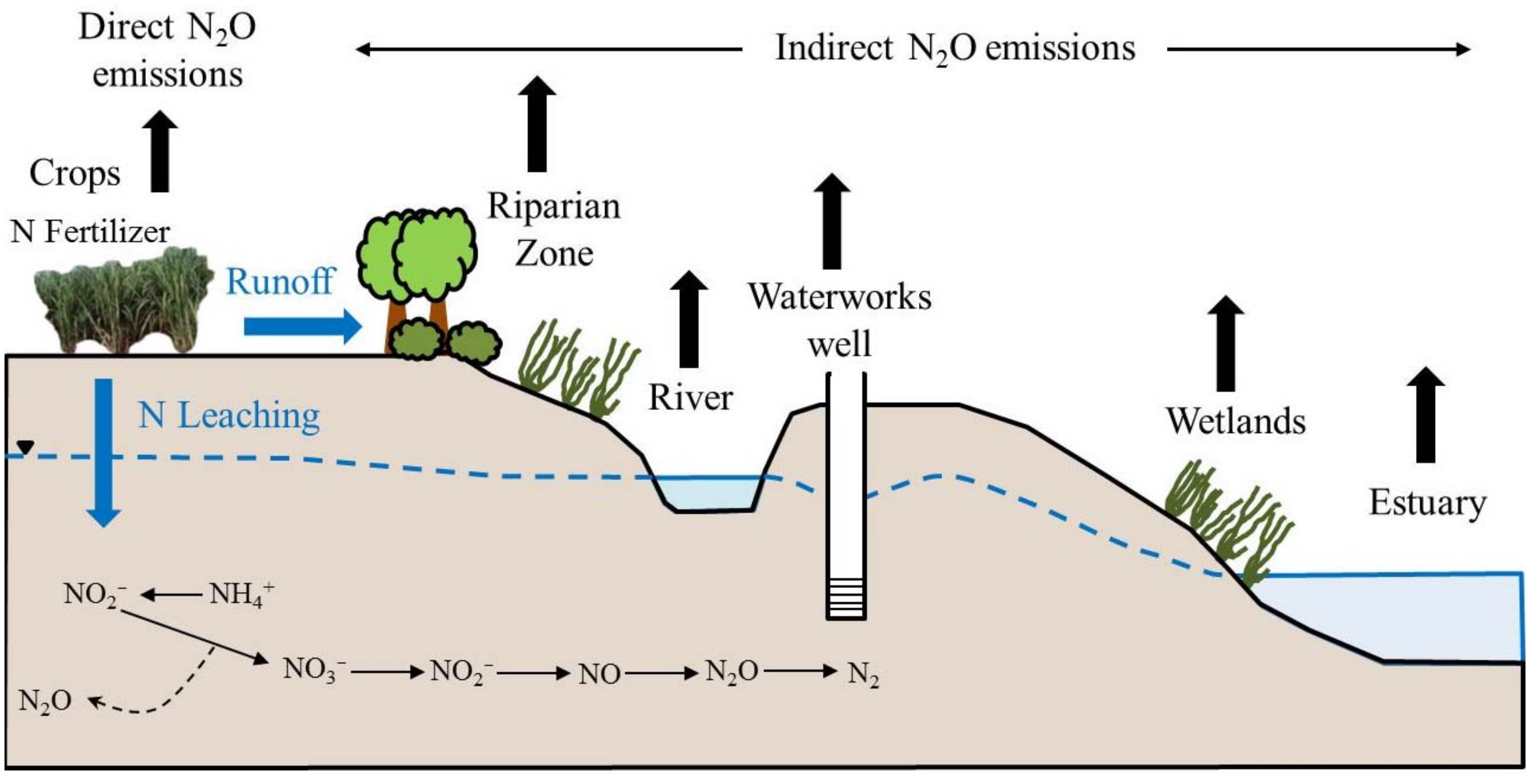
Most significant greenhouse gases

Strong ozone depleting substance (N_2O)

Agricultural landscapes : 1/3 of total anthropogenic emissions (Gilbert 2012)

Direct vs Indirect emissions : Groundwater as a source of GHGs

Groundwater has been proposed as a potential indirect source of GHGs to the atmosphere, particularly in agricultural areas (Anderson et al., 2014: Jahangir et al., 2012, Minamikawa et al., 2011)

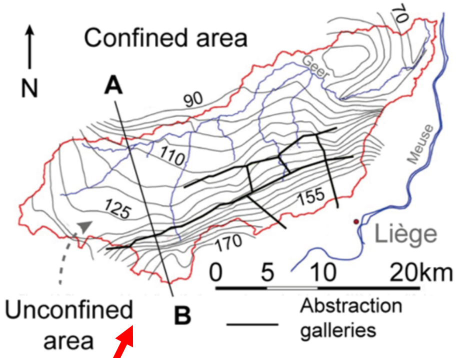


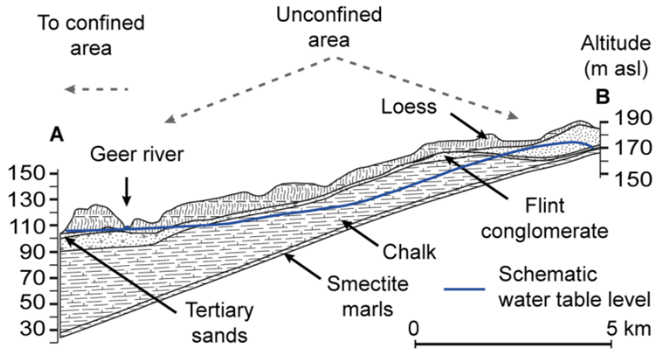
Source: Jurado et al. STOTEN (2017)

In this context, several questions arise:

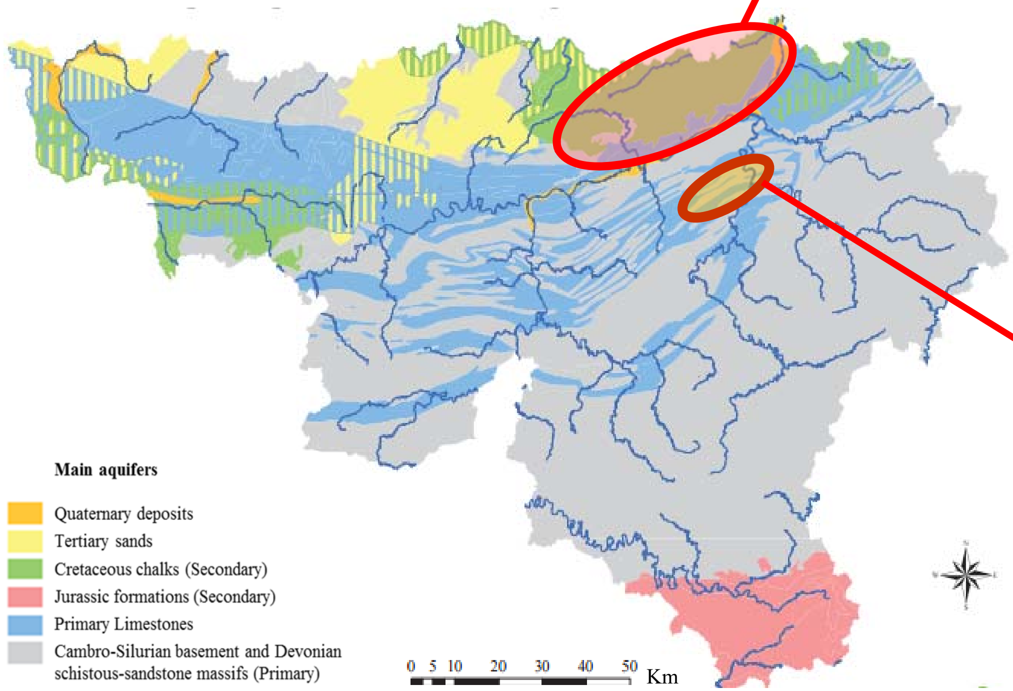
1. What are the mechanisms effectively driving the production and consumption of GHGs in groundwater?
2. To which extent does groundwater contributes to GHGs emissions in the atmosphere?

Case studies in the Walloon Region of Belgium

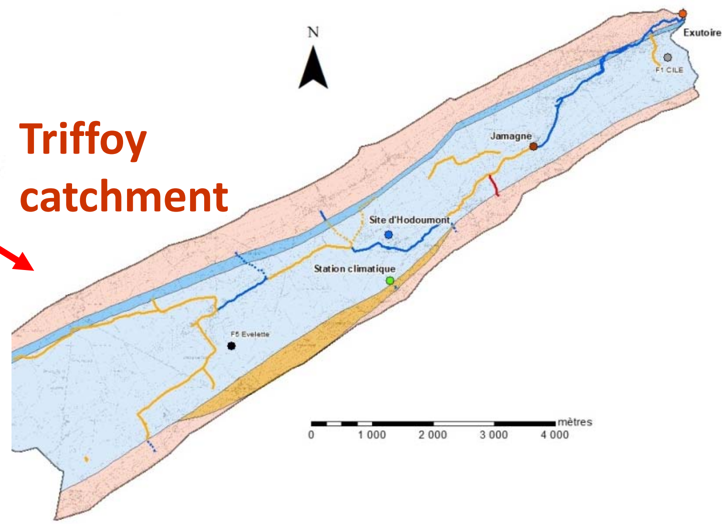




Geer catchment



Triffoy catchment



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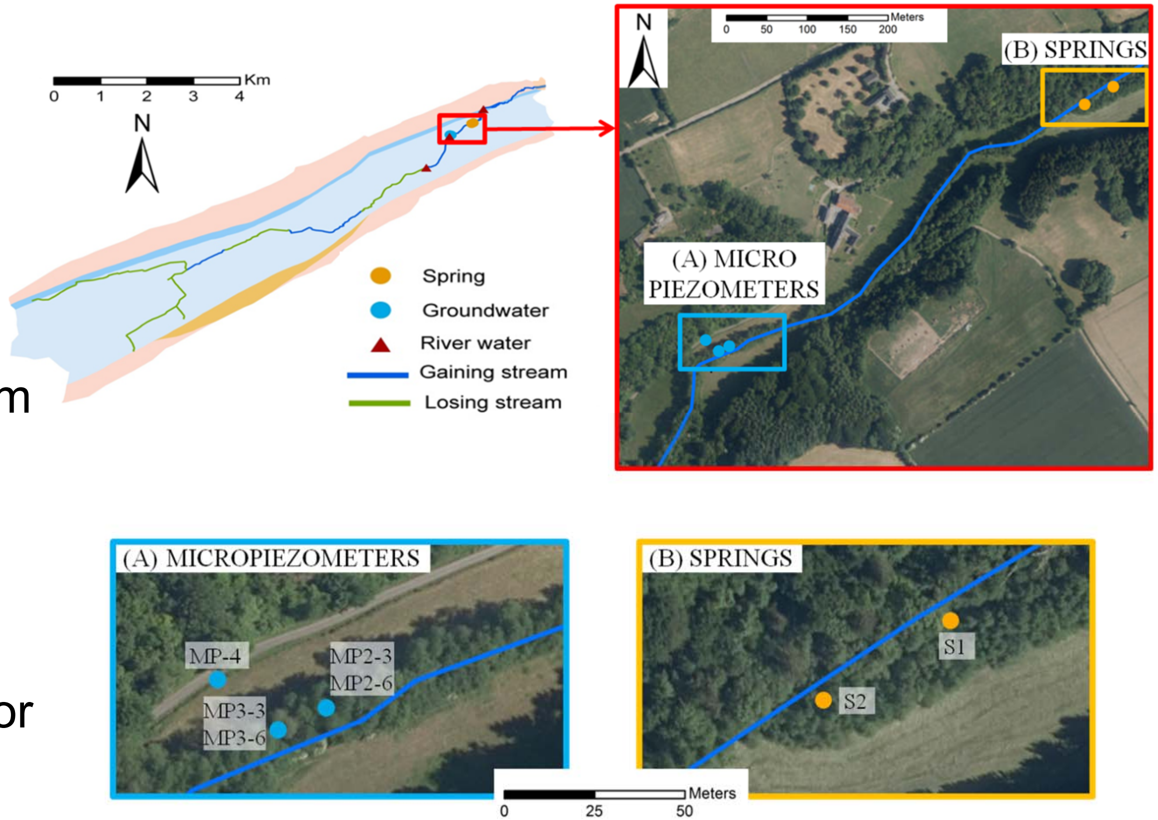
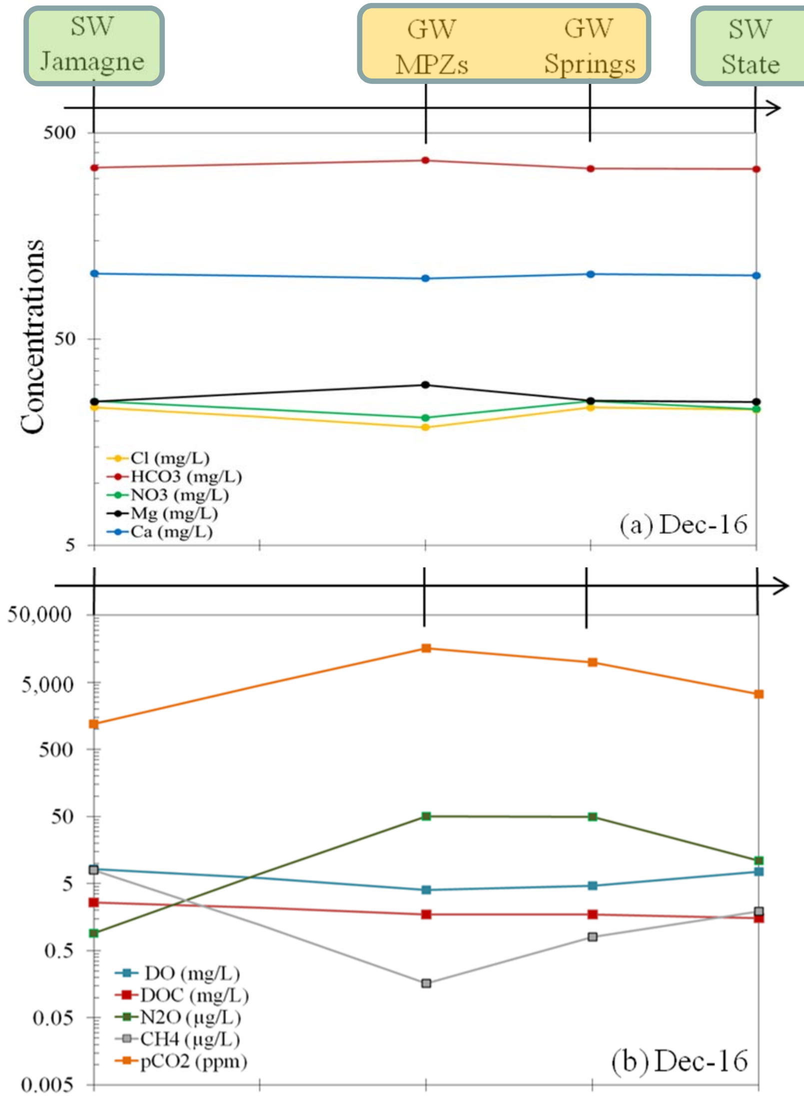
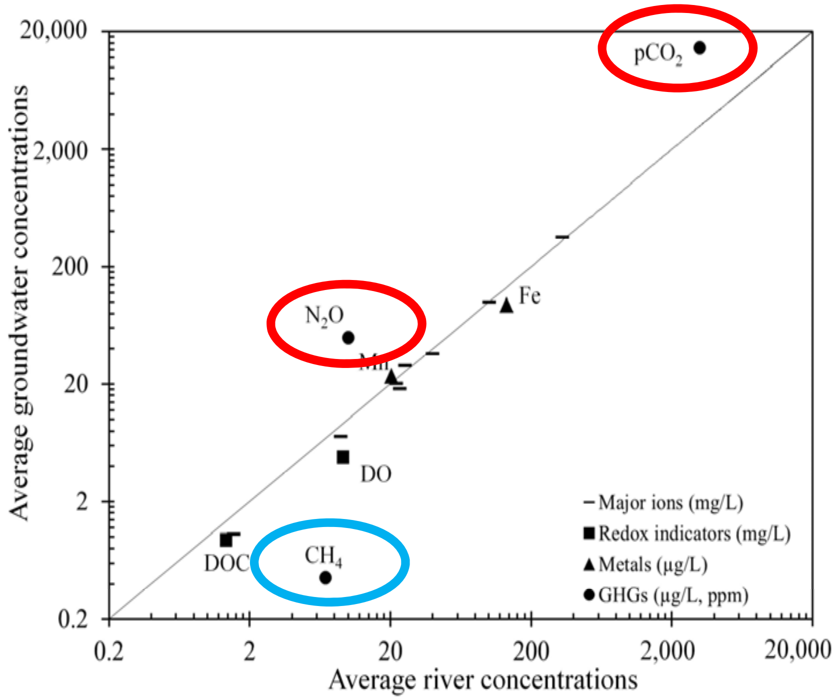
Occurrence of GHGs in groundwater : Triffoy river catchment

- Agricultural catchment
- River flows through Carboniferous limestone syncline between two Devonian sandstone crests
- Monitored river stretch = 2 km gaining stream with average discharge of ±6000 m^3 d^{-1}.
- River and groundwater samples collected from October 2016 to May 2017 for the analysis of GHGs, major and minor ions and stable isotopes of nitrate



Occurrence of GHGs in groundwater : GW & SW hydrogeochemistry





C_{equil_atm}:

CO_2 : 400 ppm
N_2O : 0,55 µg/L
CH_4 : 0,056 µg/L

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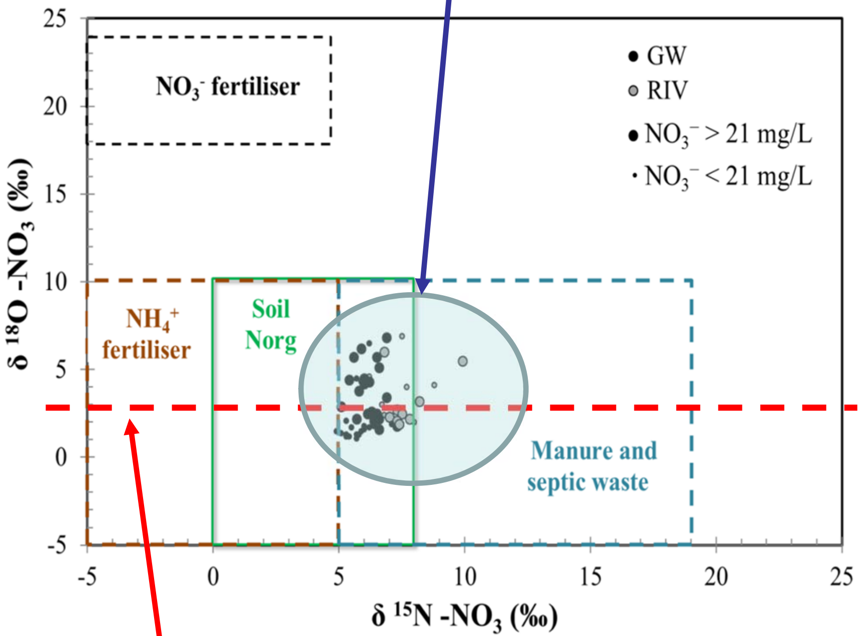
N_2O production - consumption : lines of evidence for nitrification

Essentially Soil N, manure or sewage

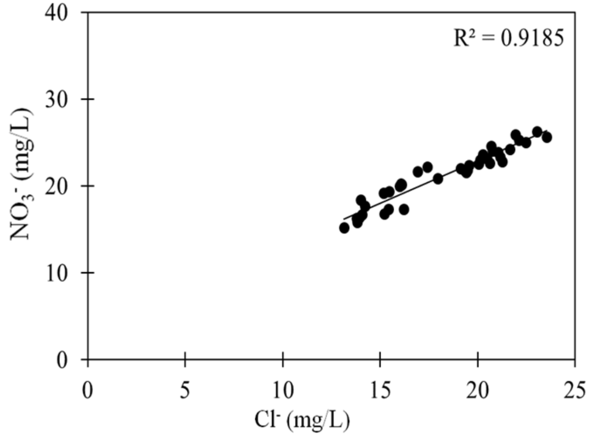


When nitrification occurs:

$\delta^{18}O_{NO3} = 2/3\ \delta^{18}O_{water} + 1/3\ \delta^{18}O_{atmos} \sim +3$ ‰

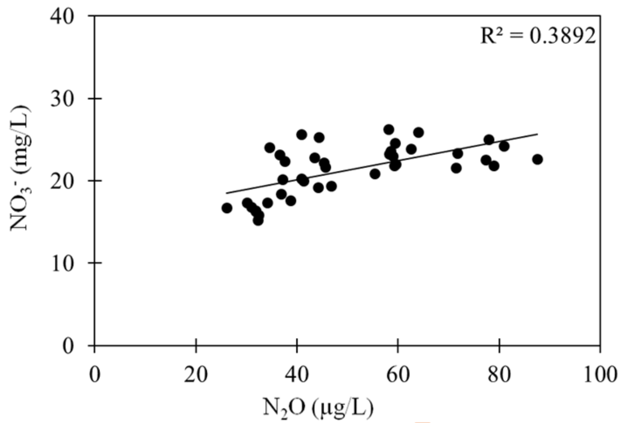
NO_3^- - Cl^- positive correlation

→ no denitrification



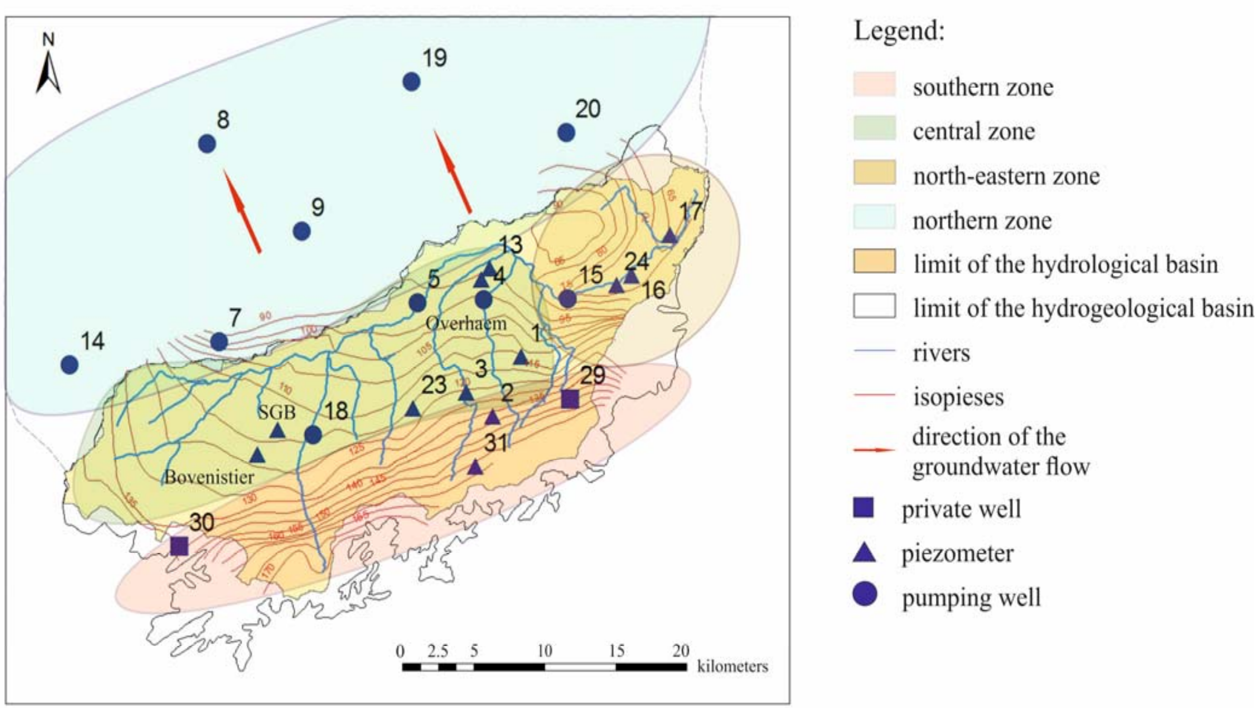
NO_3^- - N_2O positive correlation

→ nitrification



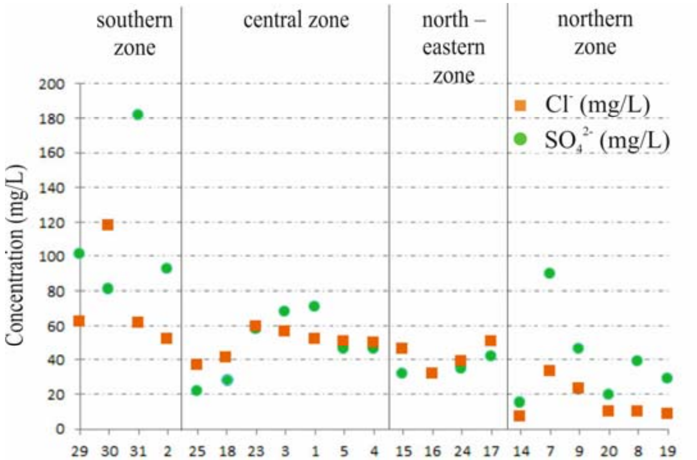
Occurrence of GHGs in groundwater : Geer catchment (chalk aquifer)

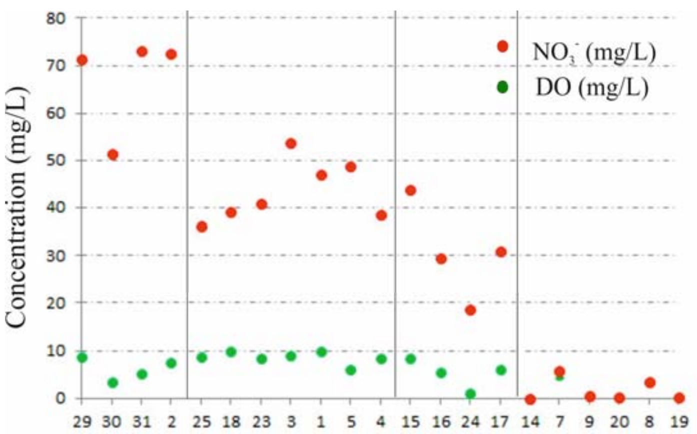
- High fracturing chalk aquifer;
- 65% of the area used for agricultural activities
- aquifer unconfined in the south, semi-confined near the Geer river and confined in the north
- groundwater samples collected across the aquifer to study the variability of GHGs along the lateral and vertical dimensions



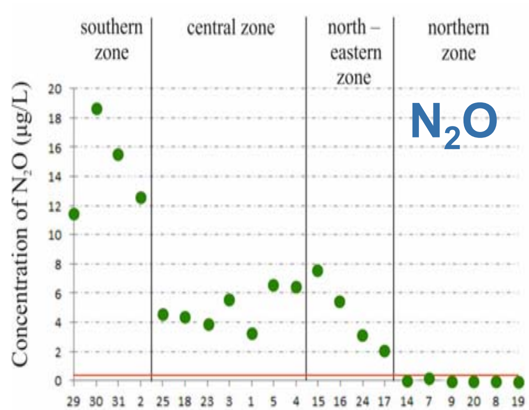
Occurrence of GHGs in groundwater: Distribution of NO_3^-, DO, N_2O

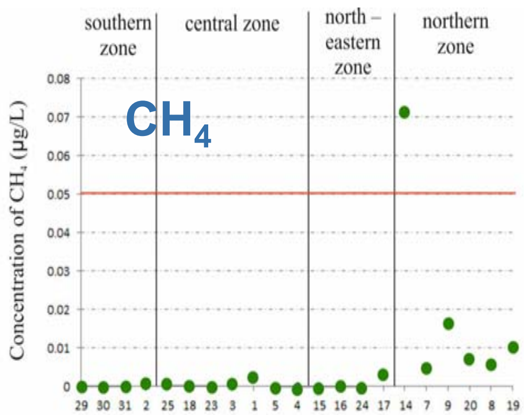
Major elements and DO

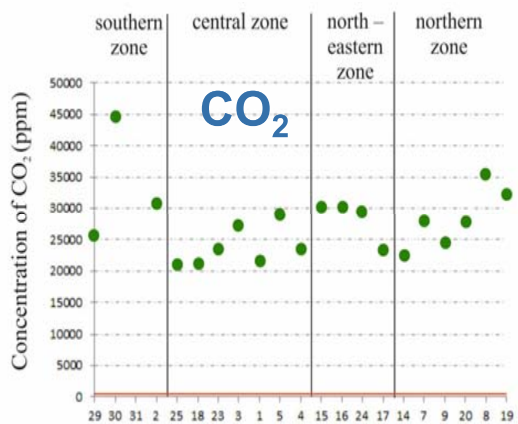




Greenhouse gases







C_equil_atmosph

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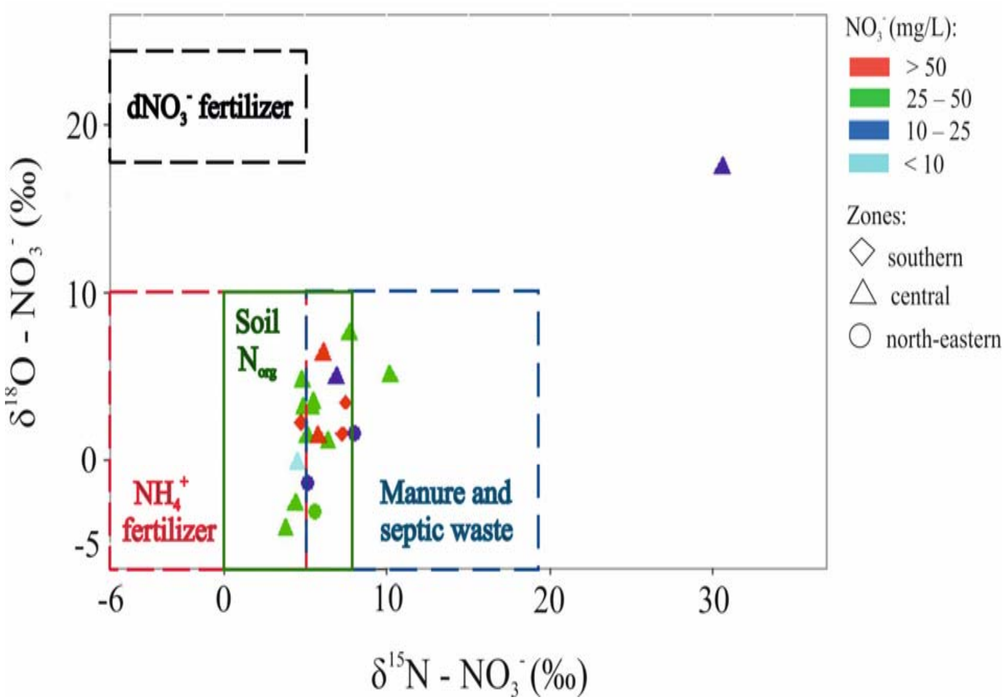
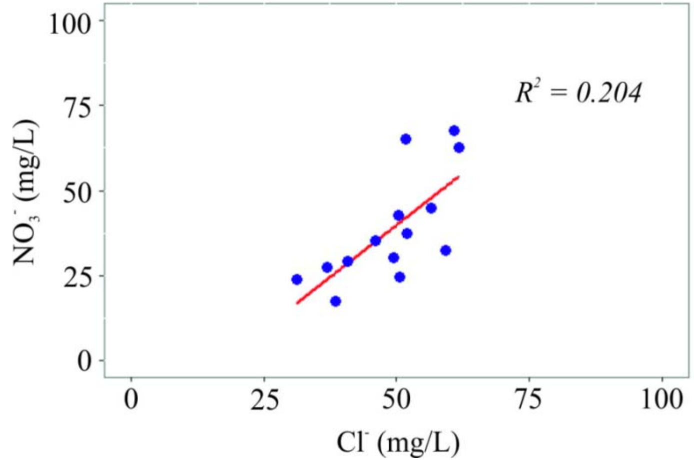
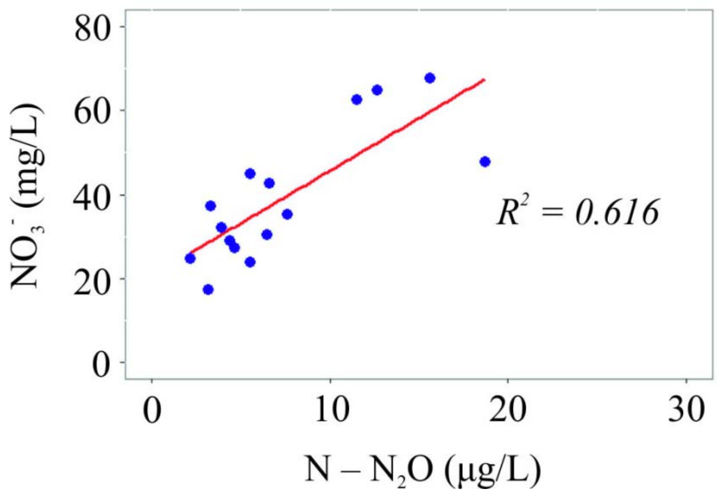
N_2O production - consumption : lines of evidence for nitrification?







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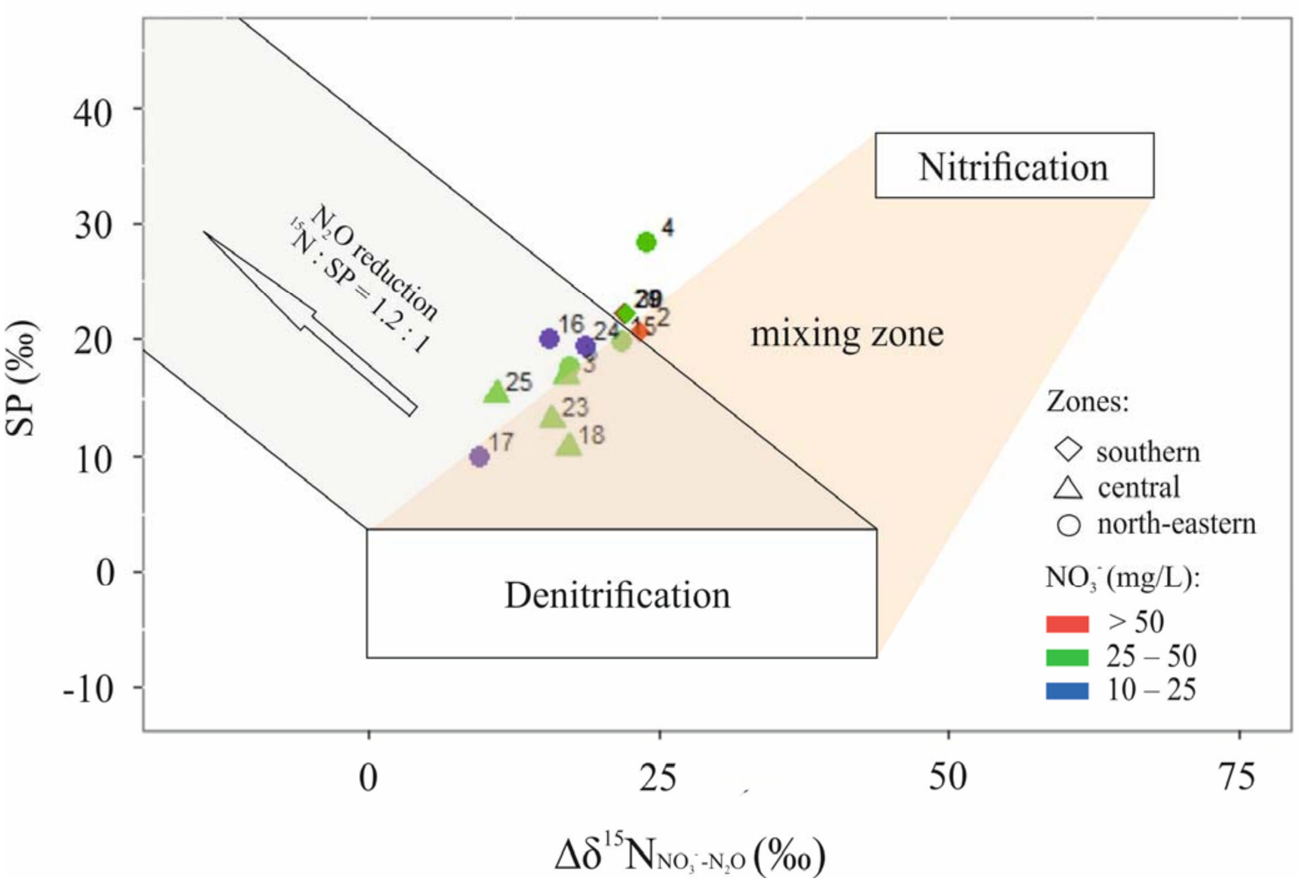
N_2O production – consumption : line of evidence for nitrification and denitrification

- $\Delta\delta^{15}N_{NO_3^- - N_2O}$ versus SP (‰) isotopomer map

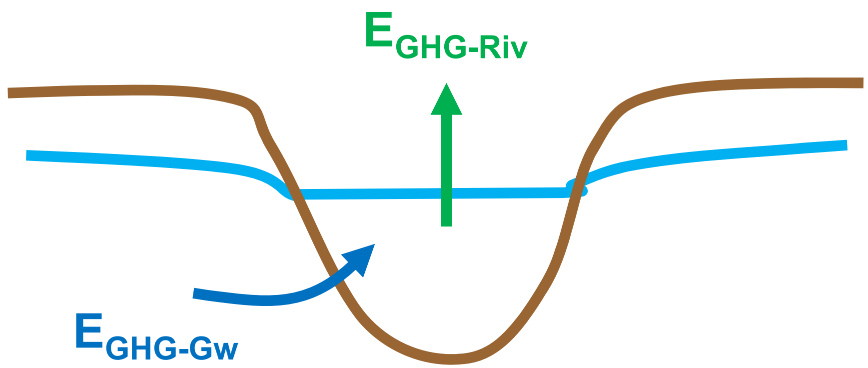


Groundwater emissions of GHGs : mass balance over river stretch / catchment (Triffoy catchment again)

River scale …

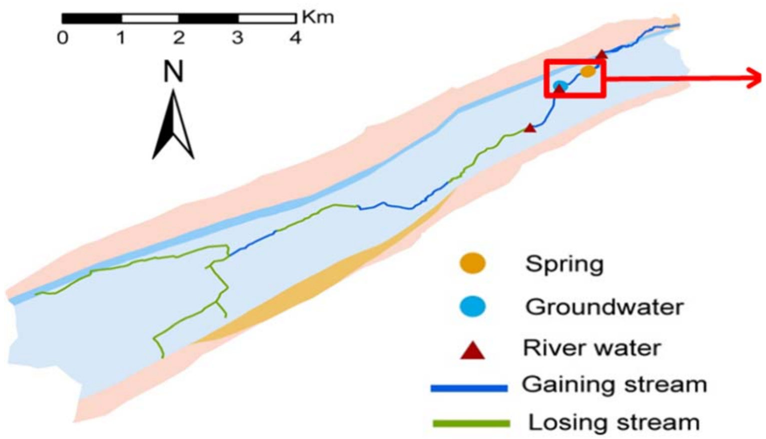
$$E_{GHG-Riv} = k \times [C_{GHG-Riv} - C_{GHG-Eq}]$$

k: gas transfer velocity



$$E_{GHG-Gw} = \frac{Q_{dis}[C_{GHG-Gw} - C_{GHG-Eq}]}{A_{river}}$$

… vs catchement scale



$$E_{GHG-catch} = \frac{Q_{dis}[C_{GHG-Gw} - C_{GHG-Eq}]}{A_{catch}}$$

IPCC 2006 : (for N_2O only) $E_{N2O-catch} = 0{,}3 \times NLeach \times EF5g$

$$= 0{,}3 \times NLeach \times \frac{N-N_2O}{N-NO_3}$$

Occurrence of GHGs in groundwater : calculated emissions

	N_2O (kg x ha^{-1} x $year^{-1}$)	CO_2 (kg x ha^{-1} x $year^{-1}$)	CH_4 (kg x ha^{-1} x $year^{-1}$)
Mean local $E_{GHG\text{-}Gw}$	207	$1,5 \times 10^5$	1,6
Mean local $E_{GHG\text{-}Riv}$	126,9	$9,7 \times 10^4$	105
Mean catchement $E_{GHG\text{-}catch}$	0,040	29,8	3×10^{-4}
IPCC Mean catchement $E_{GHG\text{-}catch}$ (*for N_2O only*)	0,037	--	--

Rem : Local estimate of EFG5 coefficient 3 times higher than the default value proposed by IPCC (0,0069 ± 0,0018 vs. 0,0025)

Occurrence of GHGs in groundwater : Conclusions

- Groundwaters of the studied catchments are oversaturated in CO_2 and N_2O relative to atmospheric concentrations.
- Methane can be produced in reducing groundwater conditions (null and low oxygen, NO_3 and N_2O and presence of Fe) but all in all, CH4 is essentially produced in surface waters
- Results show that N_2O is essentially produced by nitrification, but also, to a less extent during denitrification which in turn can contribute to N_2O consumption
- Indirect emissions from the studies aquifers is a minor pathway of N_2O atmospheric emissions but their quantification help to better constrain the N_2O budget

Any questions?

Groundwater Quality 2019

The next IAHS conference on Groundwater Quality (**GQ 2019**) will be held in Liège (Belgium) on 9-12 September 2019 !

With the support of IAH, UK CL:AIRE, NICOLE and EU H2020 ITN iNSPIRATION

More information : **aimontefiore.org/GQ2019**

Contact: c.dizier@aim-association.org – serge.brouyere@uliege.be

Further reading on GHGs

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Related papers:

Jurado Elices, A., Borges, A., Pujades, E., Hakoun, V., Otten, J., Knoeller, K., & Brouyère, S. (2018, January). Occurrence of greenhouse gases in the aquifers of the Walloon Region (Belgium). Science of the Total Environment. http://hdl.handle.net/2268/215313

Jurado, A., Borges, A., Pujades, A., Briers, P., Nikolenko, O., Dassargues, A., & Brouyère, S. (2018). Dynamics of greenhouse gases in the river-groundwater interface in gaining river stretch (Triffoy catchment, Belgium). Hydrogeology Journal. http://hdl.handle.net/2268/226422

Nikolenko, O., Jurado Elices, A., Borges, A., Knöller, K., & Brouyère, S. (2017, October). Isotopic composition of nitrogen species in groundwater under agricultural areas: A review. Science of the Total Environment. http://hdl.handle.net/2268/215300

Jurado Elices, A., Borges, A., & Brouyère, S. (2017). Dynamics and emissions of N2O in groundwater: A review. Science of the Total Environment, 584-585C, 207-218. http://hdl.handle.net/2268/207095