Modeling lixiviated nitrate by coupling agro-hydrological (SWAT) & hydrogeological (MARTHE) models

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Plan

1. **Motivation & objectives**
2. **Background**
3. **Methodology**
4. **The MARTHE model**
5. **The modeling framework**
6. **Coupling results**

Perspectives

1. **Motivation** & objectives

Provide local and water resource stakeholders with a decision aid tool to help them carry out a global assessment of water resources, as specified in the WFD.

1. Motivation & **Objectives**

A three-step research plan:

- *Step 1:* Evaluate feasibility of external coupling in terms of time calculations, temporal and spatial processing scales, and identifying parameters that allow lixiviated nitrate to be integrated into MARTHE meshes (2012).
- *Step 2:* External coupling, confronting the SWAT & MARTHE water and nitrate balances. Identify the processes and constraints (2013-2015) .
- *Step 3:* Develop a specific interface for internal model coupling, to simulate hydric and nitrogen balances using SWAT & MARTHE and expand the current modeled area to include the whole Charente watershed (10,000 km² wide) and nitrate/pesticide modeling. Transfer the application to local stakeholders (foreseen in preparation 2016-2018).

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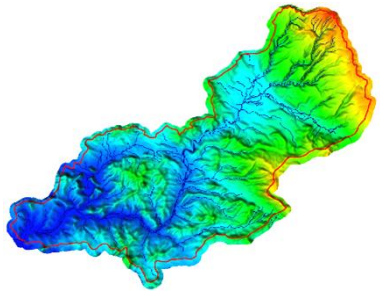
2. Background

The **1,300 km²** wide Boutonne watershed is located in SW France.

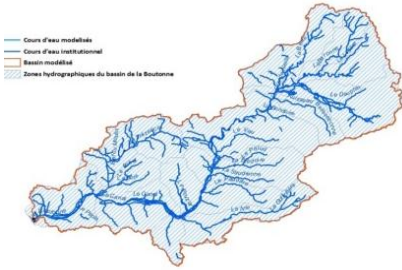
The basin is characterized by*:*

- **Heavily-farmed** watershed close to the coast
- **Oceanic** climate - 820 mm of average annual rainfall



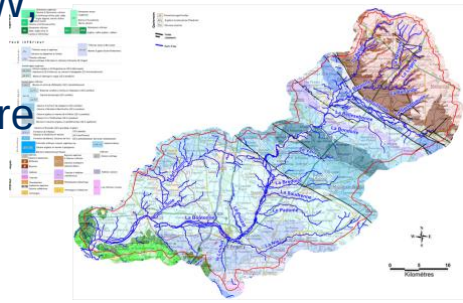
Topography: a few meters in the South to 190m high in the North

Hydrography: the Boutonne river is 310km long, with almost 8,000km of surface streams. It is the closest Charente tributary to the estuary



Geology:

- The whole basin lies on a clay-limestone layer affected by 4 faults
- Six overlapping Jurassic compartments run from the NE to the SW, from Lias Cretaceous through the Dogger and the Malm
- In the North, aquifers are generally confined due to the solid nature of silty marl and alluvium, whereas in the South, there is greater connectivity with rivers, due to the permeability of limestone



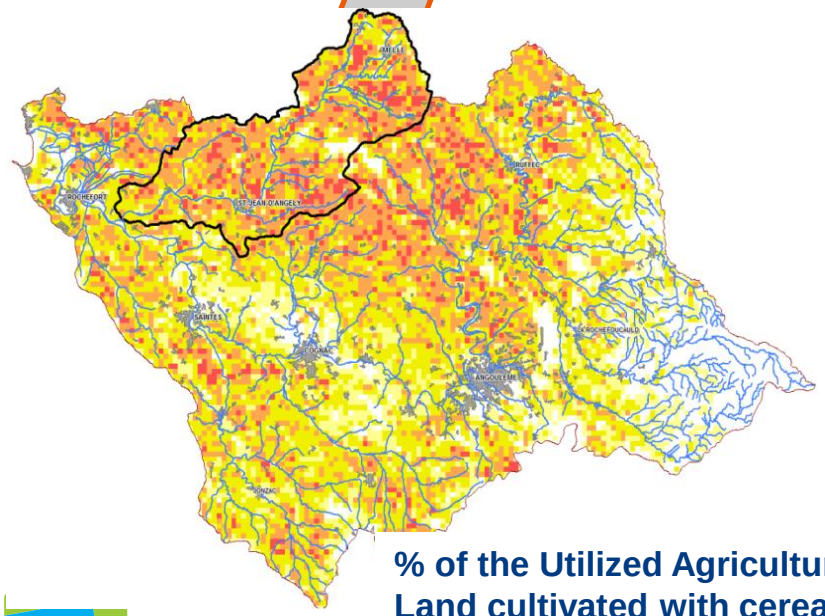
2. Background: Nitrate NPS pollution

The regional global degradation of water quality in streams and aquifers

Agriculture

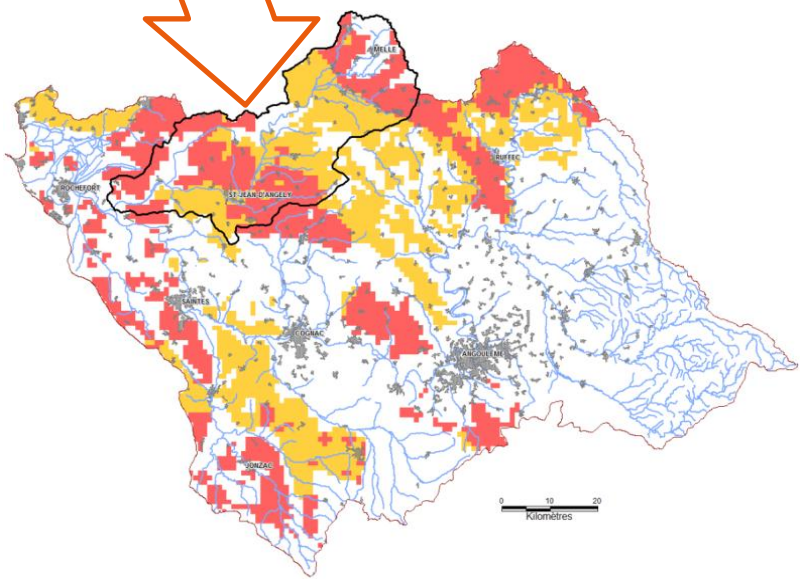
Farming-related pollution

Nitrate concentrations in fresh water



% of the Utilized Agricultural Land cultivated with cereals

- No cereals
- Less than 10%
- From 10 to 30%
- From 30 to 50%
- Above 50%

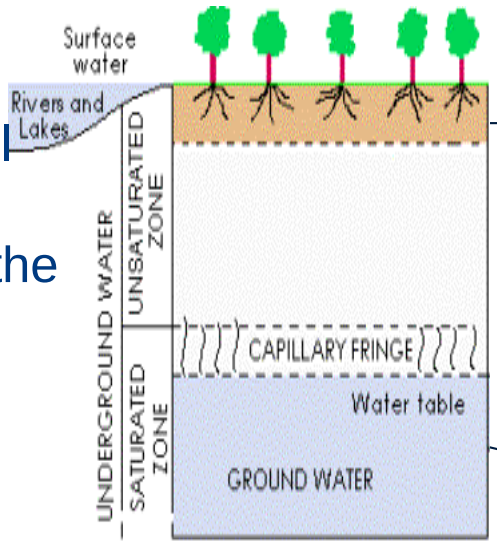


- NO3 concentrations exceed 50 mg/l all year.
- NO3 concentrations exceed 50 mg/l at high water.

3. Methodology for externally coupling

- **SWAT – GenLU (IRSTEA) - Semi distributed agrohydrological model** that benefits from the expertise of IRSTEA in agronomical practices and soil characterization which are implemented into SWAT with the GenLU application

- **MARTHE (BRGM) - Fully distributed hydrodynamic model** that benefits from the expertise of **BRGM** in geo-hydrological and hydro dispersive modeling



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Agrohydrological model SWAT

Géosciences pour une Terre durable
brgm

Hydrogeological model MARTHE

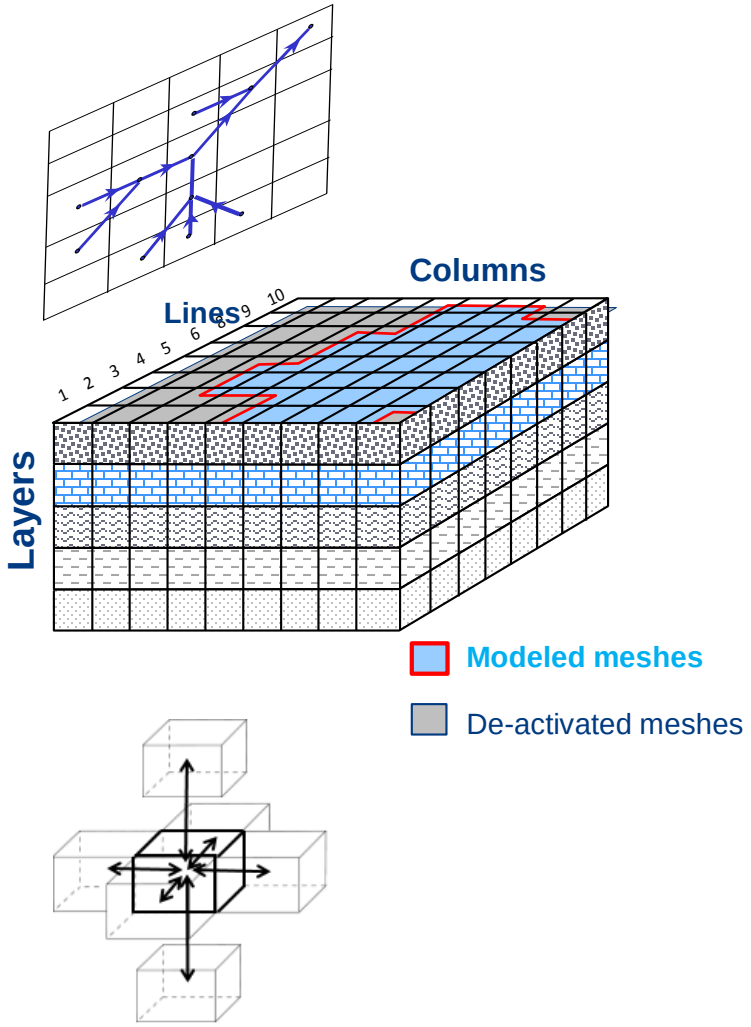
Common knowledge and input data sharing
Constraint the processes and balances

4. The MARTHE model

The MARTHE model developed by BRGM uses the finite volume method flows energy mass and transport 3D calculations

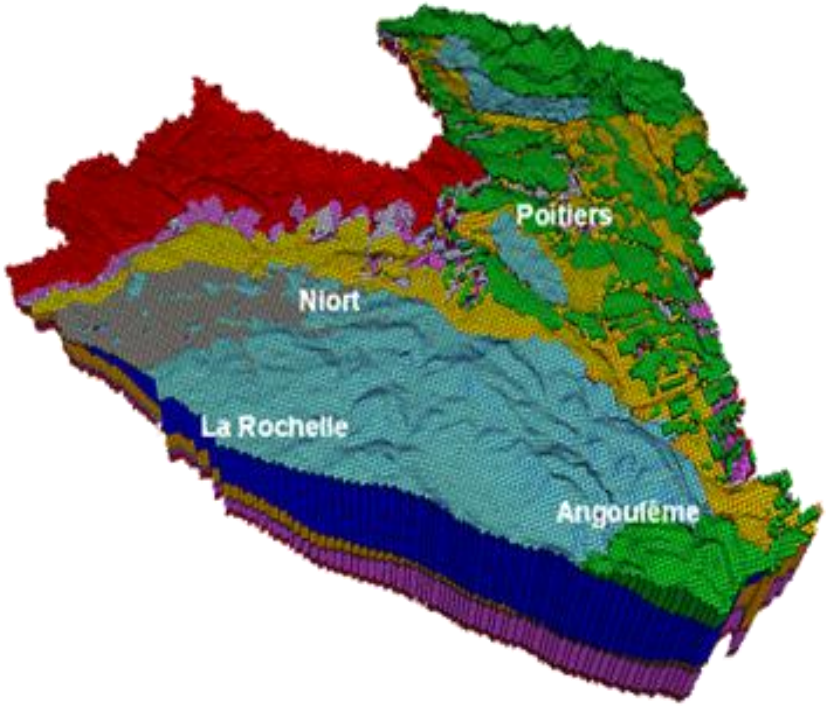
(Cf. Thiéry, 2006).

The river network is connected to the meshes of the first layer of the hydro-dispersive model.



4. The MARTHE Model

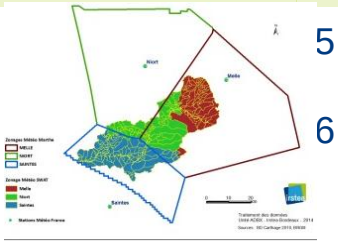
The whole Charente river watershed is covered by two regional models: Jurassic in the North and Cretaceous in the South



- Wetlands
- Cretaceous and alterites
- Altered late Jurassic
- Non-altered late Jurassic
- Dogger
- Toarcian
- Infra-Toarcian
- Basement

4. Identifying the main processes & parameters

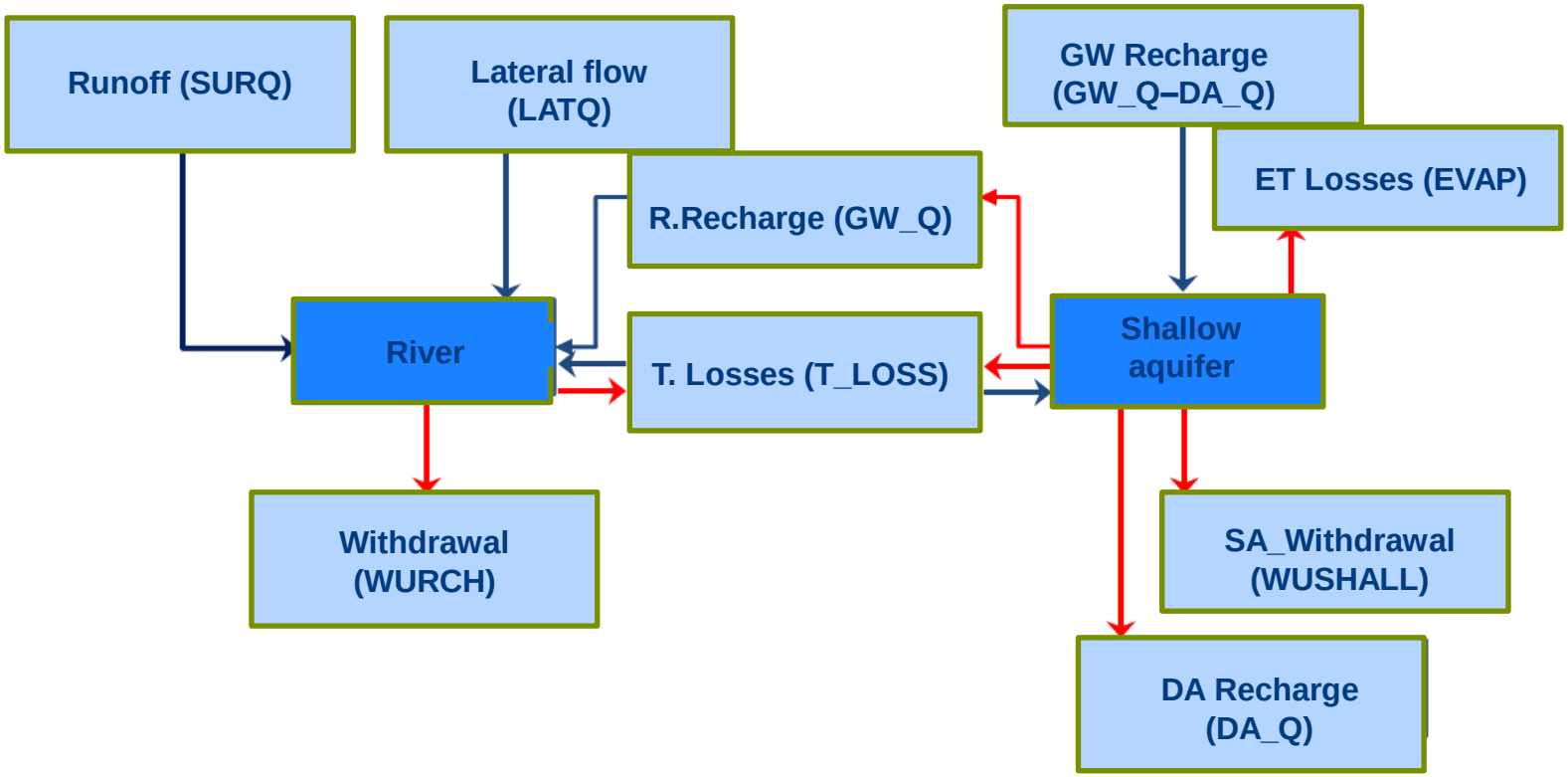
External coupling feasibility assessment

Examples	SWAT	MARTHE
Spatial scales	Subbasins (9) HRUs (269)	Meshes (1km * 1km) (1460)
Temporal scales	Calculation at daily time step	Calculation at monthly time step
Number of parameters	Over 200	4 main parameters: • Permeability • Stockage • Porosity • Dispersivity
Climate 	5 weather stations 6 weather variables	3 climate zones 1 climate variable

4. Identifying the main processes & parameters

The water balance

Each model treats hydrological processes differently

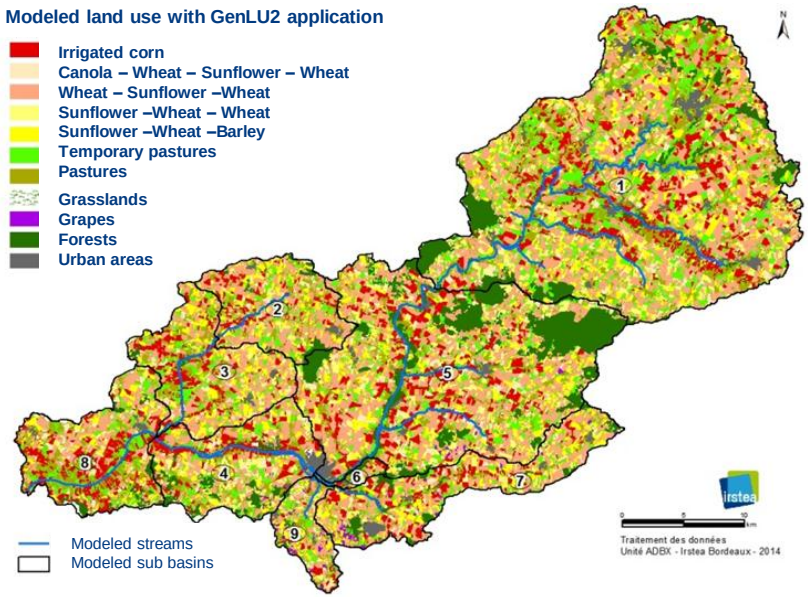


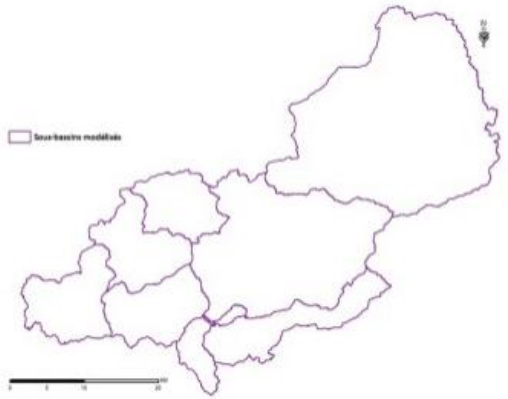
Simplified water input output which will be kept for the SWAT-MARTHE modeling system (arrows). For SWAT, refers to (Neitsch et al. 2011)

5. The modeling framework

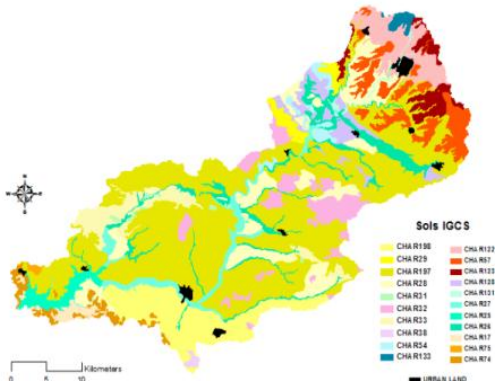
The SWAT Boutonne project set up

Land use





9 modeled watersheds

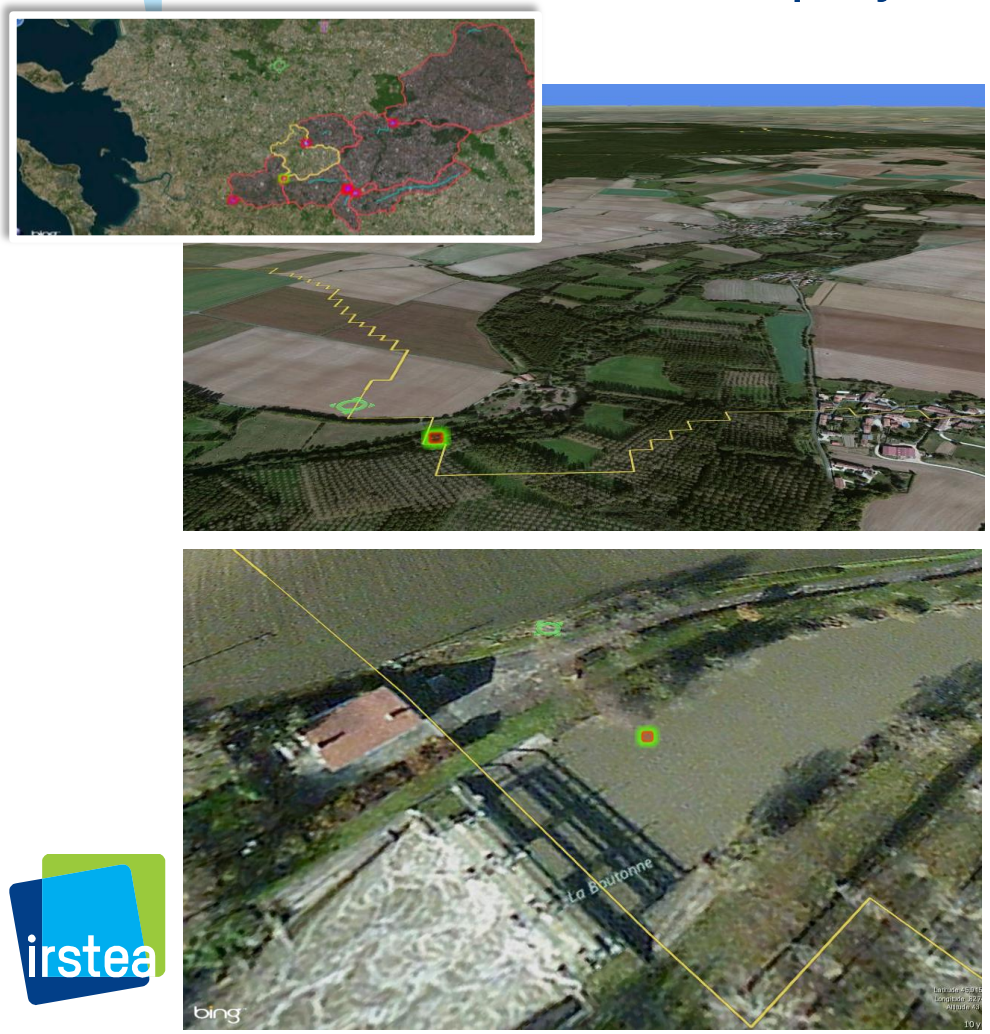


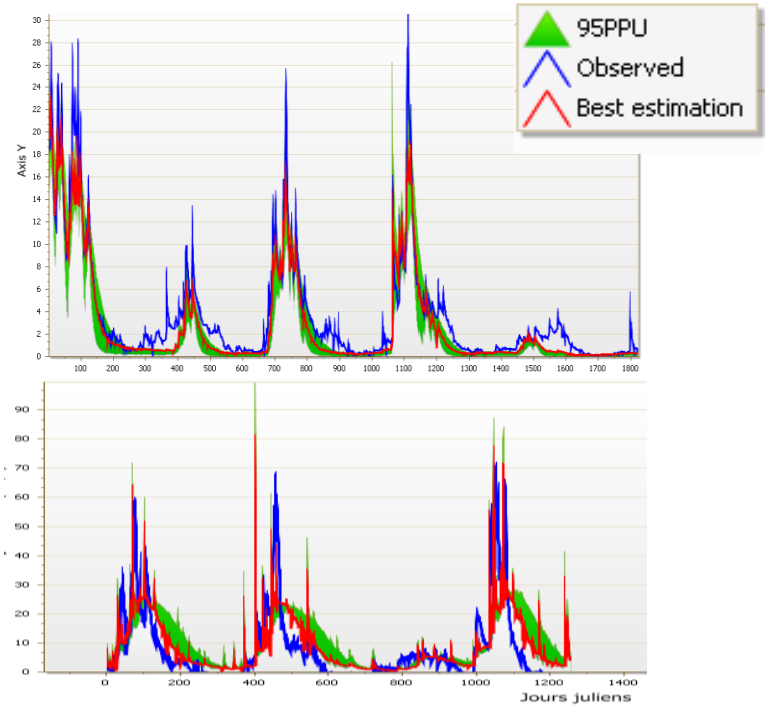
22 soil types

Implementing crop rotations
and agricultural practices with the
Irstea developed application GenLU2

5. The modeling framework

The SWAT Boutonne project - Calibration to stream flows



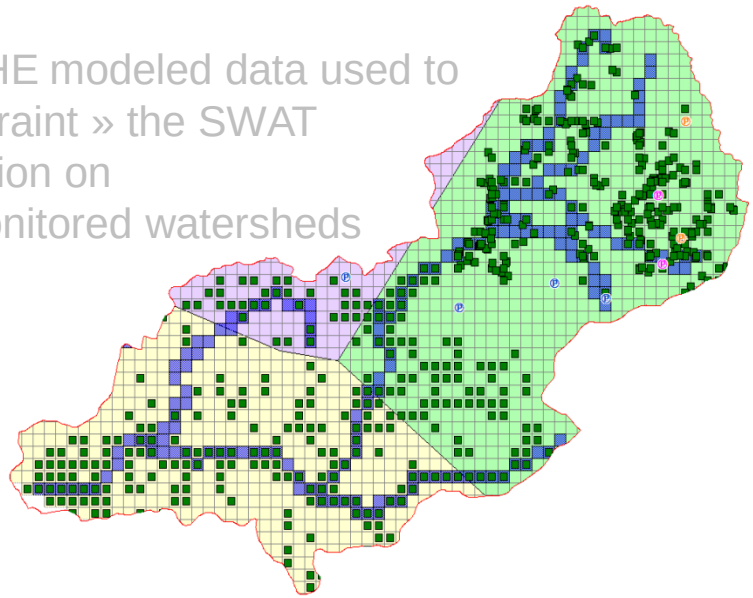


Calibration and 95PPU at St Séverin and Carillon gauging stations from 2001 to 2005. Respective Nash Succliffe Efficiencies are 0.83 and 0.7

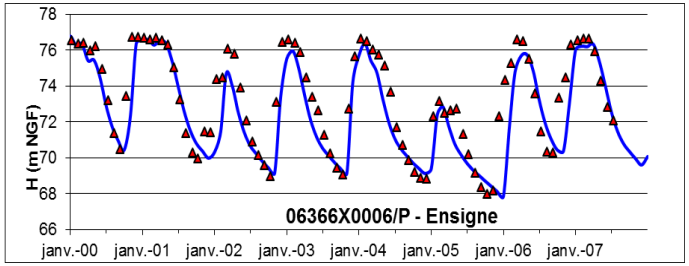
5. The modeling framework

Calibration &validation for non monitored watersheds

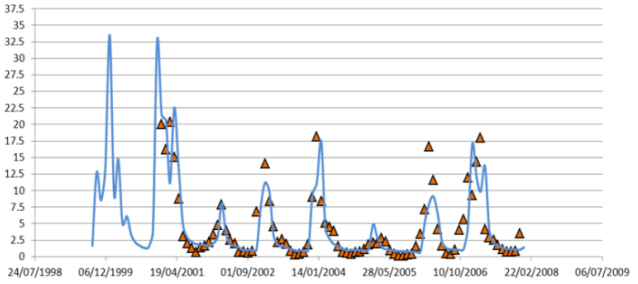
MARTHE modeled data used to « constraint » the SWAT calibration on non-monitored watersheds



Piezometer



Gauging station



Constraints

Fresh and Aq. Water withdrawals

Weather climate zonages

Water balance validation

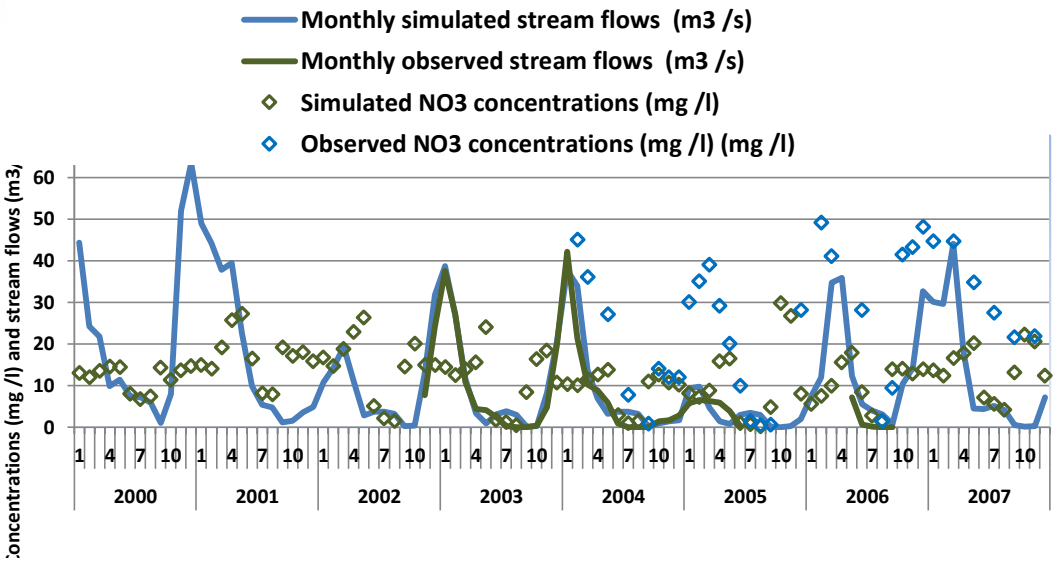
Aquifer & stream flows

Surface runoff and percolation

5. The modeling framework

SWAT results - Nitrate concentrations in streams

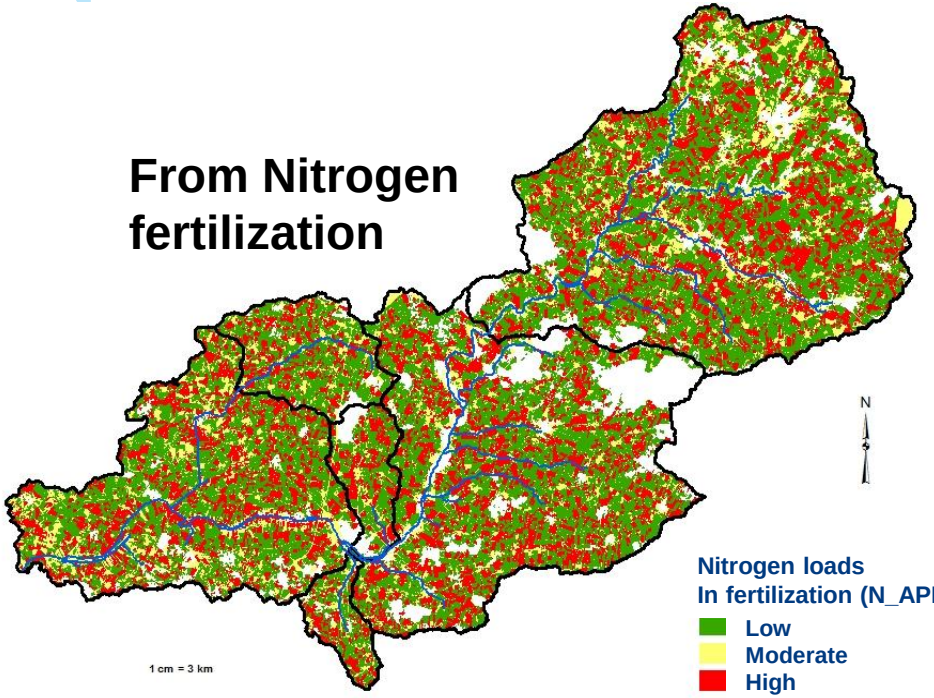
An illustration on watershed #1



5. The modeling framework

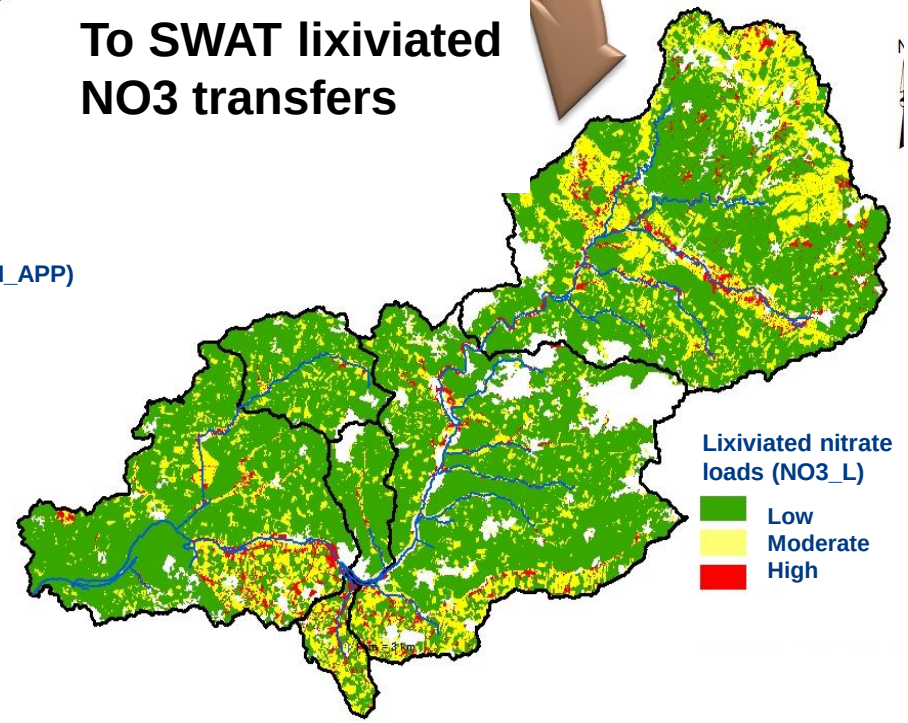
SWAT results - Lixiviated nitrate

From Nitrogen fertilization



Nitrogen loads
In fertilization (N_APP)
Low
Moderate
High

To SWAT lixiviated NO3 transfers



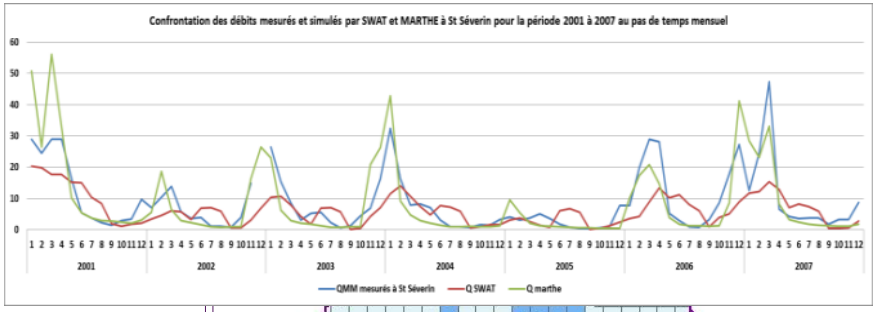
Lixiviated nitrate loads (NO3_L)
Low
Moderate
High

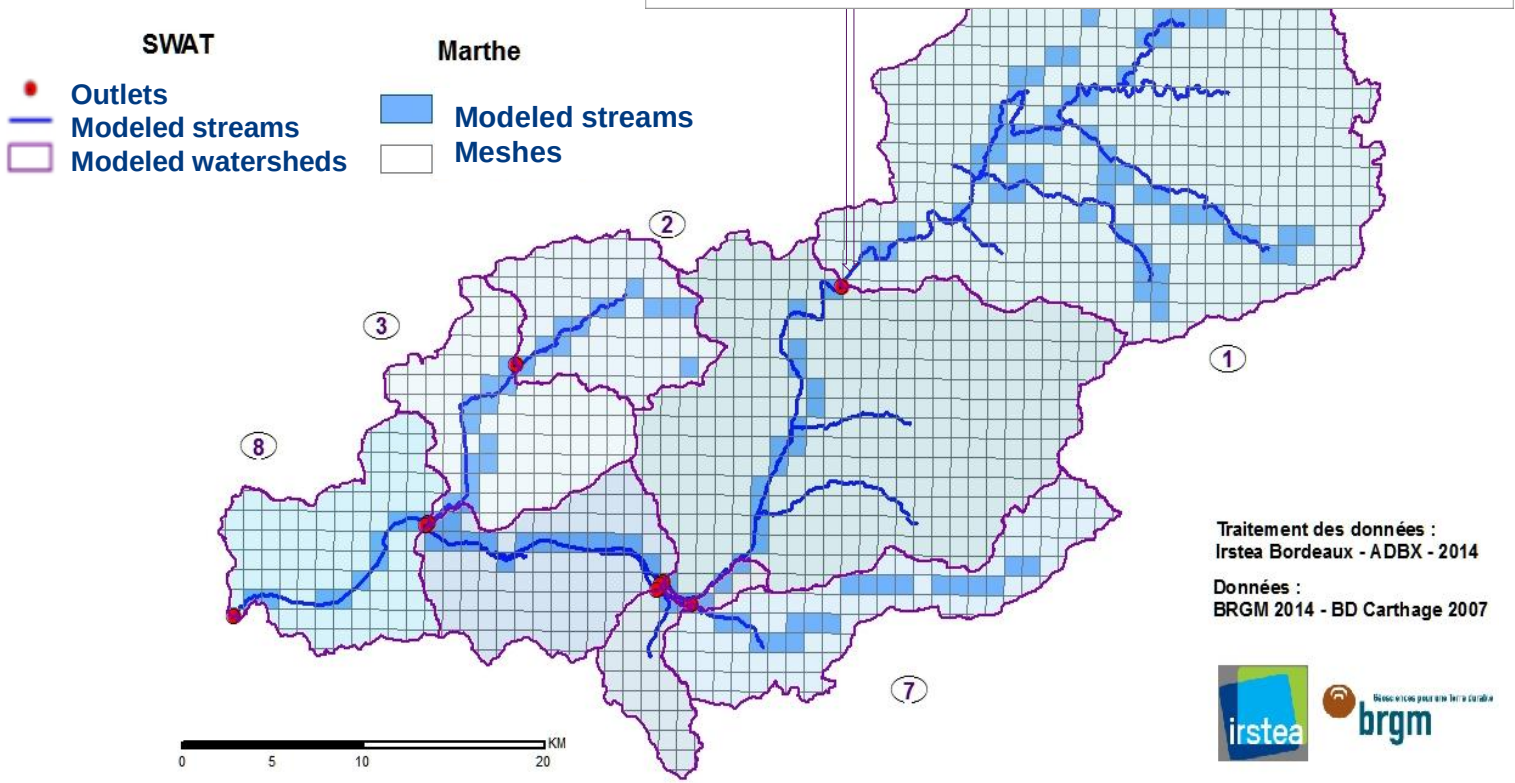
routed to the aquifers by MARTHE

6. Coupling results

Calibration gauging stations for stream flows

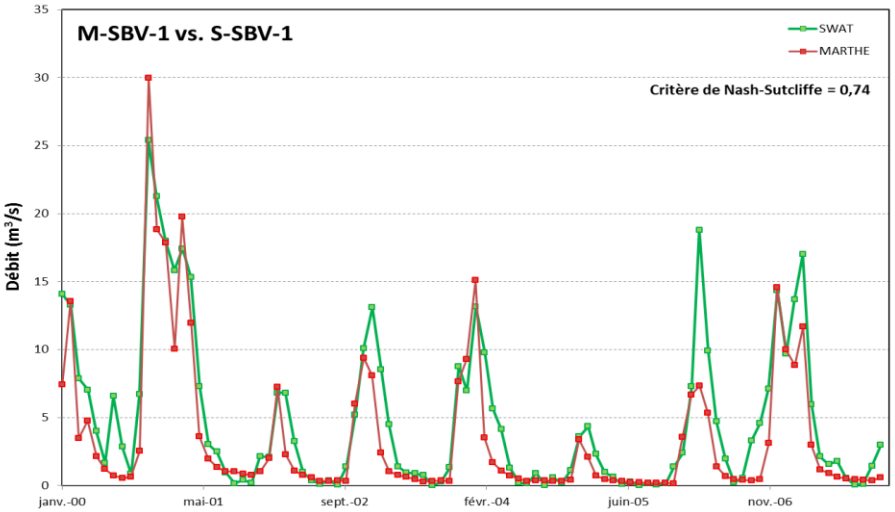
Confrontation carried out at two actual gauging stations and at six virtual gauging stations (MARTHE flows)

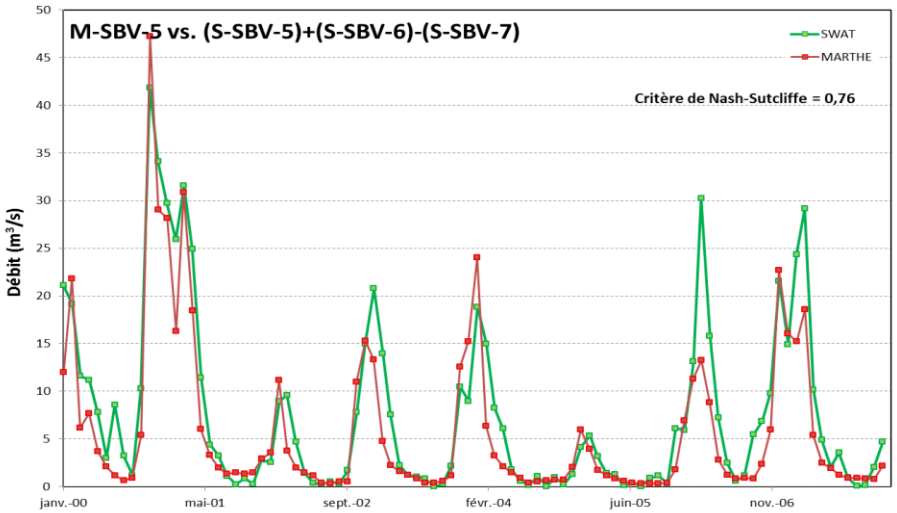


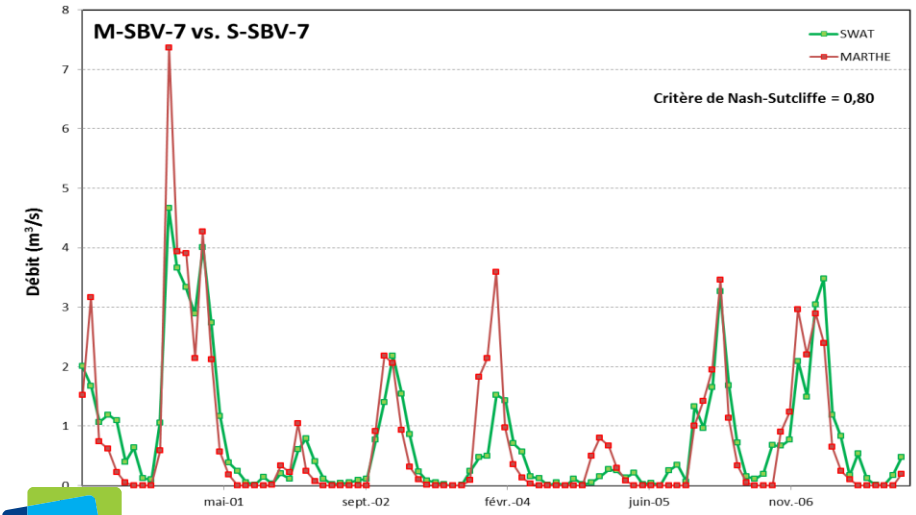


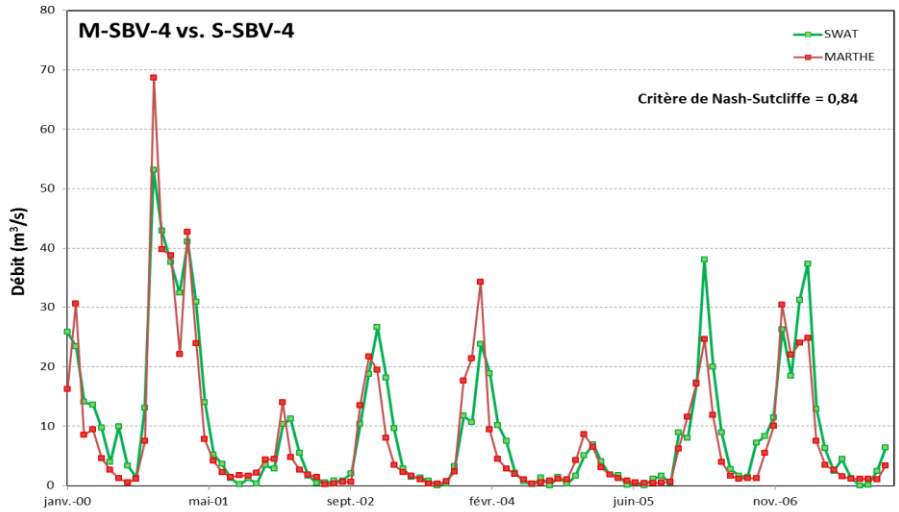
6. Coupling results

SWAT - MARTHE stream flow confrontations (4 ex.)

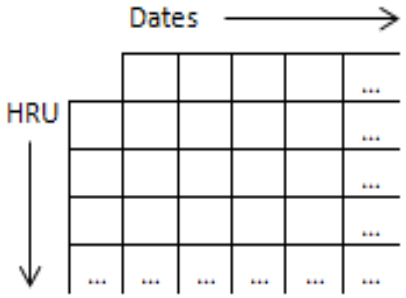




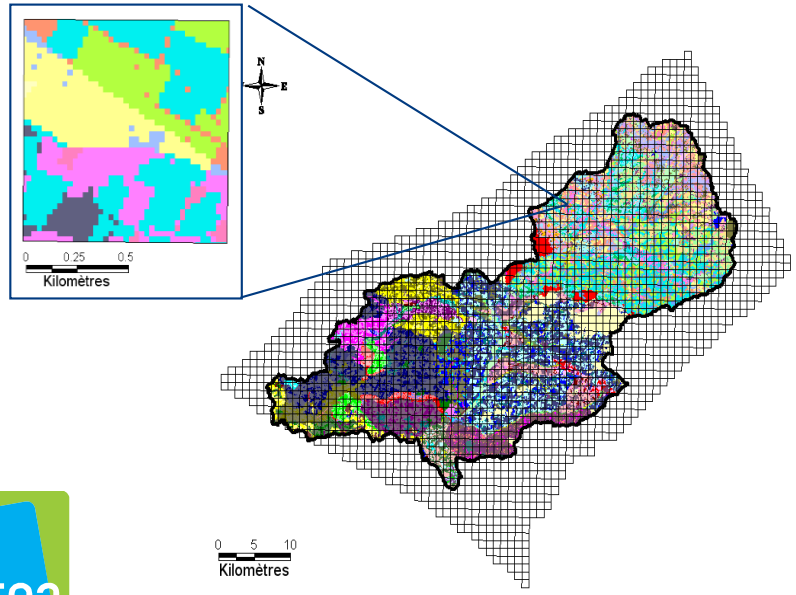




6. Coupling results

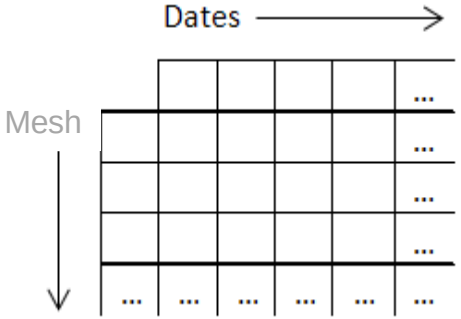


Lixiviated nitrate ouput series at HRU scale



HRU areas by mesh

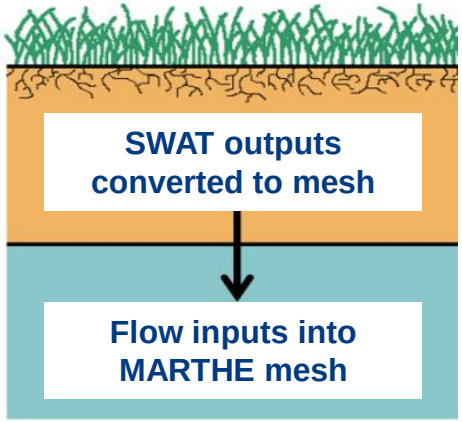
Post-processing SWAT nitrate fluxes and pre-processing MARTHE input for nitrate spatialization



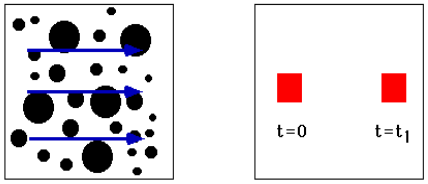
Nitrate series at monthly time step

6. Coupling results

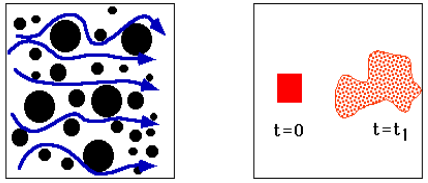
Modeling nitrate transfers into the late Jurassic aquifer



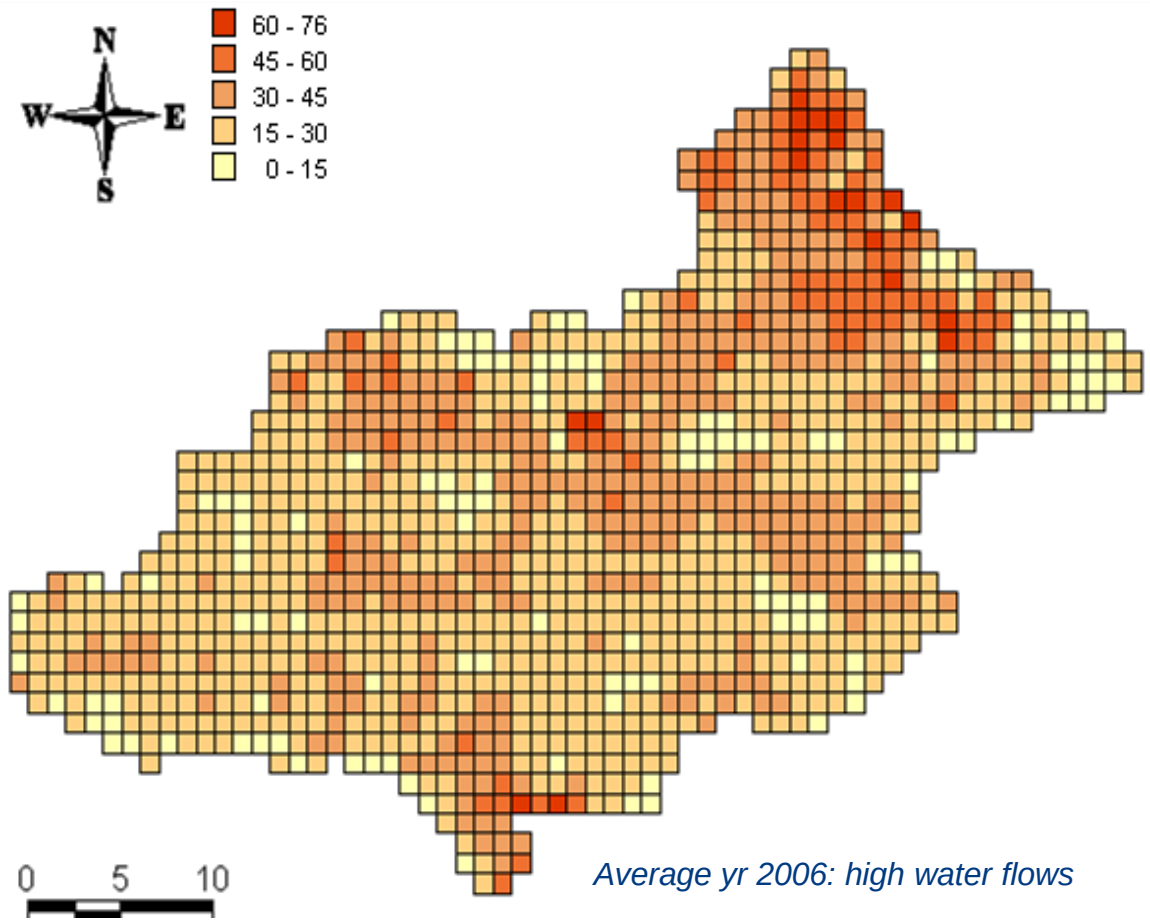
Advective transport of a solute:



Actual transport of a solute:



NO3 concentrations (mg/l)



Average yr 2006: high water flows

Conclusions

The Irstea and BRGM collaborative coupling modeling research programs have come to reach an acceptable representation of reality in:

- Comparing distributions between runoff and infiltration of the two models SWAT and MARTHE at the whole basin
- The confrontation between simulated SWAT and MARTHE stream flows
- Adjusting the SWAT parameters (the management practices, the nitrogen parameters) and MARTHE transport parameters
- Developing specific computer based processing so as to transfer data from a model to the other and then, to facilitate the implementation of mitigation measure scenarios at the HRU and at the MARTHE mesh scales

Perspectives

- Still, ameliorations and process integrations and designs need do be further investigated so as to build a common tool « SWAT-GenLU2-MARTHE » on the entire watershed of the Charente basin river

- The goal is to simulate the dynamics of nitrogen transfers in water so as to be able to test the impacts of growing anthropized activities and climate change on both fresh and groundwater

- Therefore methods need also to be developed so that they can be used by public decision makers; methods and tools may be widen to integrated assessment modeling with spatial environmental indicators and economic evaluation (Cf. Lescot, J. M., Leccia O., Vernier F- 2013)

Thank you for your attention !

Some references:

- Chatelier, M., Leccia O., Vernier F. and Bichot F.- 2013. Modélisation spatialisée des transferts d'azote par couplage SWAT(IRSTEA) et MARTHE(BRGM): exemple du bassin de la Boutonne.
- Lescot, J. M., Leccia O., Vernier F- 2013. Challenges for integrated assessment and Cost-Effectiveness analysis of mitigation measures for controlling water pollution. Transboundary water management across borders and interfaces: present and future challenges. TWAM2013
- Neitsch, S., Arnold J.. , Kiniry J., and Williams J. 2011. SWAT2009 Theoretical documentation. Texas Water Resources Institute.
- Vernier, F., Galichet B and Leccia O. - 2013. MODCHAR: Définition de scénarios d'évolution des pratiques agricoles et modélisation des impacts des pressions agricoles (pollution diffuse) dans le bassin versant de la Charente (2012).
- Thiery D. (2006) - Didacticiel du pré-processeur WinMARTHE v4.0.. BRGM/RP 54652-FR, 83p.