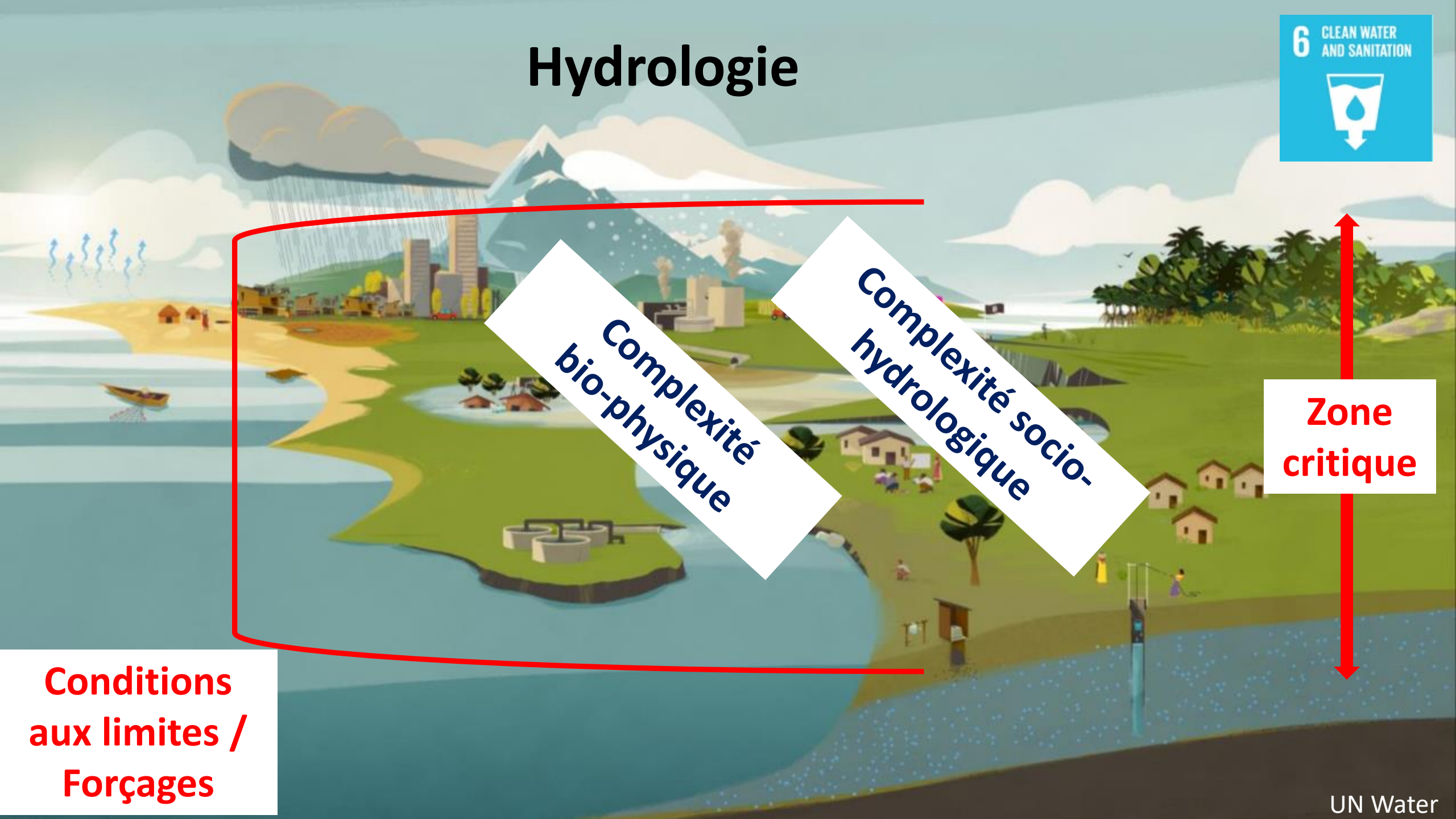
Modélisation de chroniques de débit en Bretagne
L'approche SIMFEN

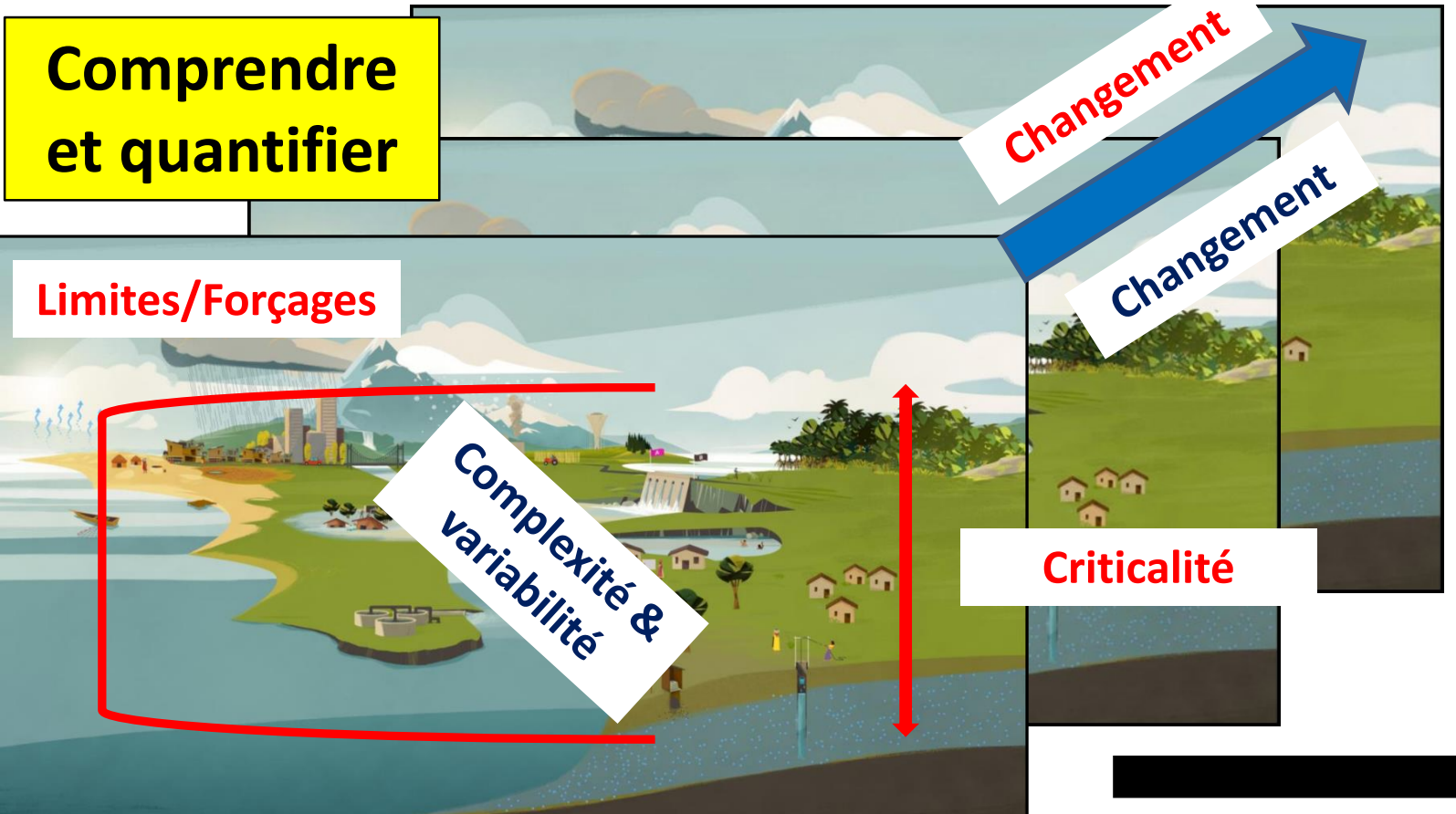
C. CUDENNEC, Institut Agro – Agrocampus Ouest

Hydrologie


6 CLEAN WATER AND SANITATION
Complexité bio-physique
Complexité socio-hydrologique
Zone critique
Conditions aux limites / Forçages
UN Water

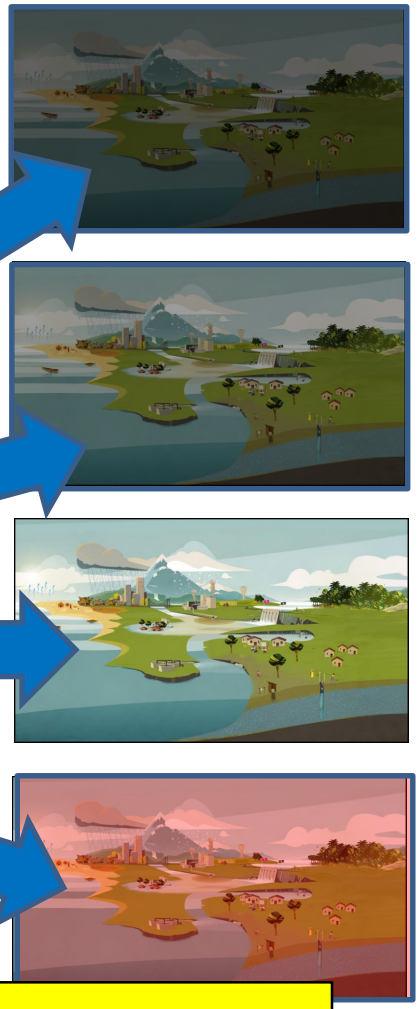
Enjeux
et fronts de science

Non-stationnarités Incertitudes



Comprendre et quantifier

...



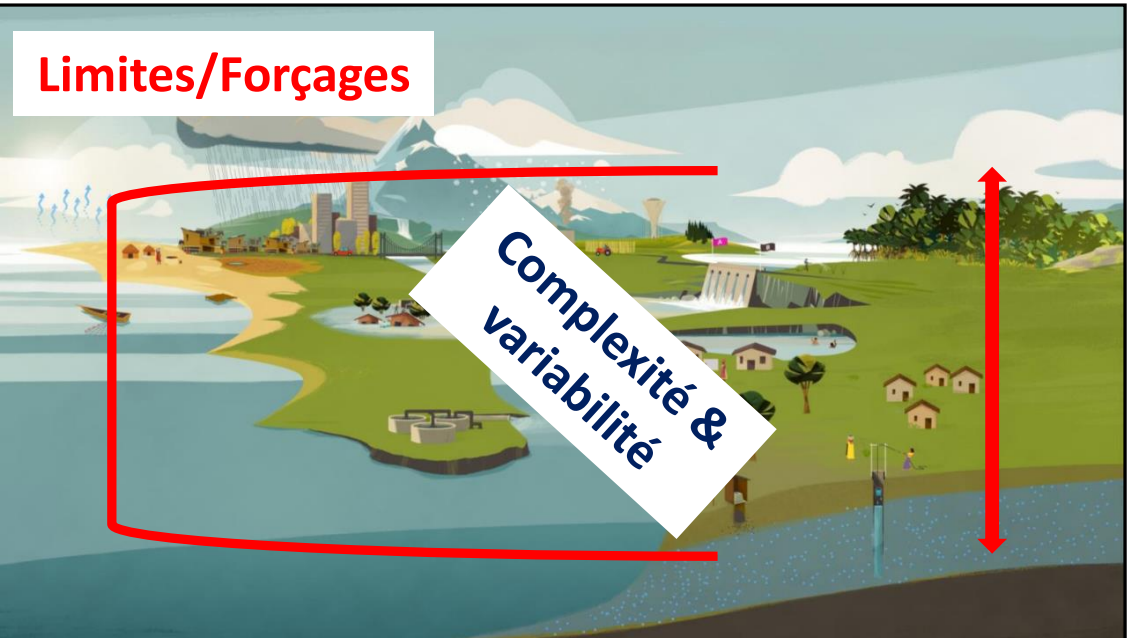
=> Bascules?

Prospective Choix Trajectoire

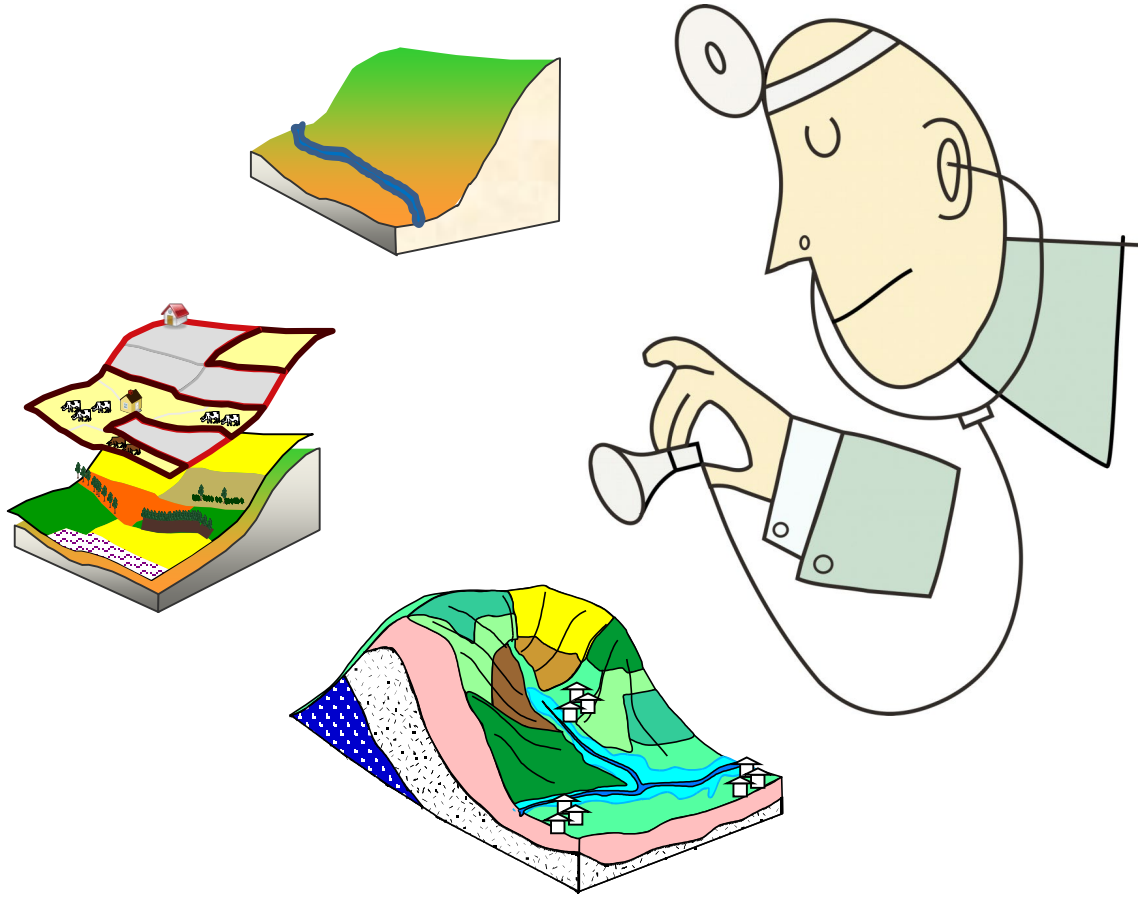
2030

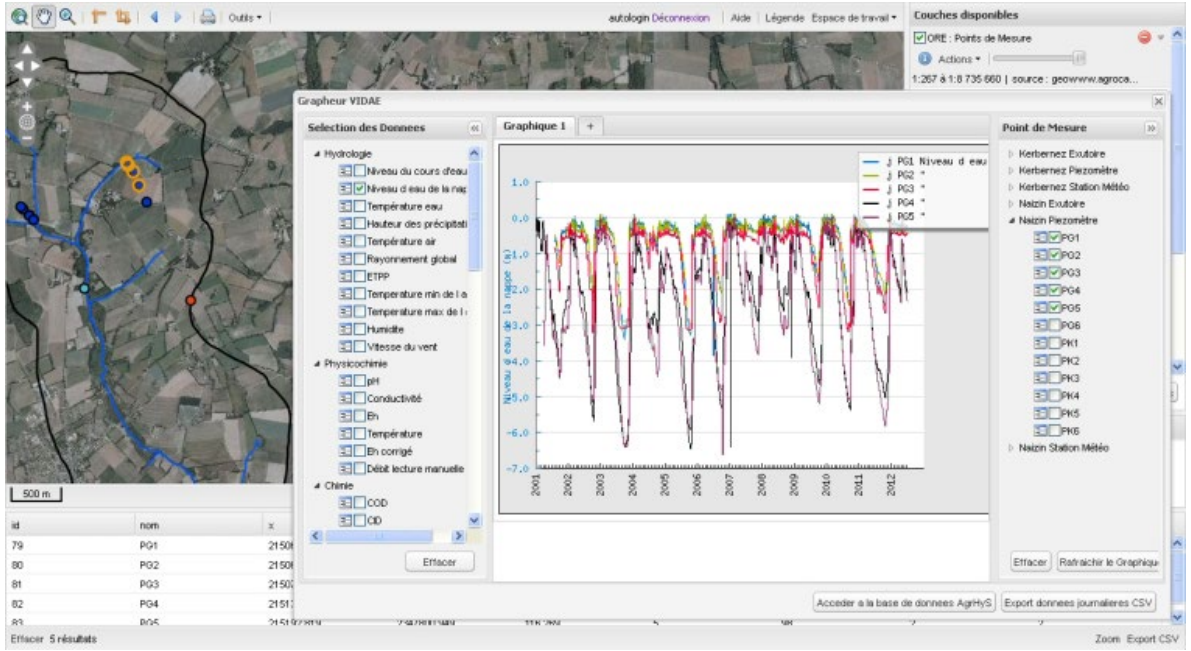
...

Comprendre et quantifier



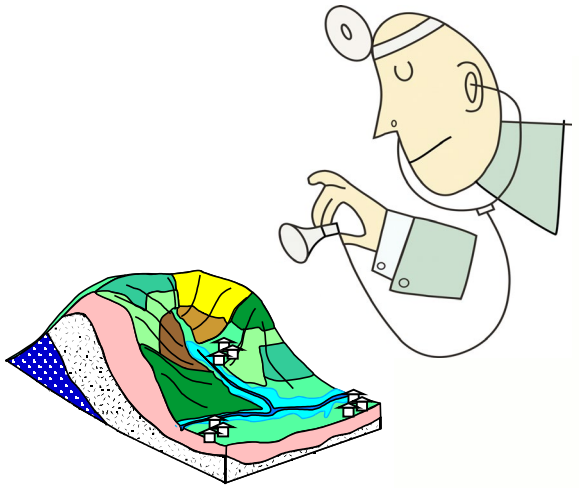
Observation – Compréhension – Quantification

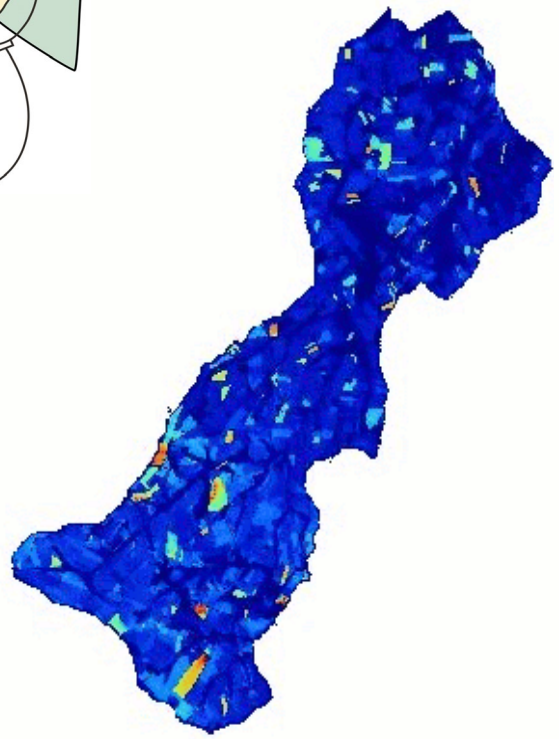


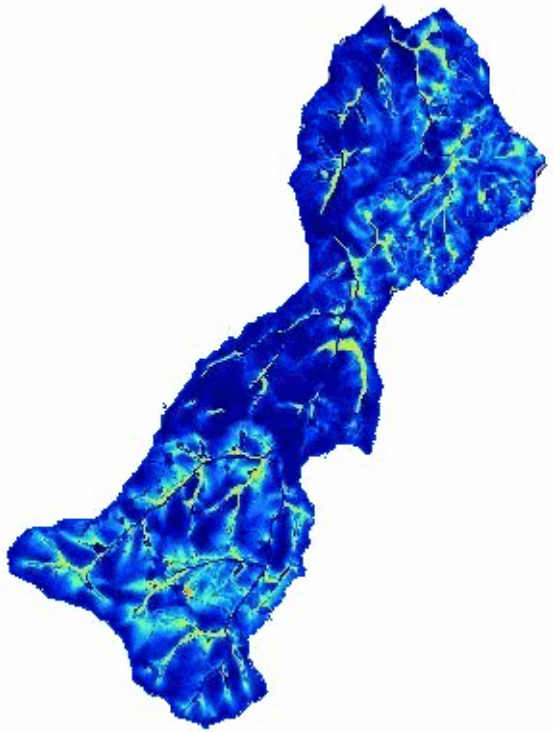


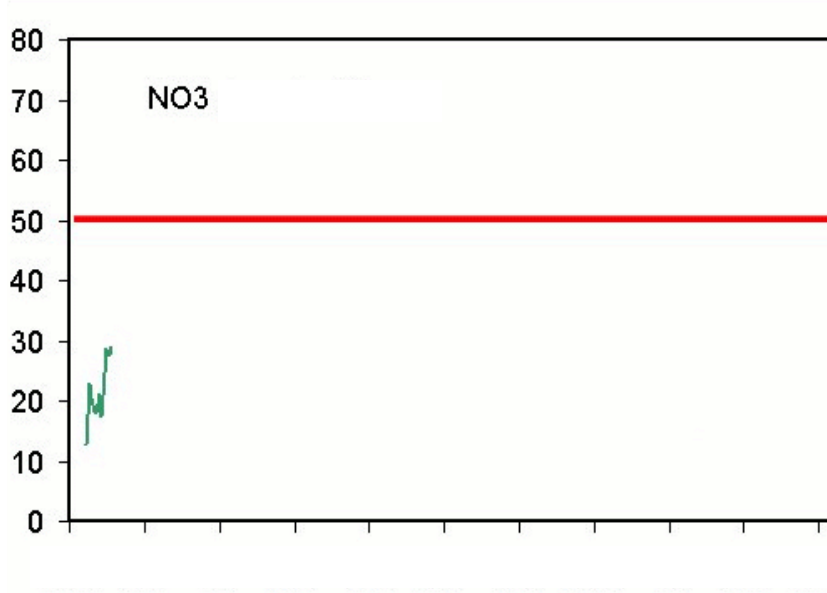
Bassins / sites observatoires

Observation – Compréhension – Quantification



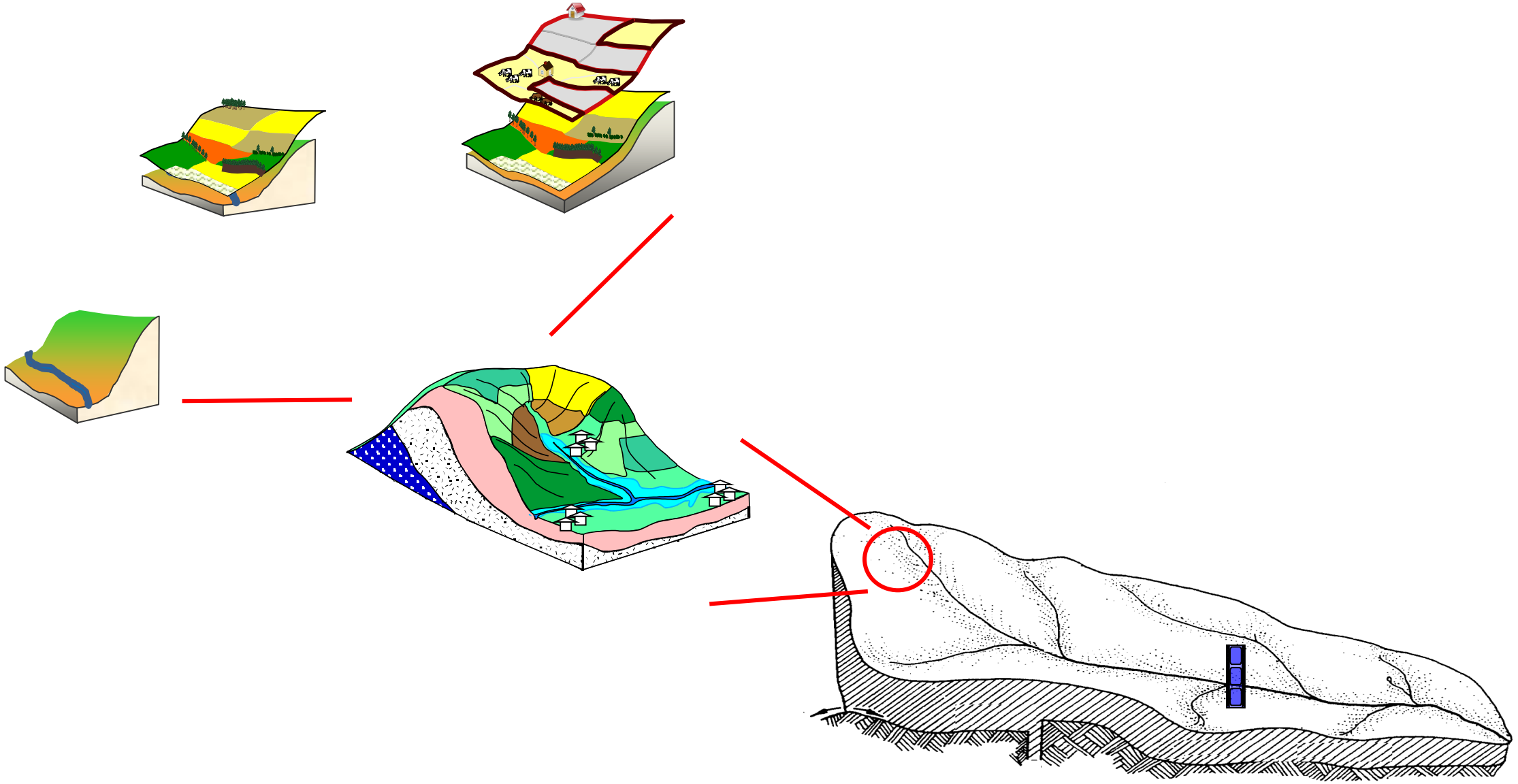




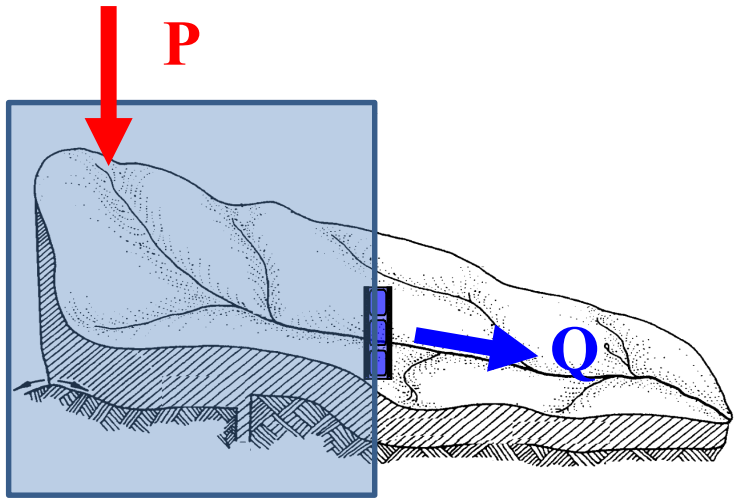


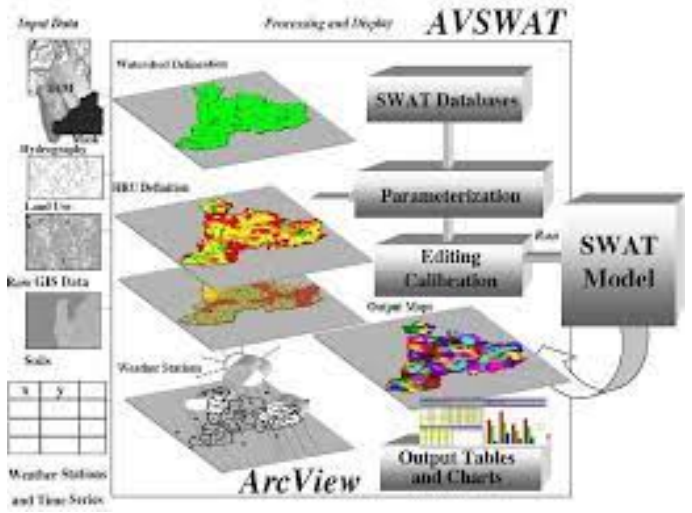
Durand et al.

Bassins de gestion :
Hétérogénéité, Echelle-Emergence, Données

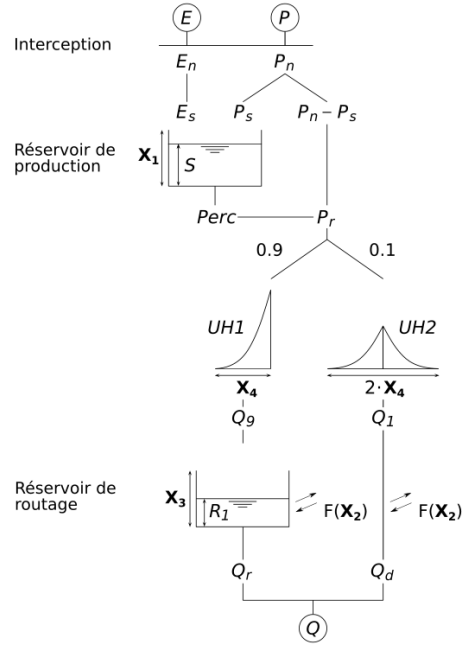


Bassins de gestion : Modélisation

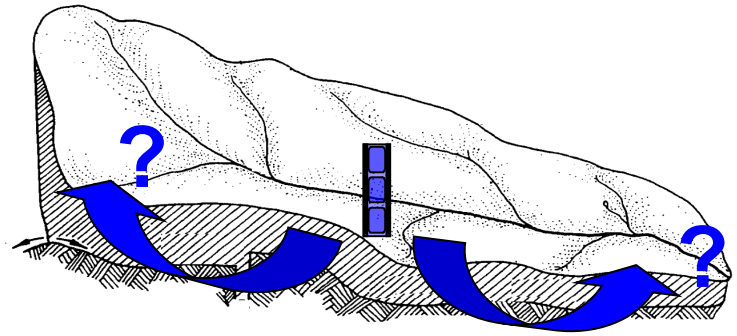




Modèles « à bases physiques », e.g. SWAT
https://swat.tamu.edu/



Modèles conceptuels, e.g. GR4J
https://webgr.inrae.fr/modeles/journalier-gr4j-2/

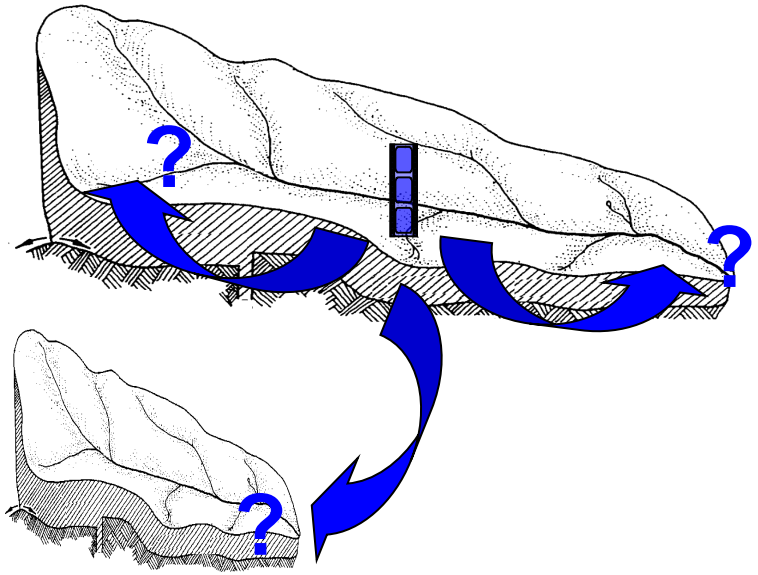


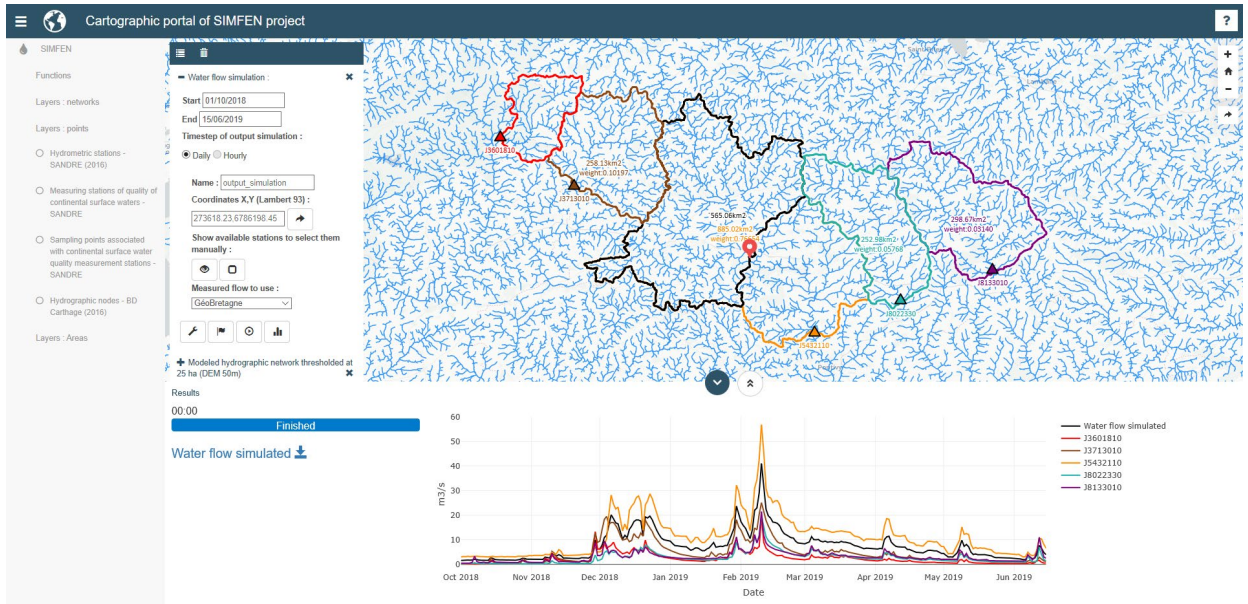
⇒ Calage statistique

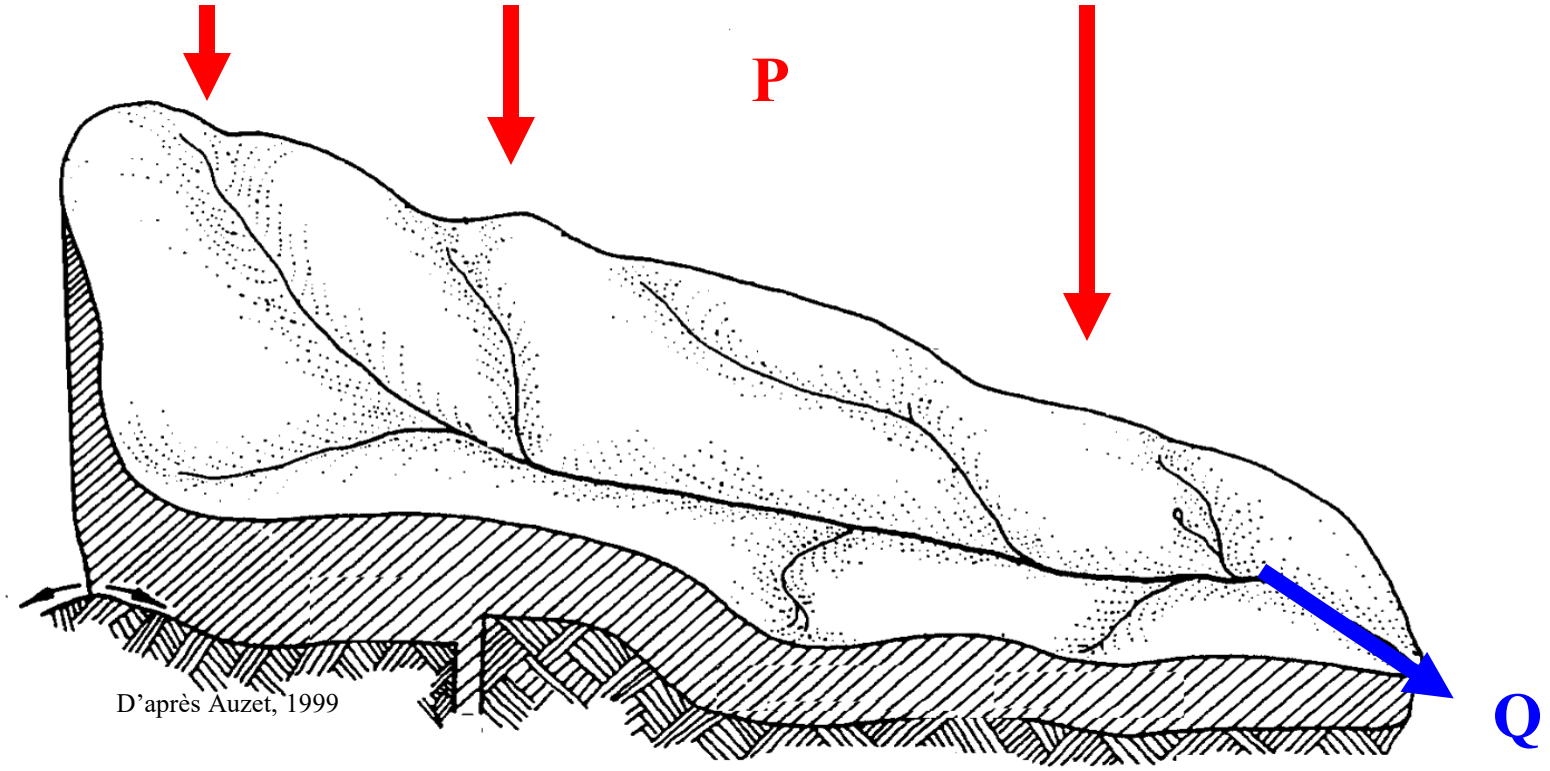
⇒ Synthèse, Reproduction de l'observation
⇒ Comblement de lacunes, Prévision temps réel, Régionalisation

⇒ Non jaugé ? Changements ?

Bassins de gestion : Approche SIMFEN



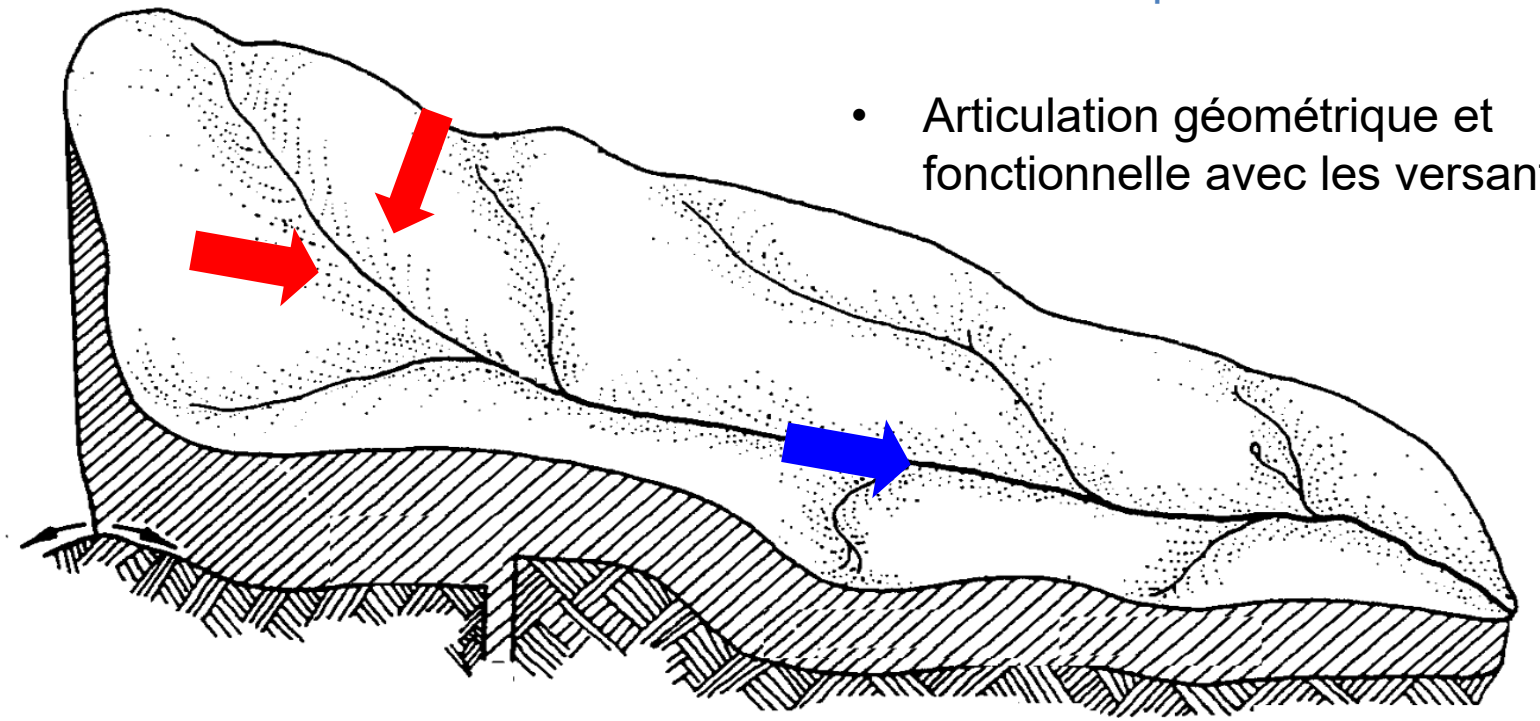




- Multiplicité et simultanéité des processus
- Multiplicité des échelles temporelles et spatiales
- Combinaison de variabilités
- Non-linéarités

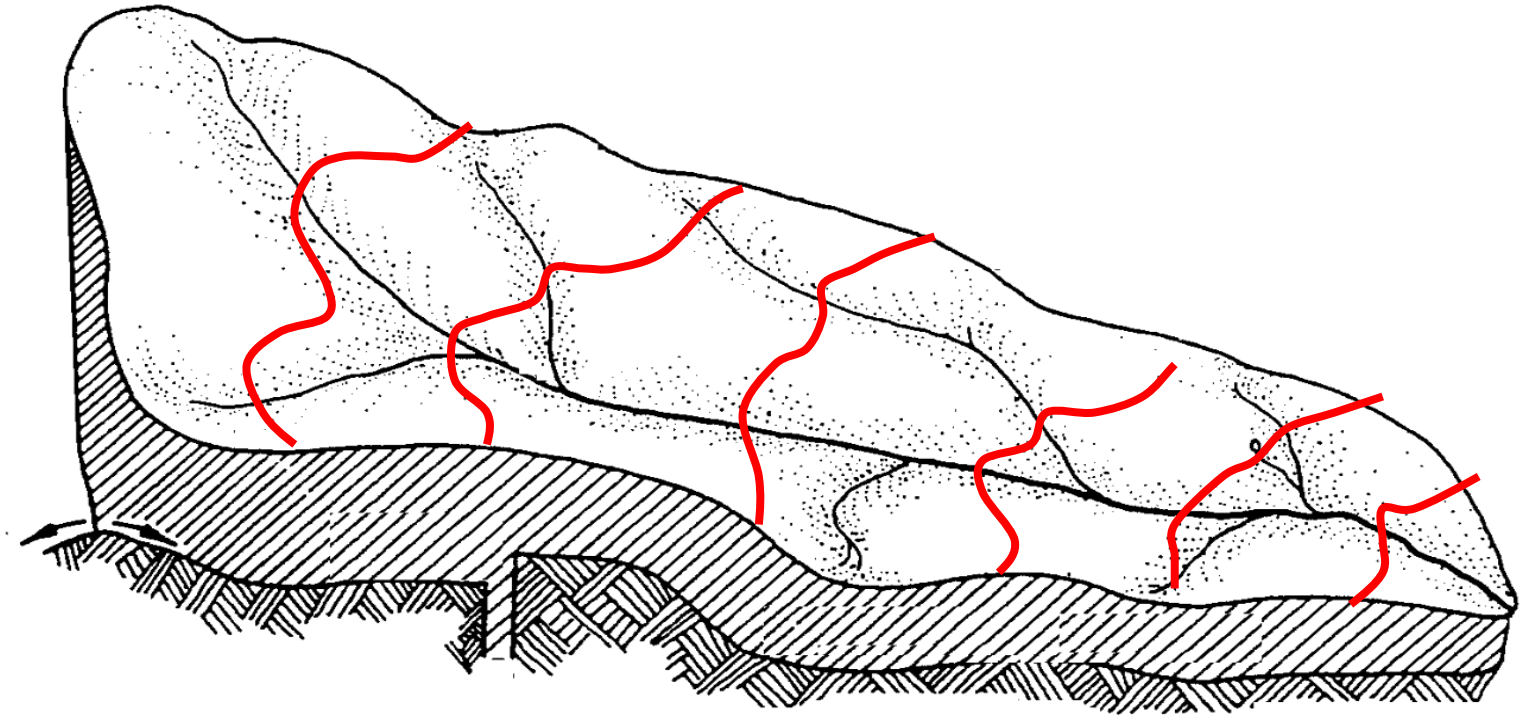
Thalwegs

- Lignes structurelles du relief, observables



- Lignes de convergence et de circulation préférentielle de l'eau
- Articulation géométrique et fonctionnelle avec les versants

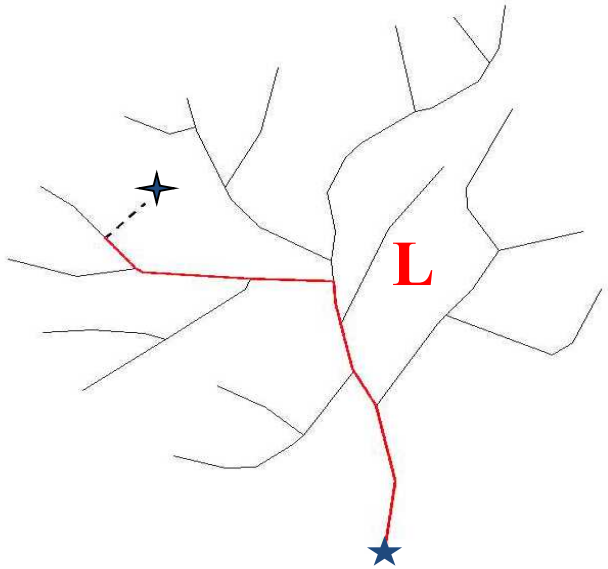
Thalwegs ➔ réseau hydrographique

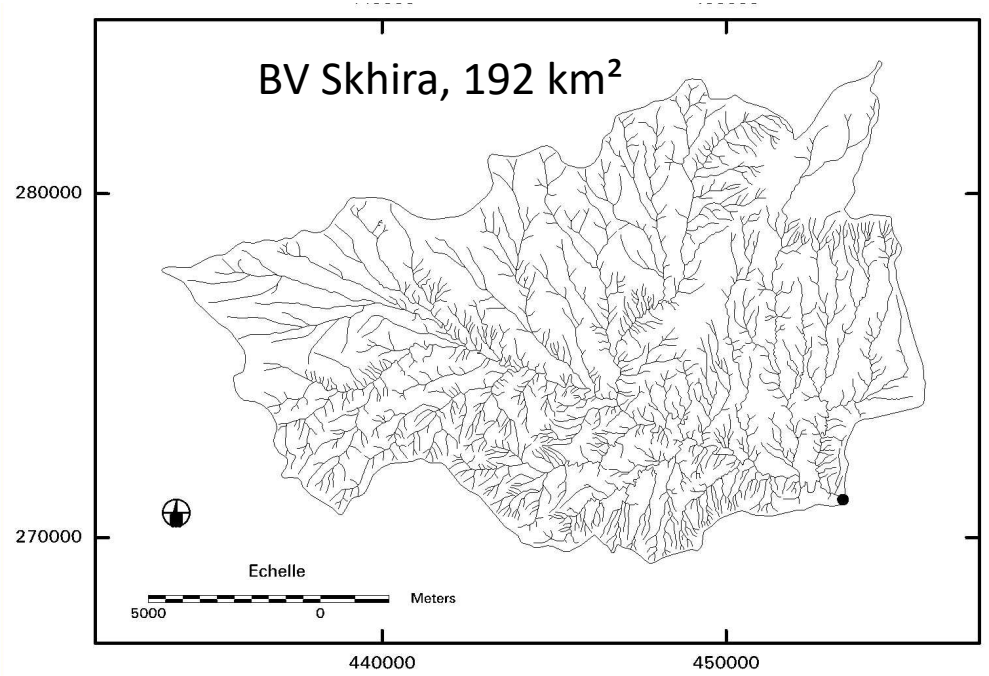


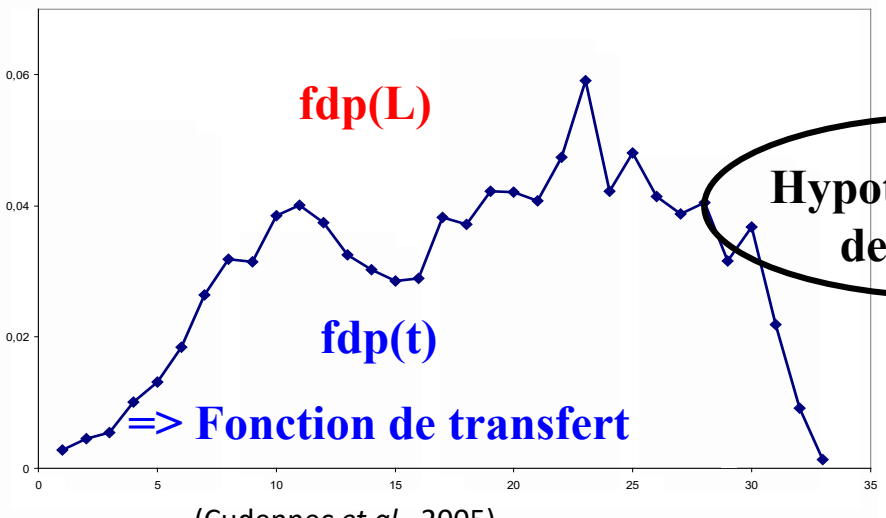
➔ **Prépondérant dans la structure fonctionnelle du bassin versant ; dans l'intégration des processus, échelles et variabilités**

➔ **Déterminant dans l'émergence des réponses et impacts macroscopiques**

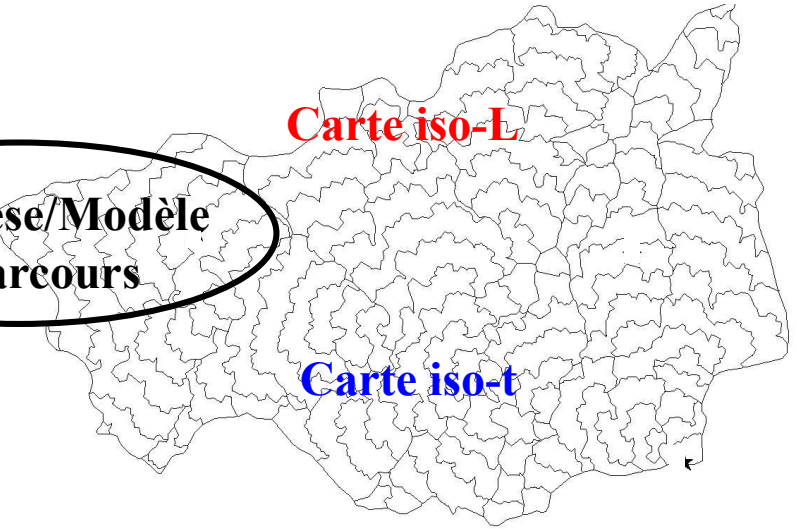
Modélisation hydrologique à base géomorphologique



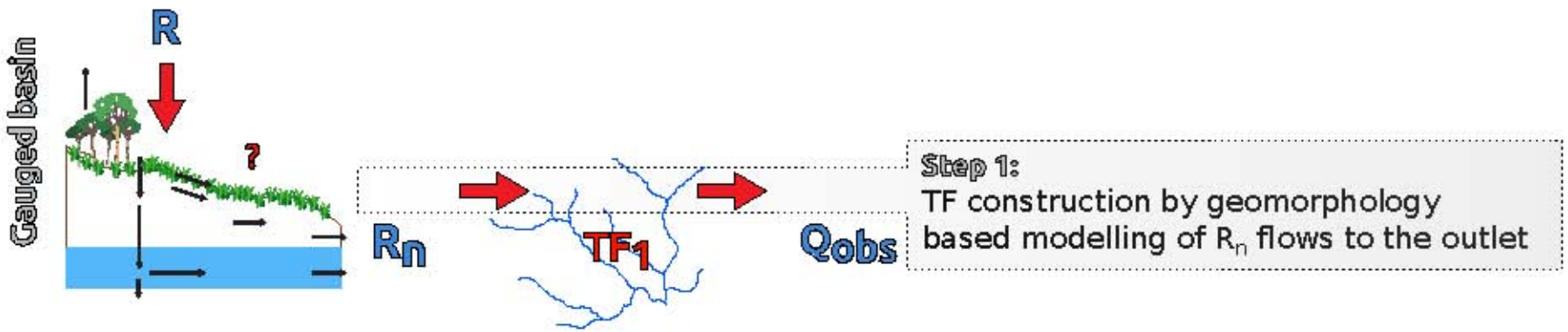


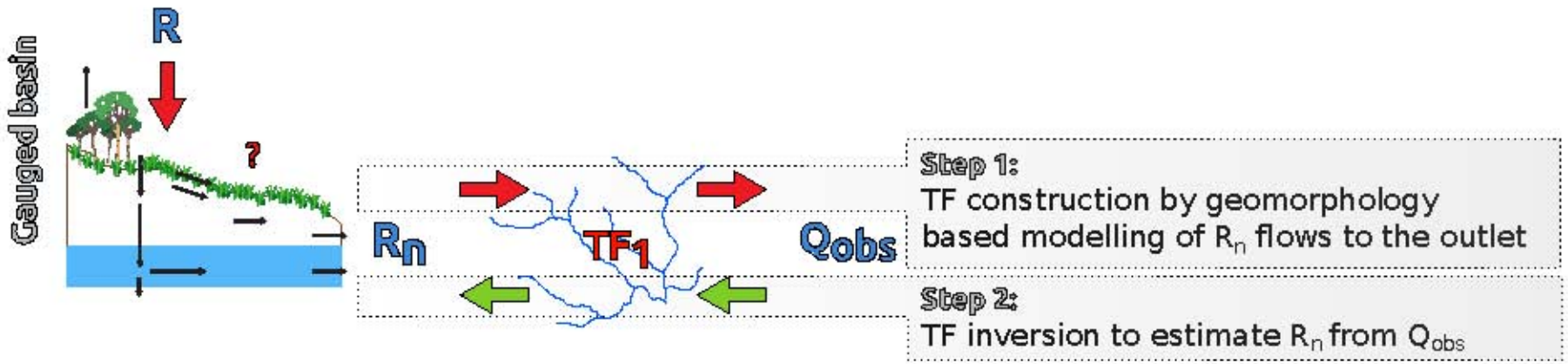


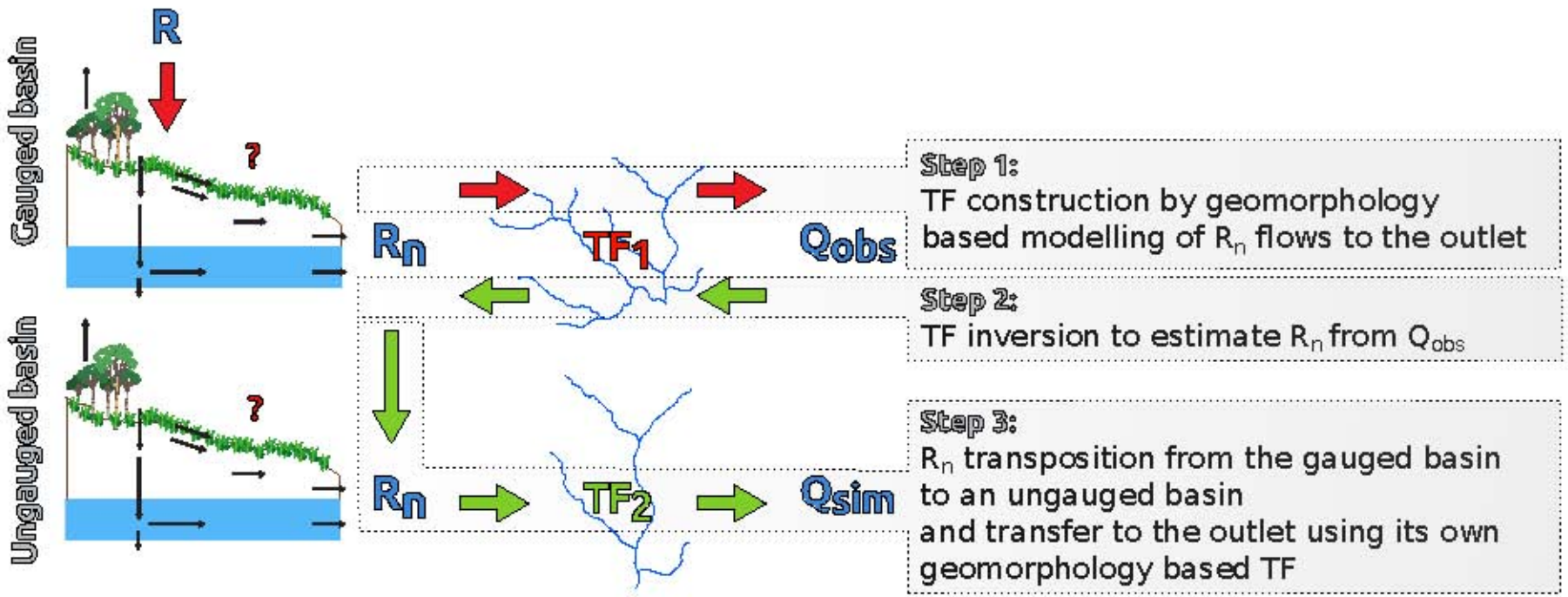
Hypothèse/Modèle de parcours

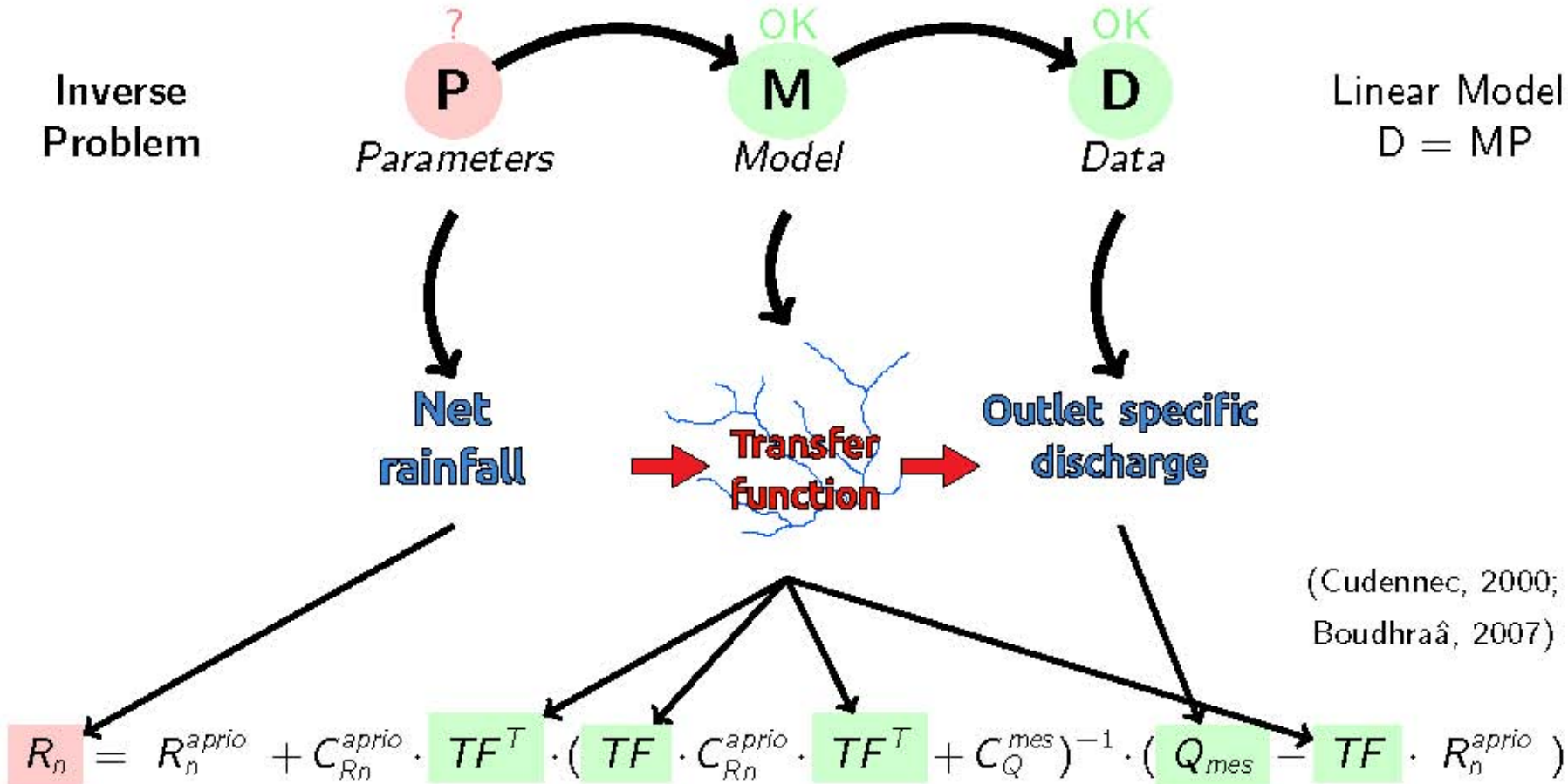


(Cudennec *et al.*, 2005)


Gauged basin
R
?
Rn
TF1
Qobs
Step 1:
TF construction by geomorphology
based modelling of Rn flows to the outlet


Gauged basin
R
?
Rn
TF1
Qobs
Step 1:
TF construction by geomorphology based modelling of Rn flows to the outlet
Step 2:
TF inversion to estimate Rn from Qobs


R
Gauged basin
?
Ungauged basin
?
Rn
TF1
Qobs
Rn
TF2
Qsim
Step 1:
TF construction by geomorphology based modelling of Rn flows to the outlet
Step 2:
TF inversion to estimate Rn from Qobs
Step 3:
Rn transposition from the gauged basin to an ungauged basin and transfer to the outlet using its own geomorphology based TF


Inverse Problem
?
P
Parameters
OK
M
Model
OK
D
Data
Linear Model:
D = MP
Net rainfall
Transfer function
Outlet specific discharge
(Cudennec, 2000; Boudhraâ, 2007)
$R_n = R_n^{aprio} + C_{Rn}^{aprio} \cdot TF^T \cdot (TF \cdot C_{Rn}^{aprio} \cdot TF^T + C_Q^{mes})^{-1} \cdot (Q_{mes} - TF \cdot R_n^{aprio})$

Volume 46, Issue 2
1 April 2015

Previous Article

Article Contents

RESEARCH ARTICLE | DECEMBER 11 2013

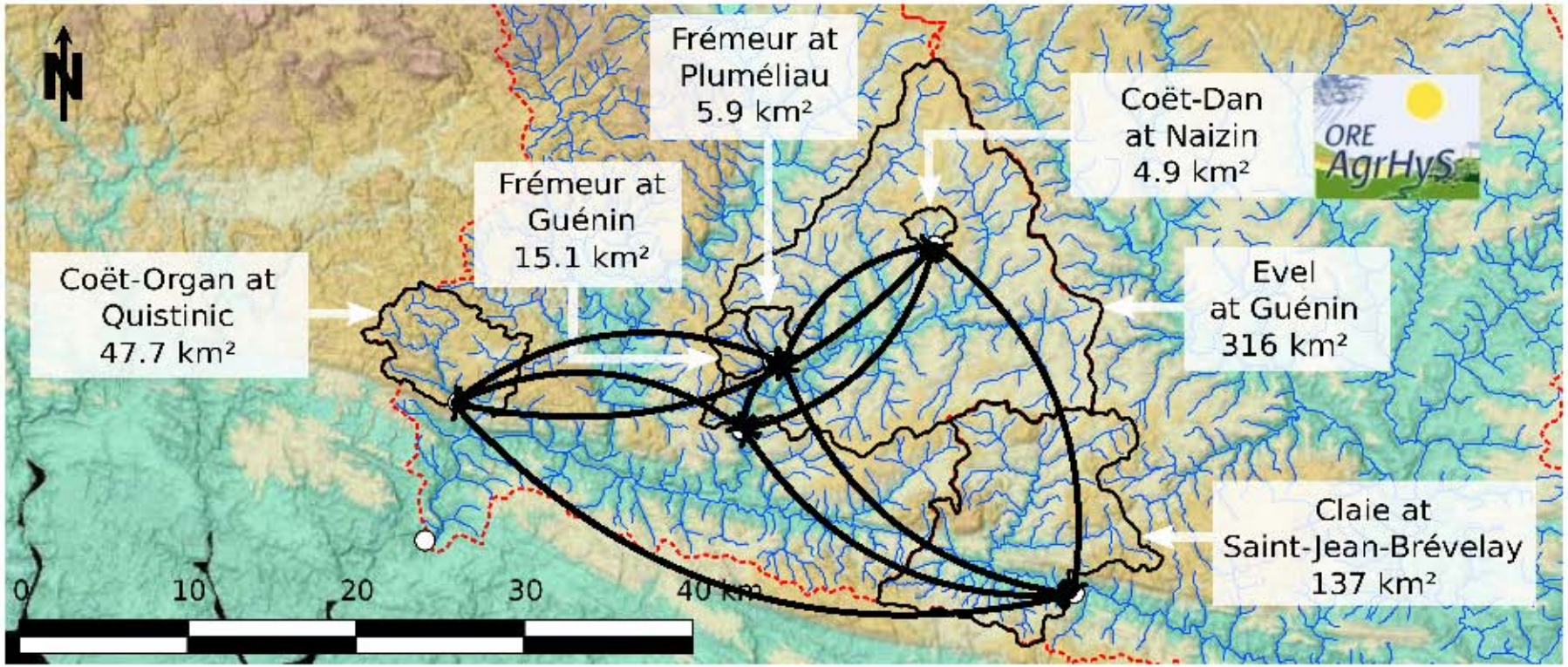
Streamflow prediction in ungauged basins through geomorphology-based hydrograph transposition

A. de Lavenne; H. Boudhraâ; C. Cudennec

Hydrology Research (2013) 46 (2): 291-302.
https://doi.org/10.2166/nh.2013.099 **Article history**

Geomorphology-based rainfall–runoff models are particularly helpful for predicting hydrology in ungauged basins. The robustness, generality and flexibility of the modelling approach make it able to deal with a wide variety of processes, events and scales. It allows a rainfall–runoff transfer function to be estimated for any basin without needing to measure discharge. The aim of this study is to transpose hydrological observations from gauged to ungauged basins to predict streamflow hydrographs. It considers pairs of nested and neighbouring basins, the first one

A set of 6 gauged basins



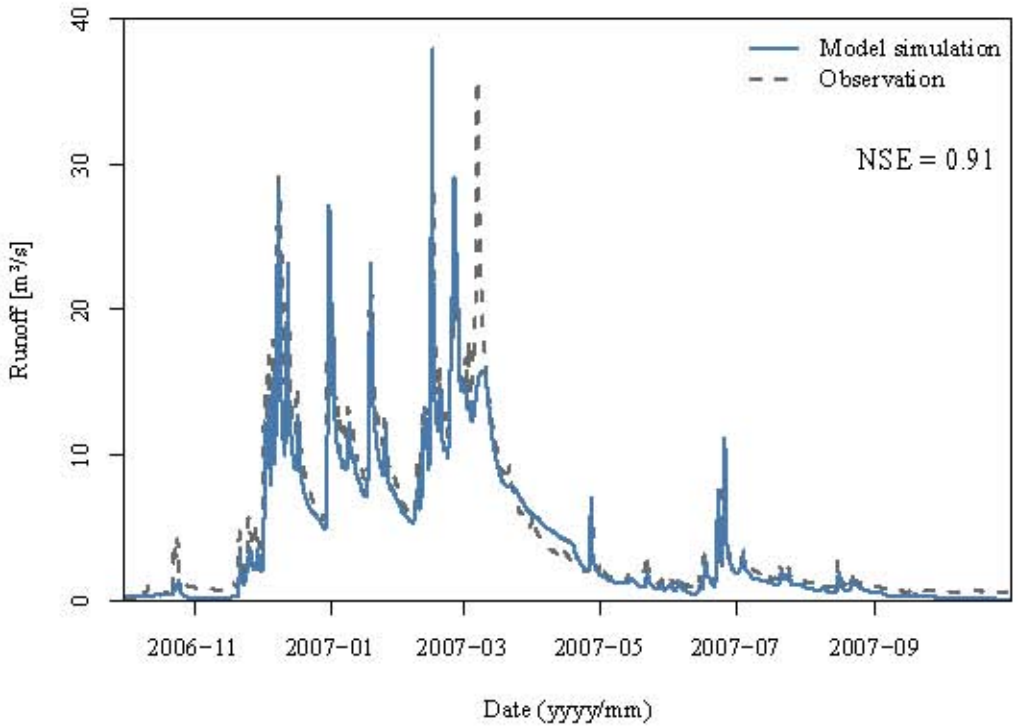
Context

- Shale and granite bedrock
- Pluviometry : 915 mm to 1270 mm
- Stream slope: 0.11% to 0.58%
- Runoff coefficient: 0.36 to 0.60

Transpositions

- Gauged basin considered ungauged
- Exploring transposition configuration

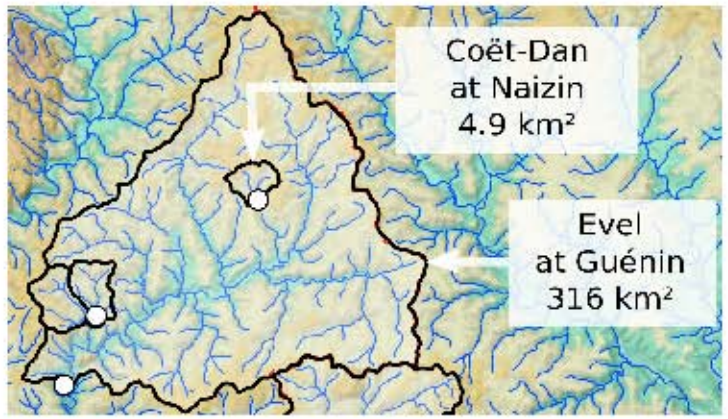
Simulation results



Coët-Dan at Naizin

↓

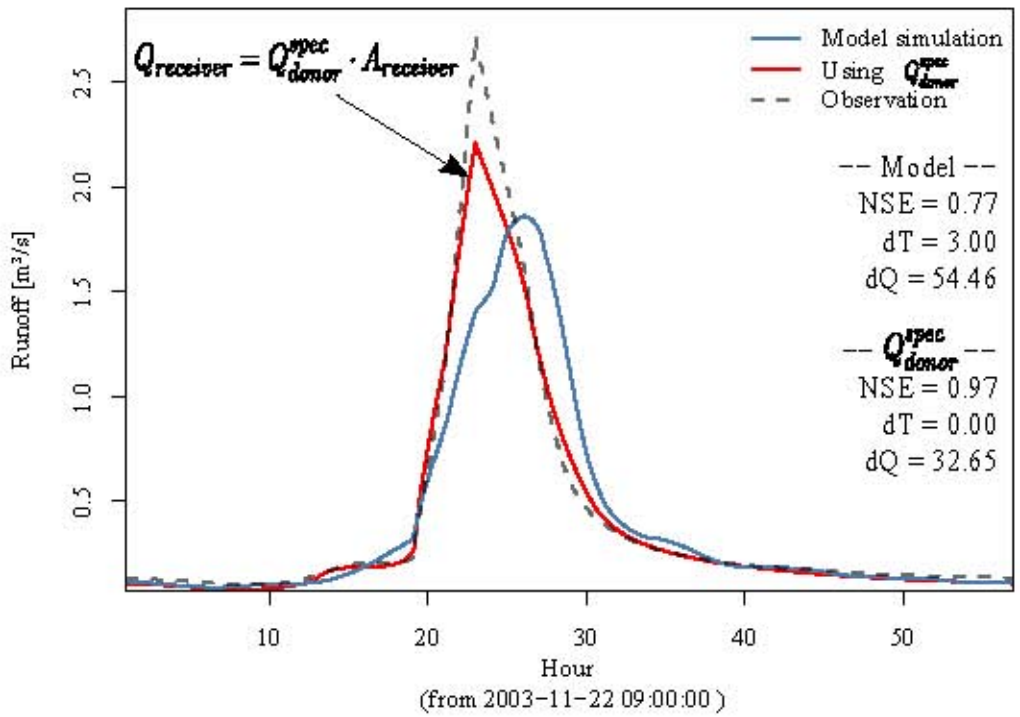
Evel at Guenin



Positive points

- Highly efficient for some pairs of basins

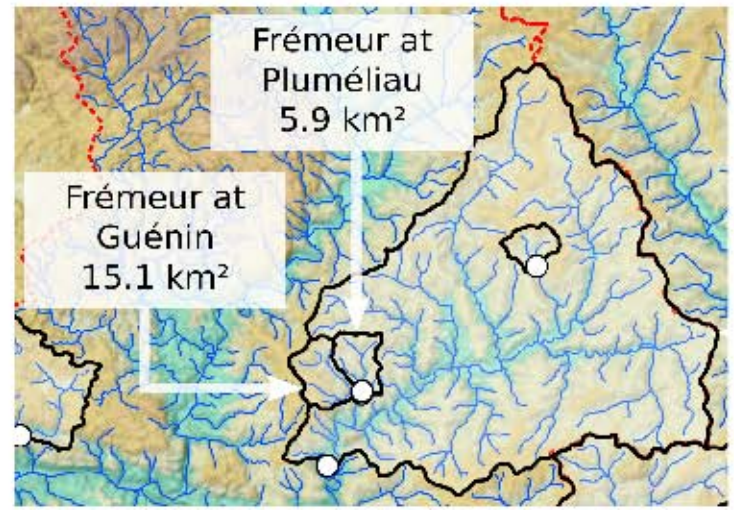
Simulation results



Frémeur at Pluméliau

↓

Fremeur at Guenin



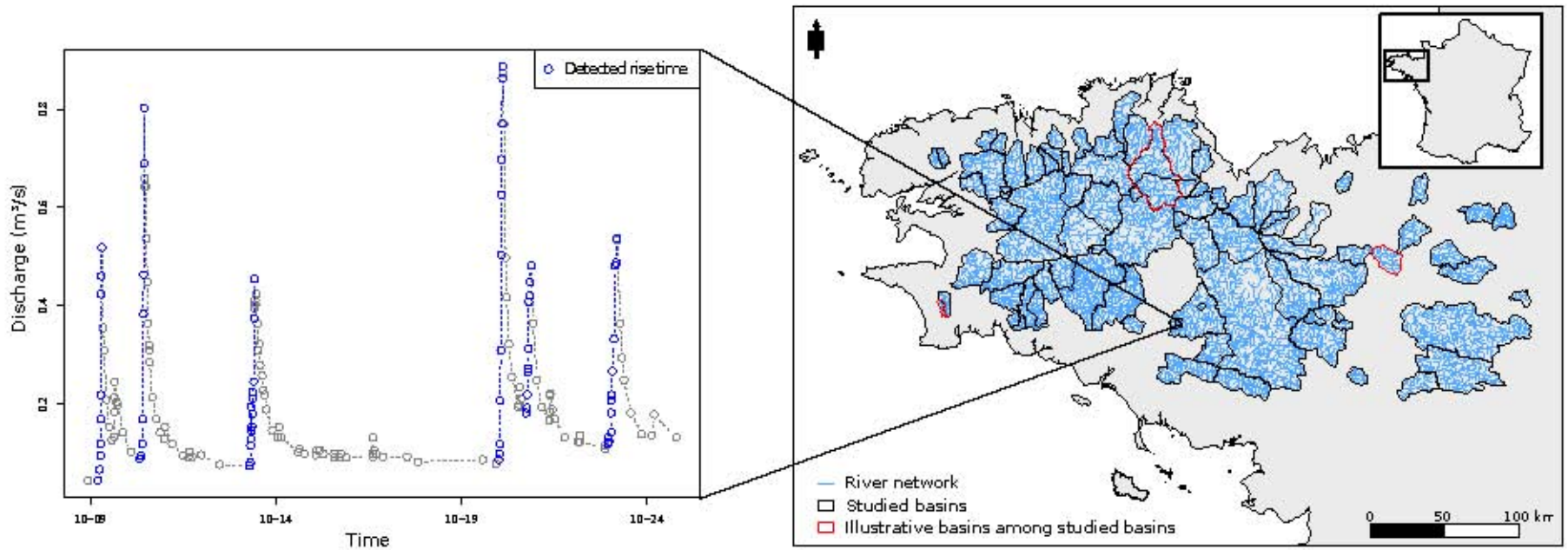
Positive points

- Highly efficient for some pairs of basins
- Enable transpositions regardless of the scale

Issues :

- *Instability*
- *Robustness*
- *Uncertainty*
- *Runoff volume*
- *Velocity parameter*

A regional approach



Data

85 basins (3 illustrative basins)

Runoff measures
from 1990 to 2010

Velocity

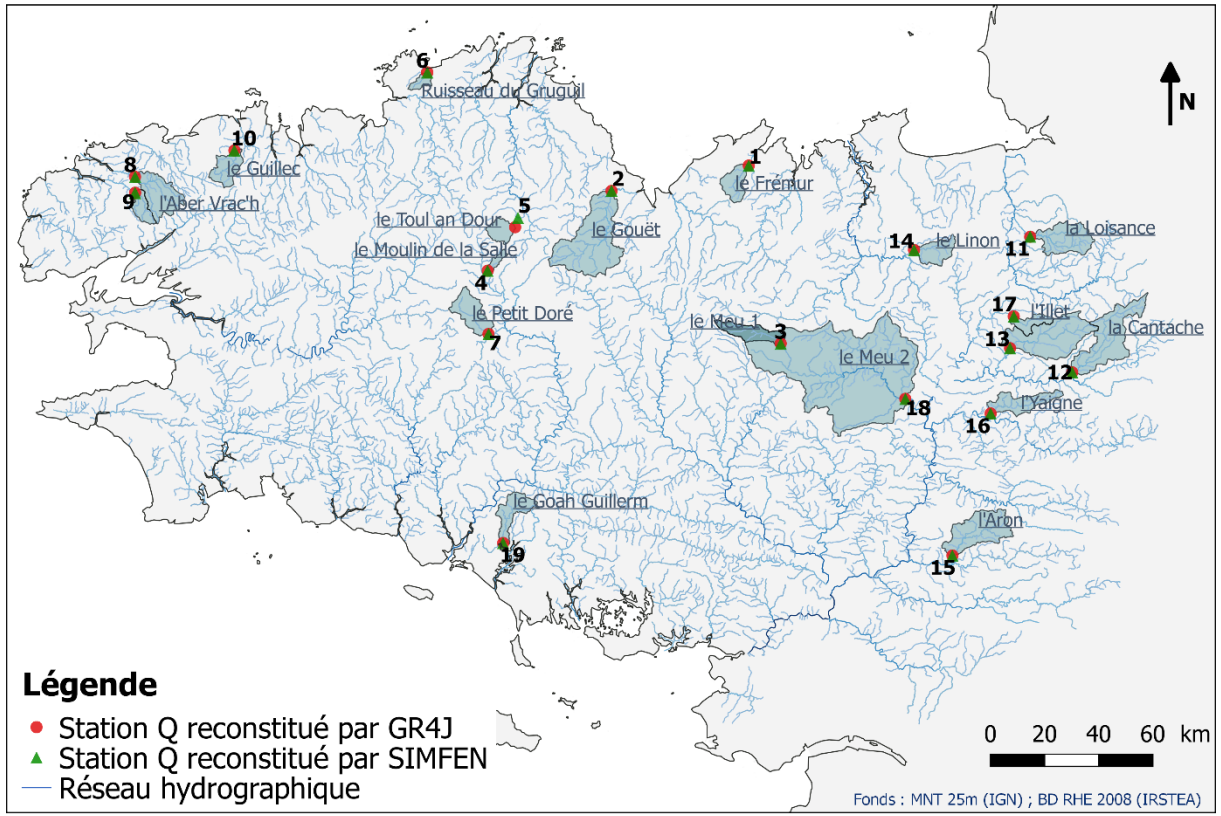
$$u_c(i) = \frac{\overline{X_c}}{t_p(i)}$$

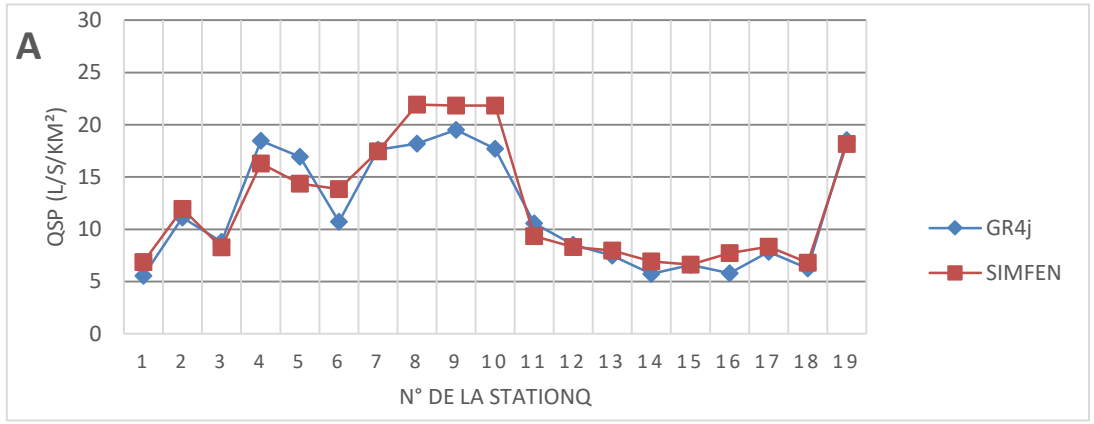
i	:	event
u_c	:	channel flow velocity
$\overline{X_c}$	:	mean hydraulic length
t_p	:	rising time

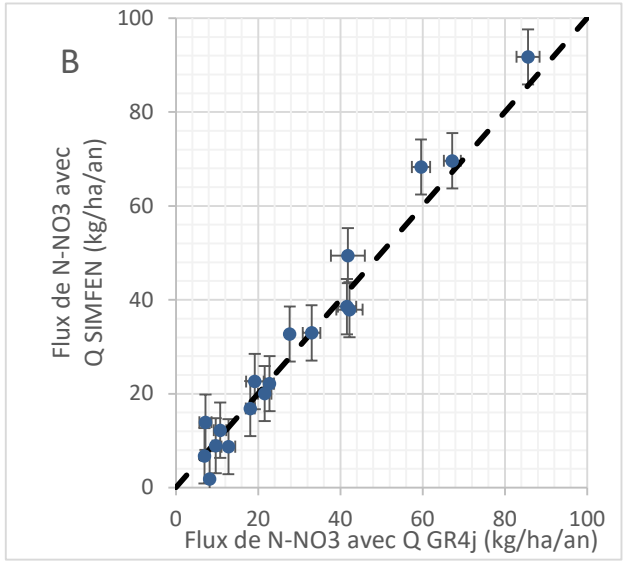
64,300 velocities

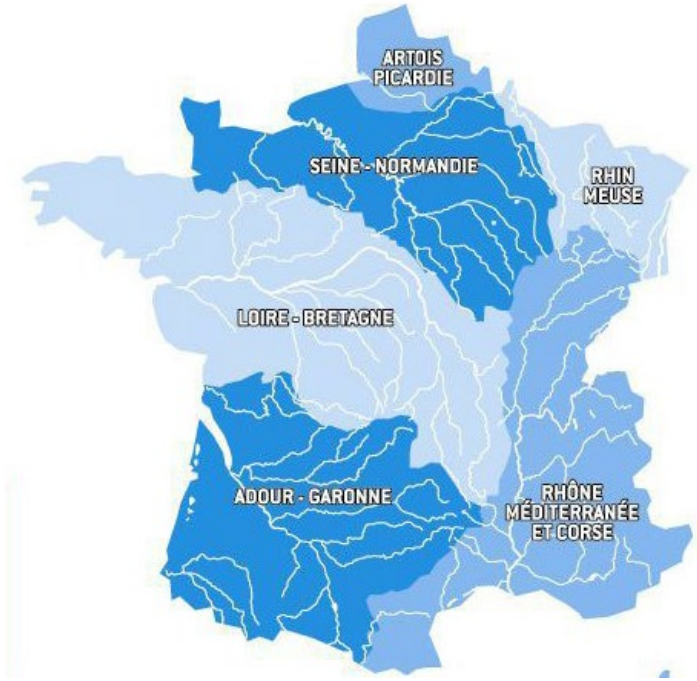
Comparaison SIMFEN / GR4J eau et Nitrate sur 19 stations

Projet ADAM (Guillemot et al.)









AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE
10.1002/2016WR018716

Key Points:
- The geomorphological inversion approach and Top-kriging are equally efficient for continuous streamflow simulation
- Small upstream catchments have higher uncertainties than larger catchments for both methods
- A rescaled Ghosh distance provides the best weighting of donor catchments for geomorphological inversion

Supporting Information:
- Supporting Information S1

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A. de Lavenne,
albaude-lavenne@irstea.fr

Citation:
de Lavenne, A., J. O. Skøien, C. Cudennec, F. Curie, and F. Moatar (2016), Transferring measured discharge time series: Large-scale comparison of Top-kriging to geomorphology-based inverse modeling, *Water Resour. Res.*, *52*, 5555–5576, doi:10.1002/2016WR018716.

Transferring measured discharge time series: Large-scale comparison of Top-kriging to geomorphology-based inverse modeling

A. de Lavenne[1,2], J. O. Skøien[3], C. Cudennec[4,5], F. Curie[1], and F. Moatar[1]

[1]Université François Rabelais - Tours, EA 6293, Géo-Hydrosystèmes Continentaux, Faculté des Sciences et Techniques, Tours, France, [2]Now at Irstea, Hydrosystems and Bioprocesses Research Unit, Antony, France, [3]European Commission, Joint Research Centre, Institute for Environment and Sustainability, Climate Risk Management Unit, Ispra, Italy, [4]AGROCAMPUS OUEST, UMR1069, Sol Agro et hydrosystème Spatialisation, Rennes, France, [5]INRA, UMR1069, Sol Agro et hydrosystème Spatialisation, Rennes, France

Abstract Few methods directly transfer streamflow measurements for continuous prediction of ungauged catchments. Top-kriging has been used mainly to predict the statistical properties of runoff but has been shown to outperform traditional regionalization approaches of rainfall-runoff models. We applied the Top-kriging approach across the Loire River basin and compared predictions to a geomorphology-based approach. Whereas Top-kriging uses spatial correlation, the other approach has the advantage of being more physically based by using a well-known geomorphology-based hydrological model (WFIUH) and its inversion. Both approaches require an equal degree of calibration and provide similar performances. We also demonstrate that the Ghosh distance, which considers the nested nature of catchments, can be used efficiently to calculate weights and to identify the suitability of gauged catchments for use as donor catchments. This result is particularly relevant for catchments with Strahler orders above five, i.e., where donor catchments are more strongly nested.

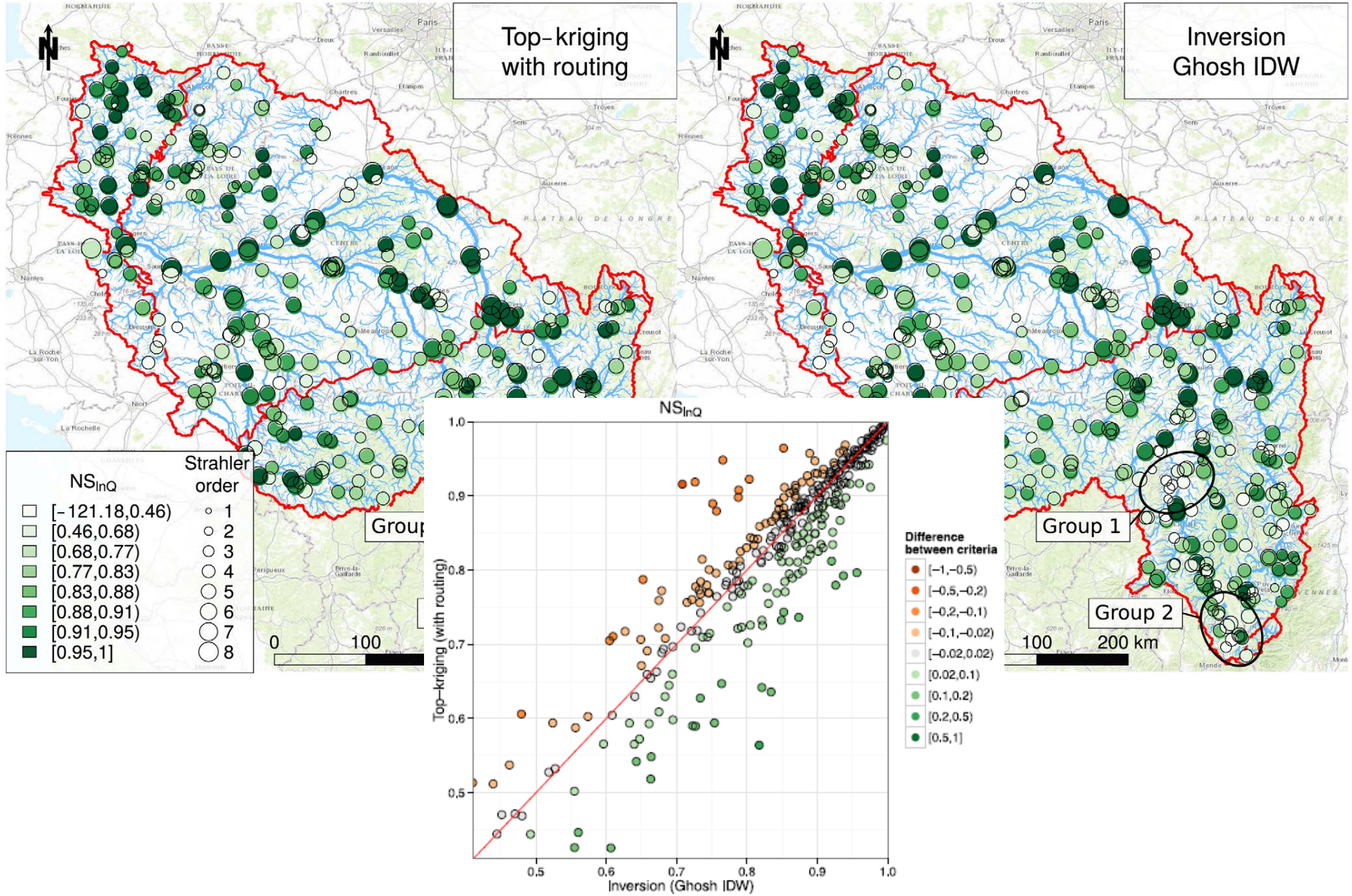


Figure 8. Scatterplot of NS_{lnQ} efficiency criteria between the geomorphological approach (using Ghosh IDW) and Top-kriging (using routing). A map of those differences is provided in supporting information (S1).

Science of the Total Environment 669 (2019) 812–820

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessment of freshwater discharge into a coastal bay through multi-basin ensemble hydrological modelling

A. de Lavenne[a, b,*], C. Cudennec[a]

[a] UMR SAS, AGROCAMPUS OUEST, INRA, Rennes 35000, France
[b] Swedish Meteorological and Hydrological Institute, 601 76 Norrköping, Sweden

HIGHLIGHTS

- Geomorphology-based approach to predict streamflow at ungauged sites along coastline
- Available gauging data valued in an ensemble modelling strategy
- Multi-basin ensembles prove robustness and low uncertainty

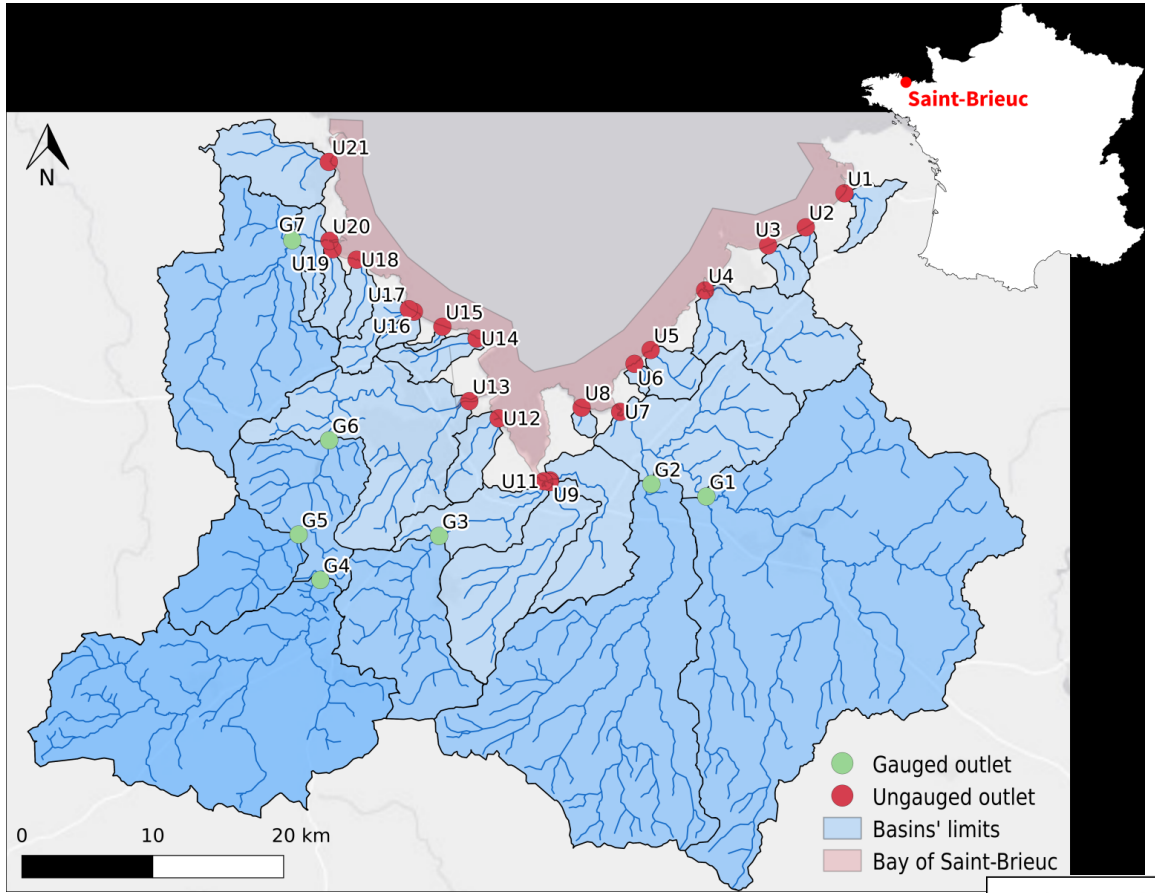
GRAPHICAL ABSTRACT

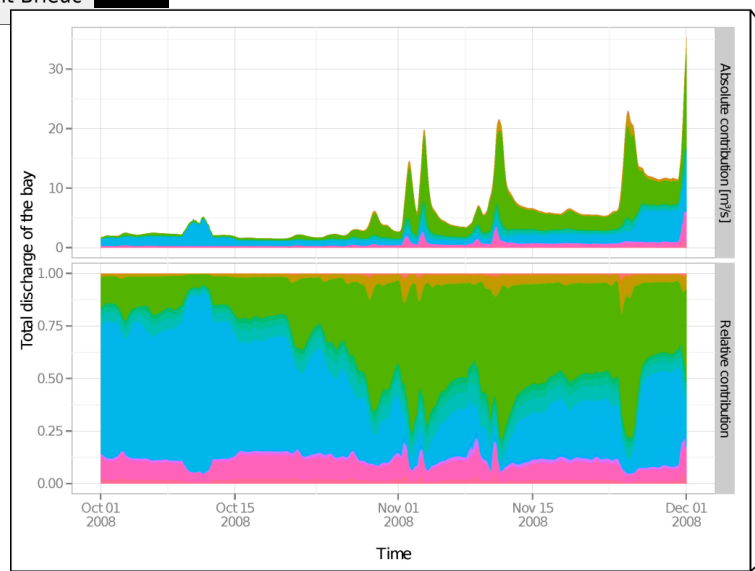
ARTICLE INFO

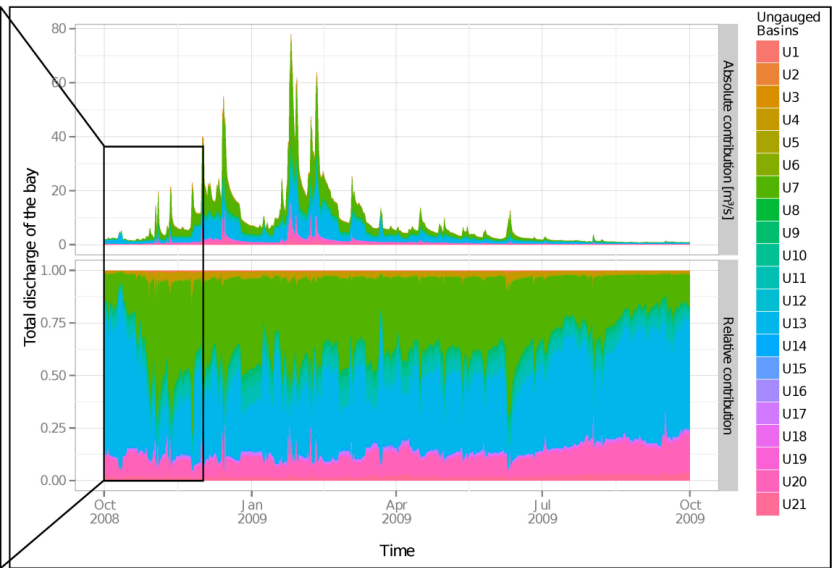
Article history:
Received 14 November 2018

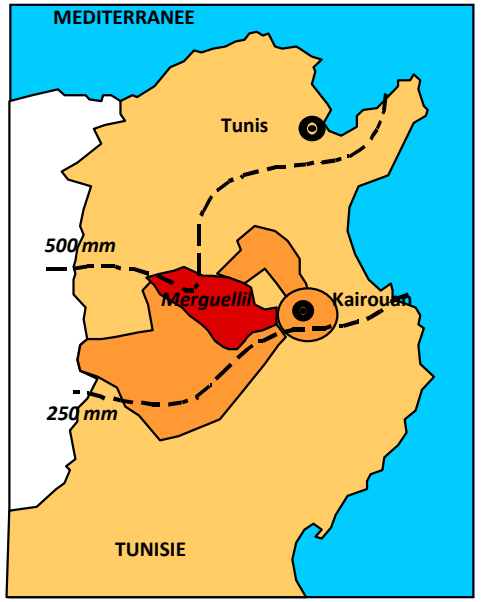
ABSTRACT

Coastal basins of the Brittany peninsula (France) are hydrological hot spots. A high level of nutrient pollu-


Saint-Brieuc
N
U21
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U13
U14
U15
U16
U17
U18
U19
U20
G1
G2
G3
G4
G5
G6
G7
0
10
20 km
Gauged outlet
Ungauged outlet
Basins' limits
Bay of Saint-Brieuc


Total discharge of the bay
Absolute contribution [m³/s]
Relative contribution
Time
Oct 01 2008
Oct 15 2008
Nov 01 2008
Nov 15 2008
Dec 01 2008


Total discharge of the bay
Absolute contribution [m³/s]
Relative contribution
Time
Oct 2008
Jan 2009
Apr 2009
Jul 2009
Oct 2009
Ungauged Basins
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
U12
U13
U14
U15
U16
U17
U18
U19
U20
U21



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VOL. 63, NO. 2, 285–301
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Net rainfall estimation by the inversion of a geomorphology-based transfer function and discharge deconvolution

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ABSTRACT

The assessment of net rainfall, defined as the intermediate hydrological variable linked in between the hillslope and the river network, is a challenge. This paper presents a method for net rainfall estimation, using inverse modelling associated to a geomorphology-based transfer function. The analysis is carried out in semi-arid Tunisia, with a dataset from event discharges in a mesoscale dryland basin. A complete sensitivity analysis is developed, along with a discussion of validity limits for simplifying assumptions and the identification of paths for improvement. This work could be relevant for data-scarce areas, thanks to the use of simple dynamic conceptualization and being

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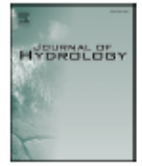

PUB in Québec: A robust geomorphology-based deconvolution-reconvolution framework for the spatial transposition of hydrographs

Stéphane Ecrepont[a,*], Christophe Cudennec[a], François Anctil[b], Anne Jaffrézic[a]

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ARTICLE INFO

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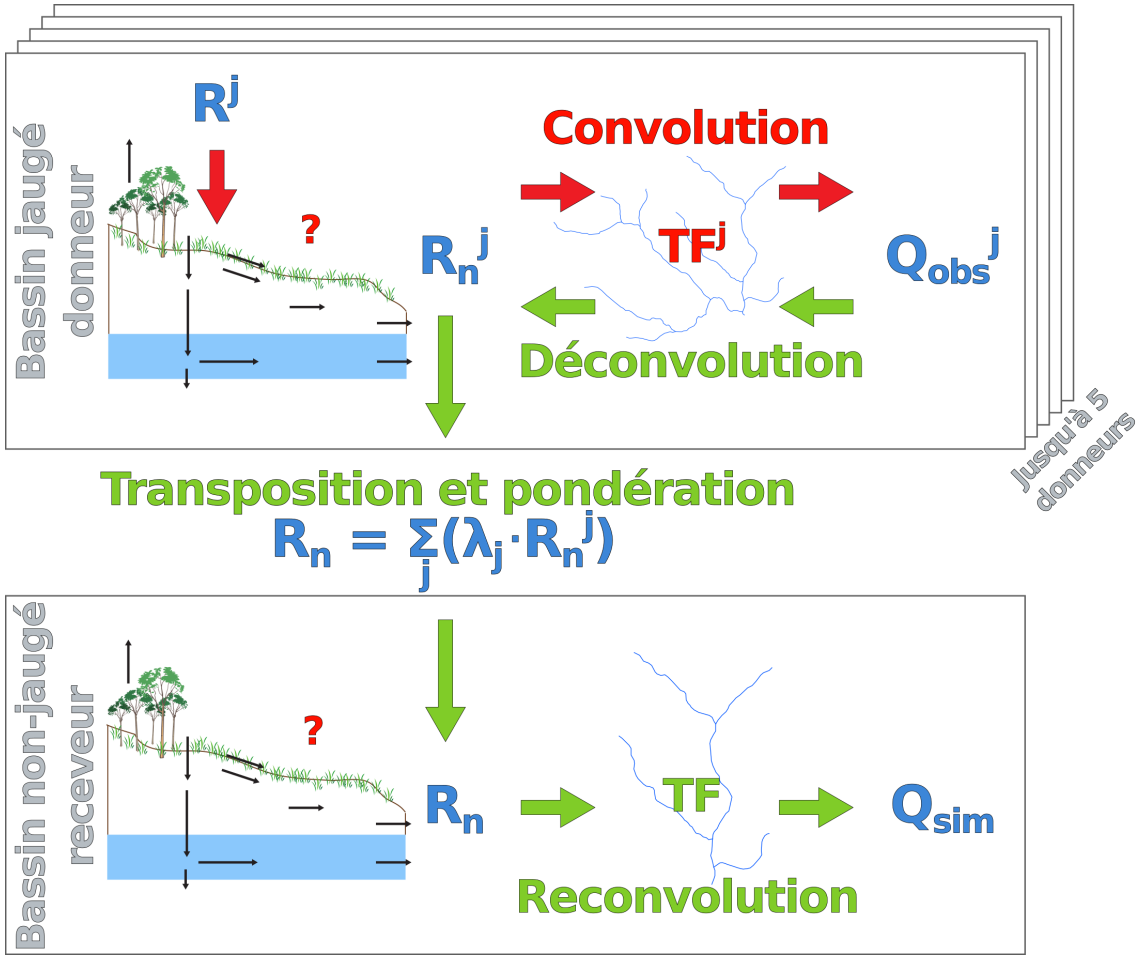
Keywords:
Ungauged basin
Geomorphology
Hydrograph transposition
Scaling
Seasonality
Nivo-pluvial regime

ABSTRACT

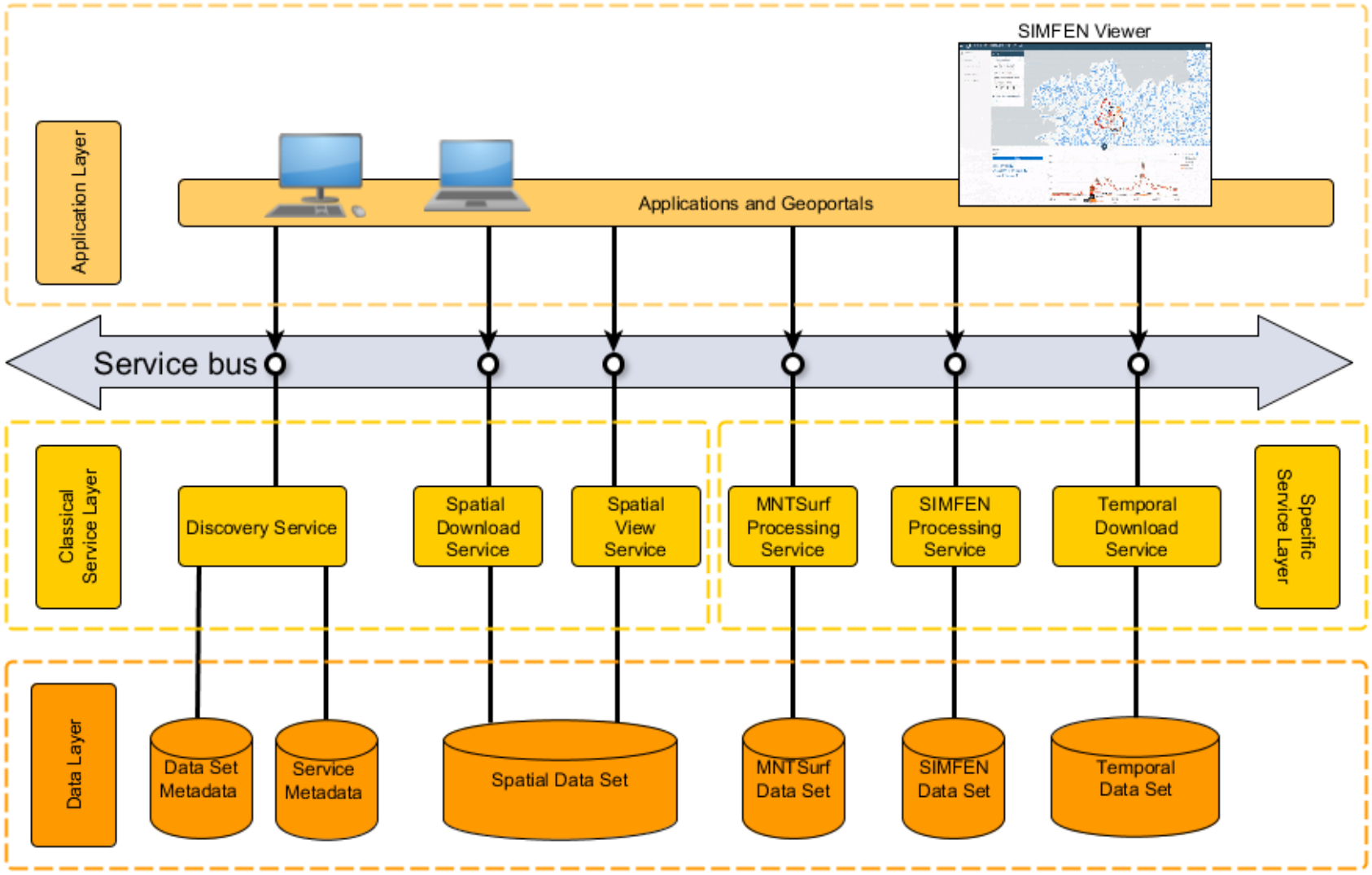
The flexibility and parsimony of transpositioning hydrographs using geomorphology-based deconvolution-reconvolution frameworks is particularly adapted to prediction in ungauged basins. Although already tested in semi-arid and oceanic-temperate hydro-climates, its predictions must be reproducible in a variety of hydrological contexts. The present study explores the nivo-pluvial hydrological regime using geomorphology-based hydrograph transposition between 21 gauged catchments ranging from 1.1 to 4466.4 km^2 in Québec, Canada, and constitutes a case study in prediction in ungauged basins. Three metrics were used to assess model performance for each donor-target pair: Nash Sutcliffe Efficiency (NSE), NSE calculated for the square root of discharge (NSE_{sqrt}), and Volumetric Efficiency (VE). The classic transposition of hydrographs using the specific discharge ratio, used as a reference, was almost always outperformed by the geomorphology-based approach. Good but seasonally variable performance values were obtained for several pairs of catchments, revealing simultaneous structural and circumstancial effects. The difference in size, the physical distance between the gauged donor and its target ungauged catchment, and the season influenced the performance of the geomorphology-based transposition.

Proposition opérationnelle *a priori* en Bretagne: jusqu'à 5 bassins donneurs, dans un rayon de 50 km



web-service SIMFEN

Financement : Région Bretagne – AELB, Agrocampus Ouest



API

API SIMFEN

Filter... x

1.Créer un projet

inversionExt
inversionHubEau

2.Simulation

xyOnNetwork
getStationsAvailable
waterFlowSimulation
getMeasuredFlow
nutrimentSimulation

Administration

checkDb
correctionStation
dbManagement
dismiss
getInfos

2.Simulation - xyOnNetwork

1.0.0

Place XY (exutoire) sur le réseau hydraulique le plus proche et donne le bassin versant de ce point (pour vérification visuelle).

GET

```
http://wps.geosas.fr/simfenV2/?service=WPS&version=1.0.0&request=Execute&identifier=xyOnNetwork&d
```

Example usage:

```
http://wps.geosas.fr/simfenV2/?service=WPS&version=1.0.0&request=Execute&identifier=xyOnNetwork&d
```

Envoyer une requête représentative

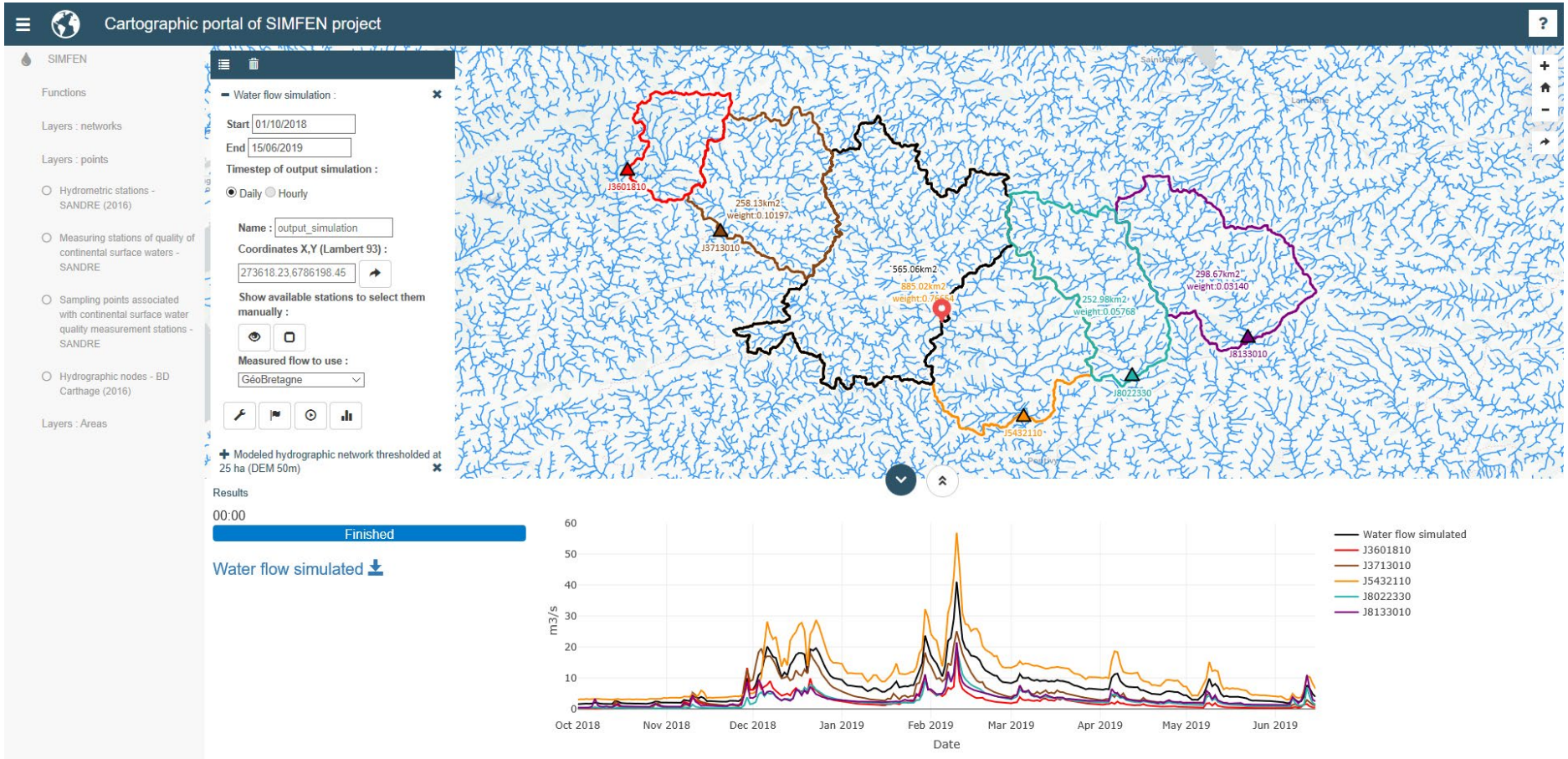
http://wps.geosas.fr/simfenV2/?service=WPS&version=1.0.0&request=Execute&identifier=xyOnNetv url

Envoyer

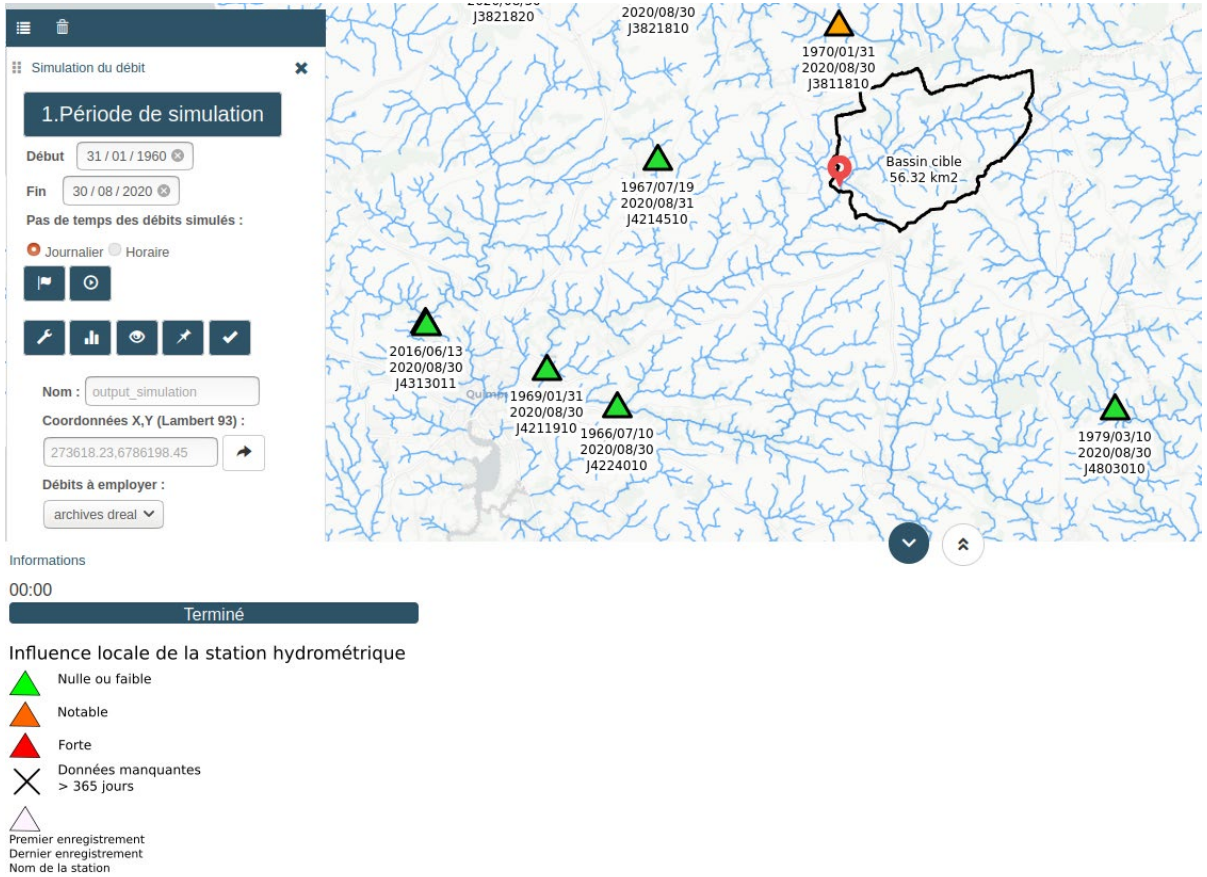
Paramètre

Champ	Type	Description
X	LiteralData	(string) coordonnées X de l'exutoire en Lambert 93 Valeur par défaut : `269315`
Y	LiteralData	(string) coordonnées Y de l'exutoire en Lambert 93 Valeur par défaut : `6814702`

Interface web : https://geosas.fr/simfen/



Modes défaut / expert



Informations sur les obstacles / influences

Nombre d'obstacles à l'écoulement par bassin versant (source : Sandre)

Hauteur de l'obstacle à l'écoulement	J4211910	J4224010	J4623020	J4803010	J4813010
Indéterminée	2		1		3
Inférieure à 0.5m	4	7	33	3	17
De 0.5m à inférieure à 1m	2	1	14	5	21
De 1m à inférieure à 1.5m	2		1	2	7
De 1.5m à inférieure à 2m	1		3	1	3
De 2m à inférieure à 3m			2	1	4

OK

Régime d'influence des stations hydrométriques (source : DREAL Bretagne)

Stations sources	Régime influencé	Poids dans le débit simulé
J4813010	Nul ou faible	0.13
J4211910	Nul ou faible	0.36
J4623020	Nul ou faible	0.12
J4224010	Nul ou faible	0.13
J4803010	Nul ou faible	0.26

OK

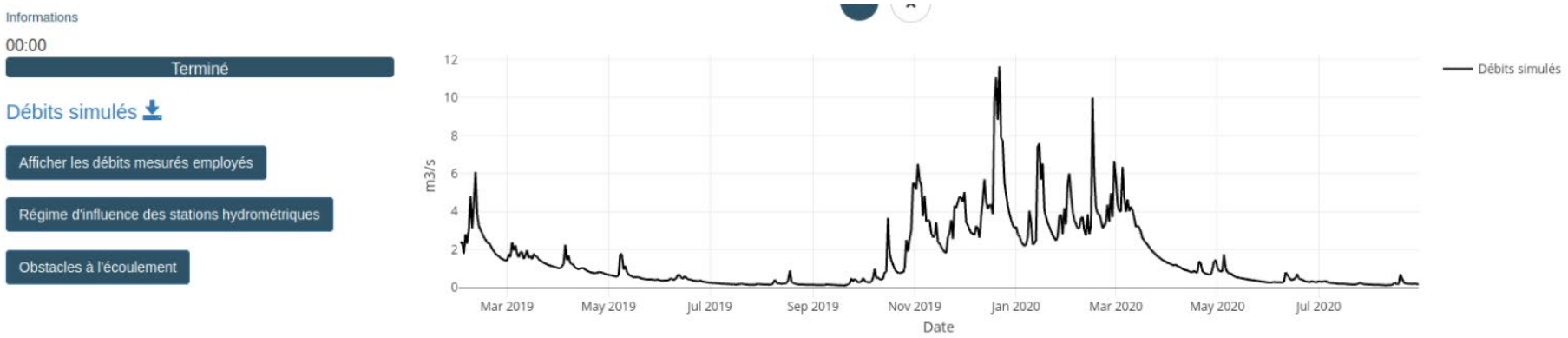
Informations

00:00

Terminé

Télécharger la couche vectorielle du bassin versant cible

Métadonnées



Développement : Calcul de signatures

Bassin versant : 67 km² **E-mail :** ph.dpch.sppr.dreal-bretagne@developpement-durable.gouv.fr

Ecoulements mensuels (naturels) - données calculées sur 52 ans

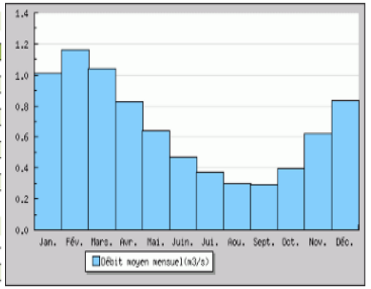
	Janv.	Fév.	Mars	Avr.	Mai	Juin	Juil.	Août	Sept.	Oct.	Nov.	Déc.	Année
Débits (m3/s)	1.010 #	1.160 #	1.040 #	0.826	0.640	0.471 #	0.372 #	0.300 #	0.290 #	0.398 #	0.620 #	0.835 #	0.661
Qsp (l/s/km2)	15.1 #	17.4 #	15.5 #	12.3	9.6	7.0 #	5.6 #	4.5 #	4.3 #	5.9 #	9.3 #	12.5 #	9.9
Lame d'eau (mm)	40 #	43 #	41 #	31	25	18 #	14 #	11 #	11 #	15 #	23 #	33 #	312

Basses eaux (loi de Galton - janvier à décembre) - données calculées sur 52 ans

Fréquence	VCN3 (m3/s)	VCN10 (m3/s)	QMNA (m3/s)
Biennale	0.200 [0.180;0.210]	0.210 [0.190;0.230]	0.240 [0.220;0.260]
Quinquennale sèche	0.150 [0.130;0.160]	0.160 [0.140;0.170]	0.180 [0.160;0.200]
Moyenne	0.208	0.219	0.255
Ecart Type	0.065	0.070	0.088

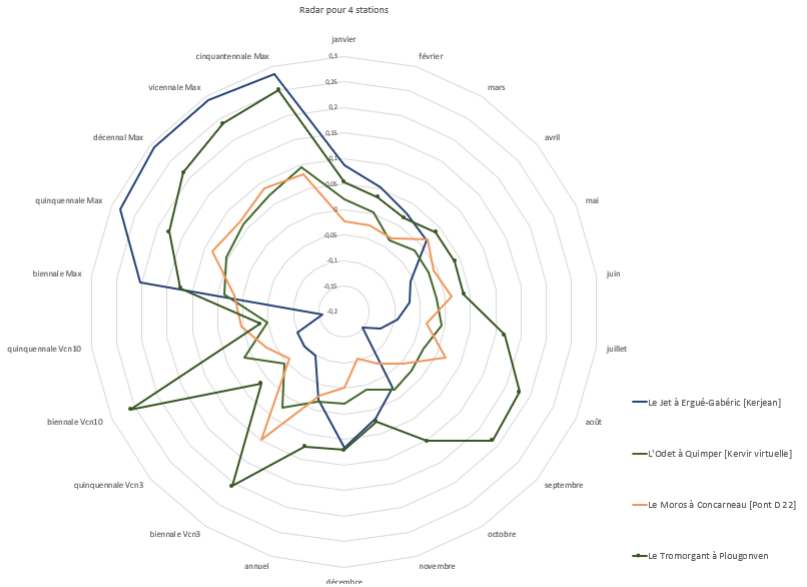
Crues (loi de Gumbel - septembre à août) - données calculées sur 50 ans

Fréquence	QJ (m3/s)	QIX (m3/s)
Xo	2.810	3.640
Gradex	1.150	1.420
Biennale	3.200 [3.000;3.500]	4.200 [3.900;4.500]
Quinquennale	4.500 [4.200;5.100]	5.800 [5.300;6.400]
Décennale	5.400 [4.900;6.100]	6.800 [6.300;7.700]
Vicennale	6.200 [5.700;7.200]	7.900 [7.100;9.000]
Cinquantennale	7.300 [6.600;8.500]	9.200 [8.300;11.00]
Centennale	Non calculée	Non calculée

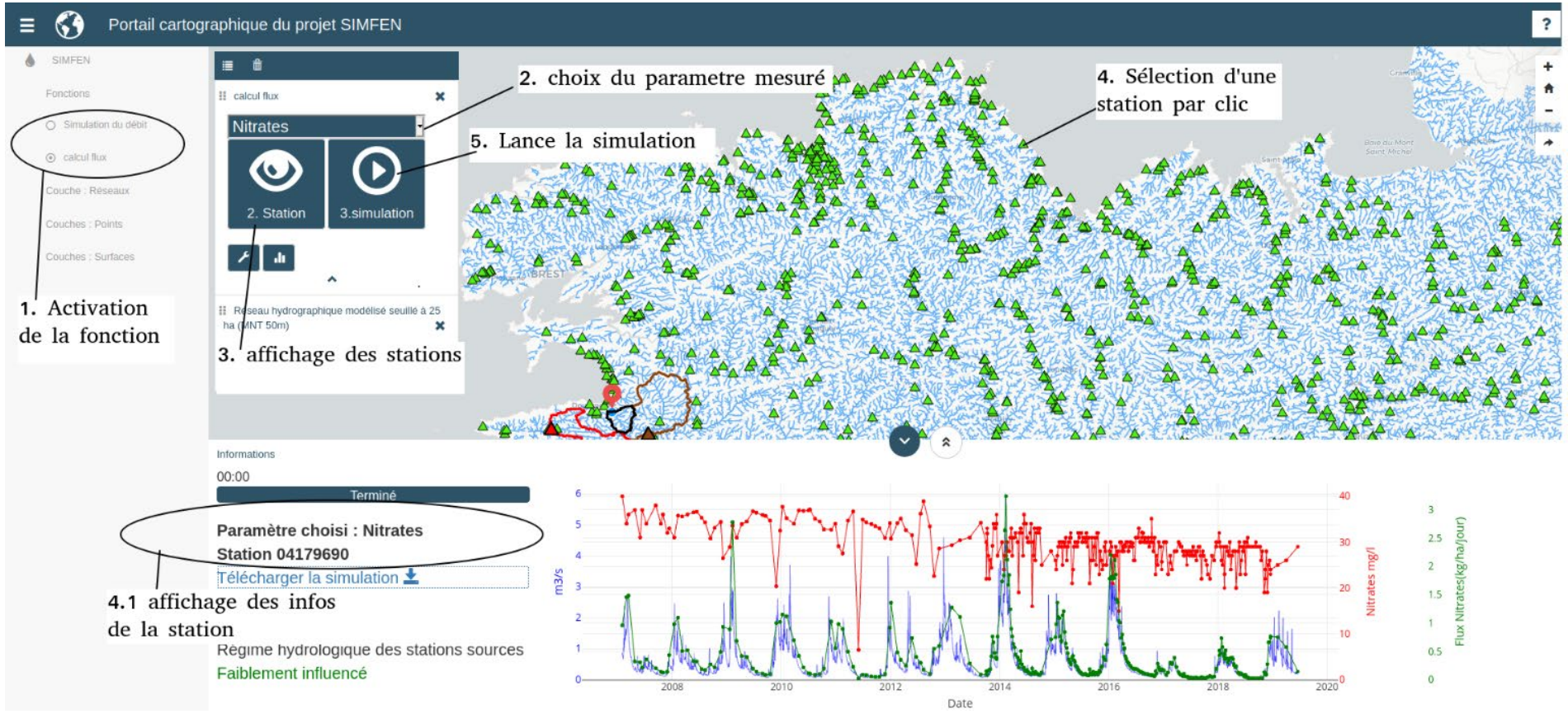


Maximums connus (par la banque HYDRO)

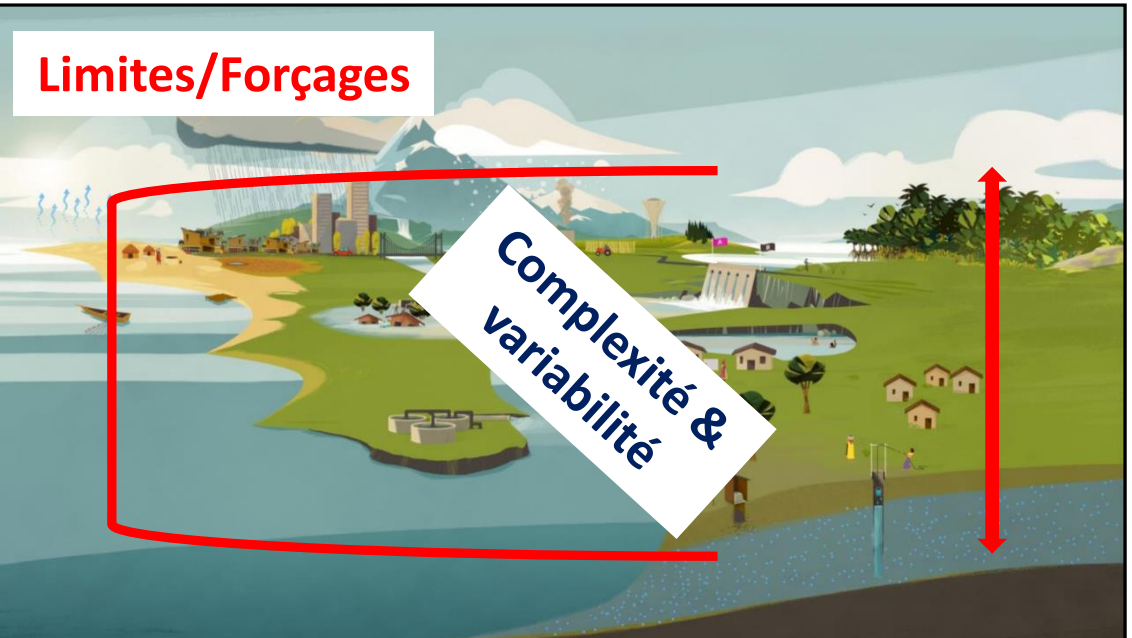
Débit instantané maximal (m3/s)	12.30 #	13/11/2000 03:13
Hauteur maximale instantanée (cm) *	217	30/05/1981 18:18
Débit journalier maximal (m3/s)	10.10 #	22/01/1995

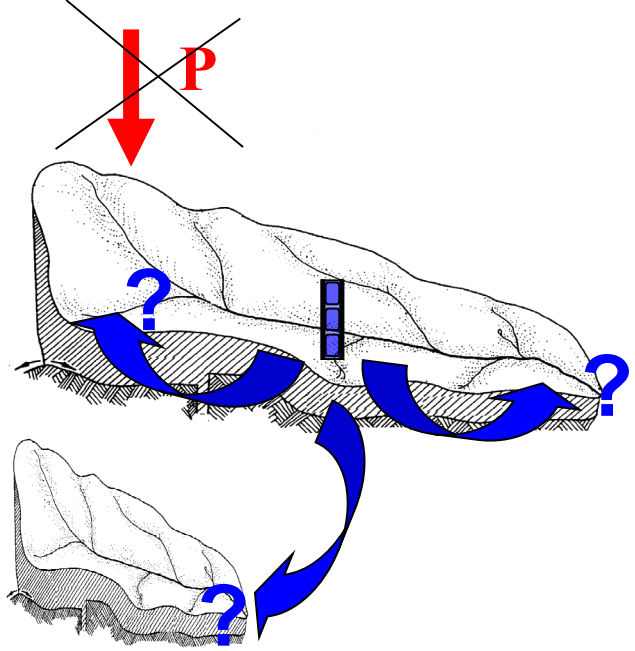


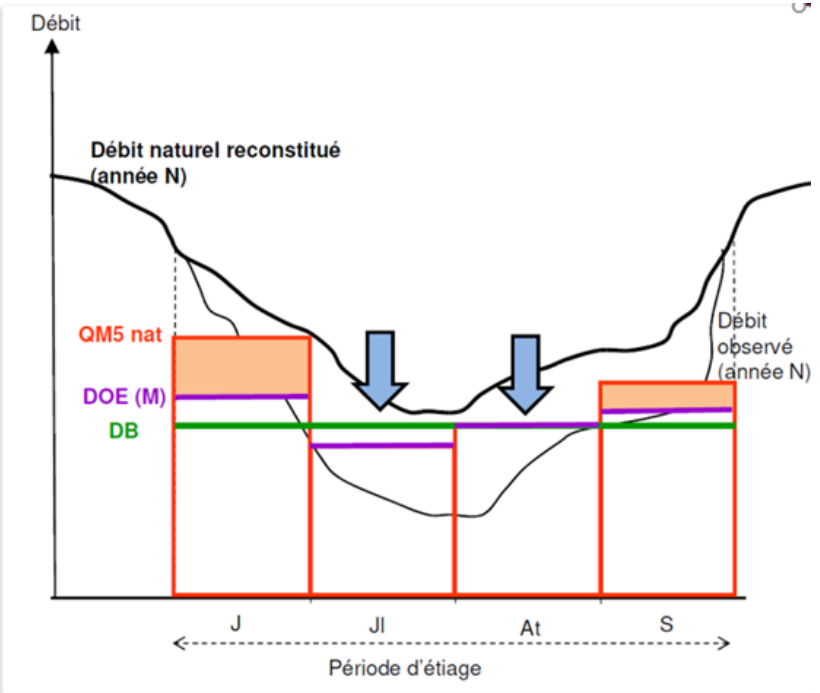
Développement : Calcul de flux avec Hub'Eau



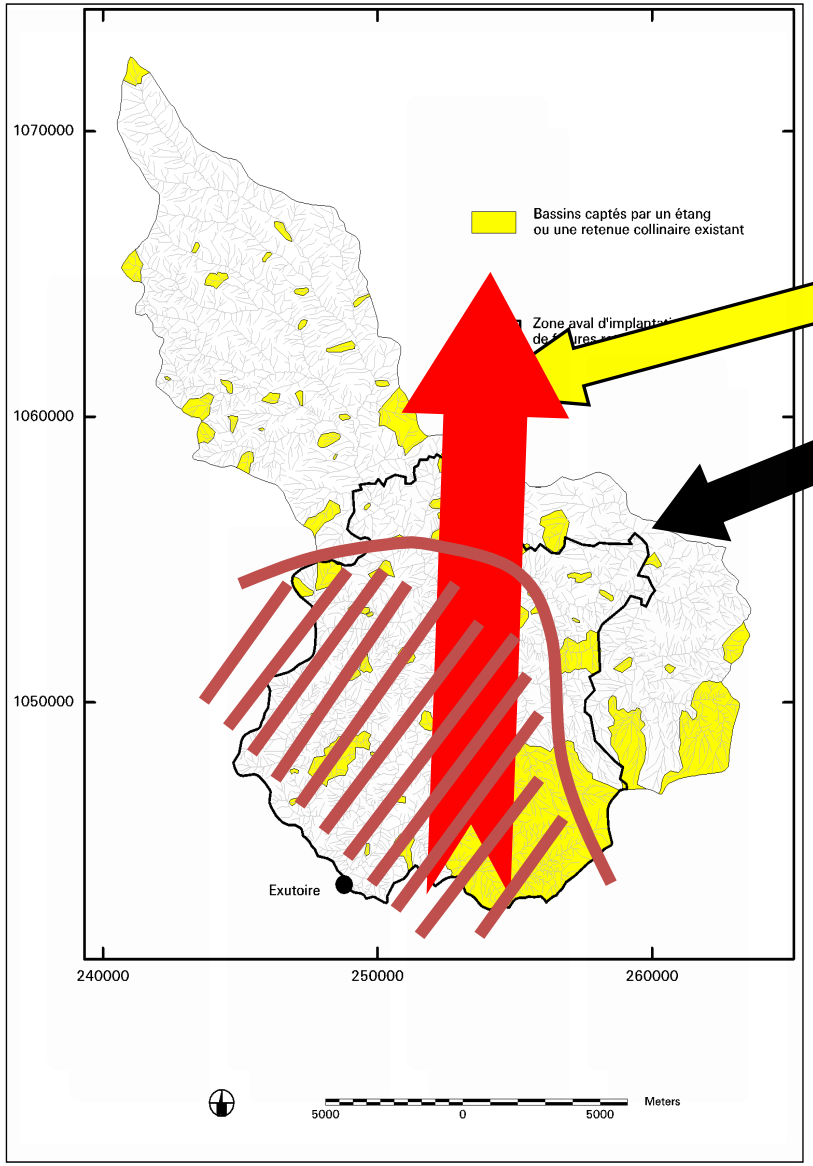
Comprendre et quantifier



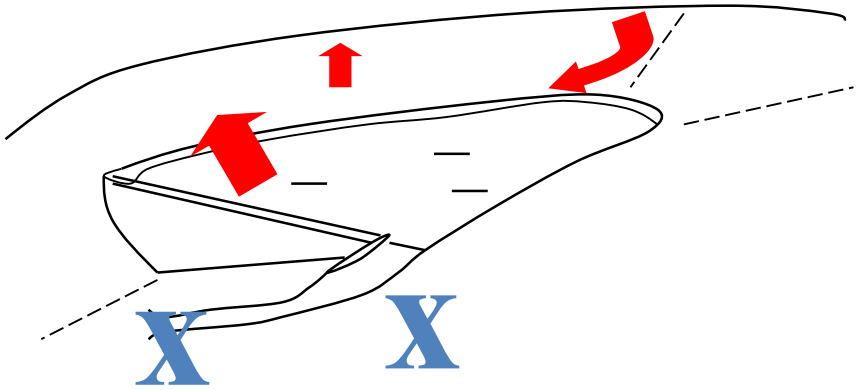


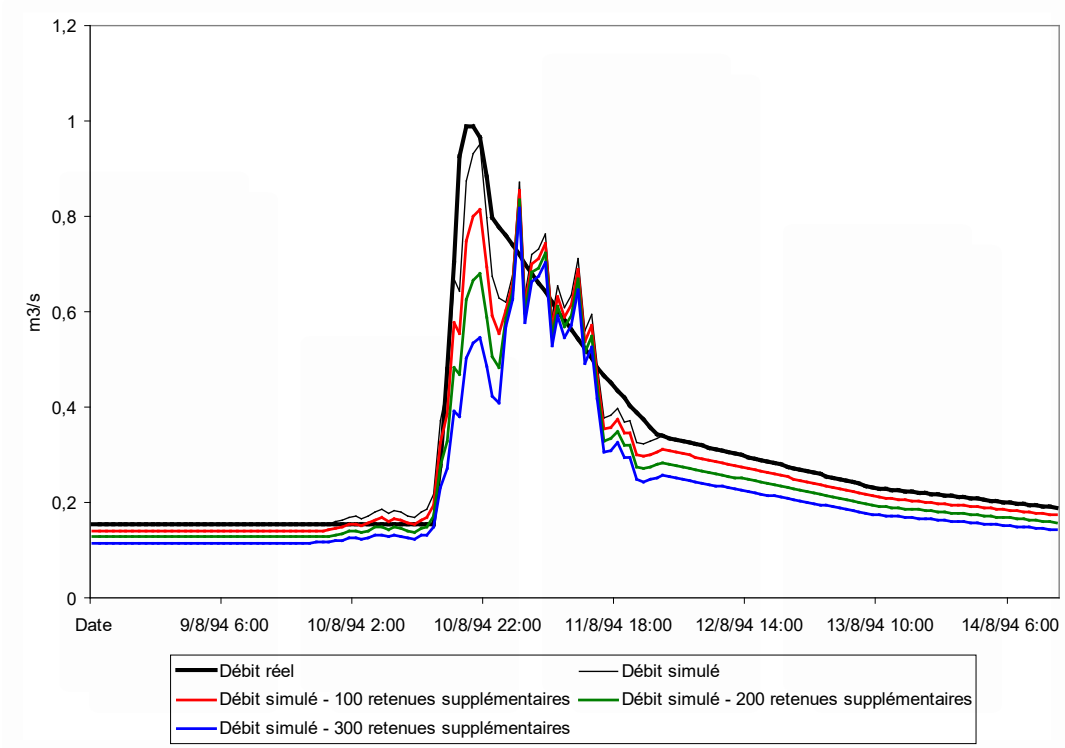


Exploration : Retenues collinaires dans le bassin versant de l'Yvel (302 km²)



- Des zones captées
- Une zone préférentielle de développement futur des retenues (x<26 km)
- Un gradient pluviométrique fréquent
- Un schéma de semi-distribution de la pluie (x<18 km)

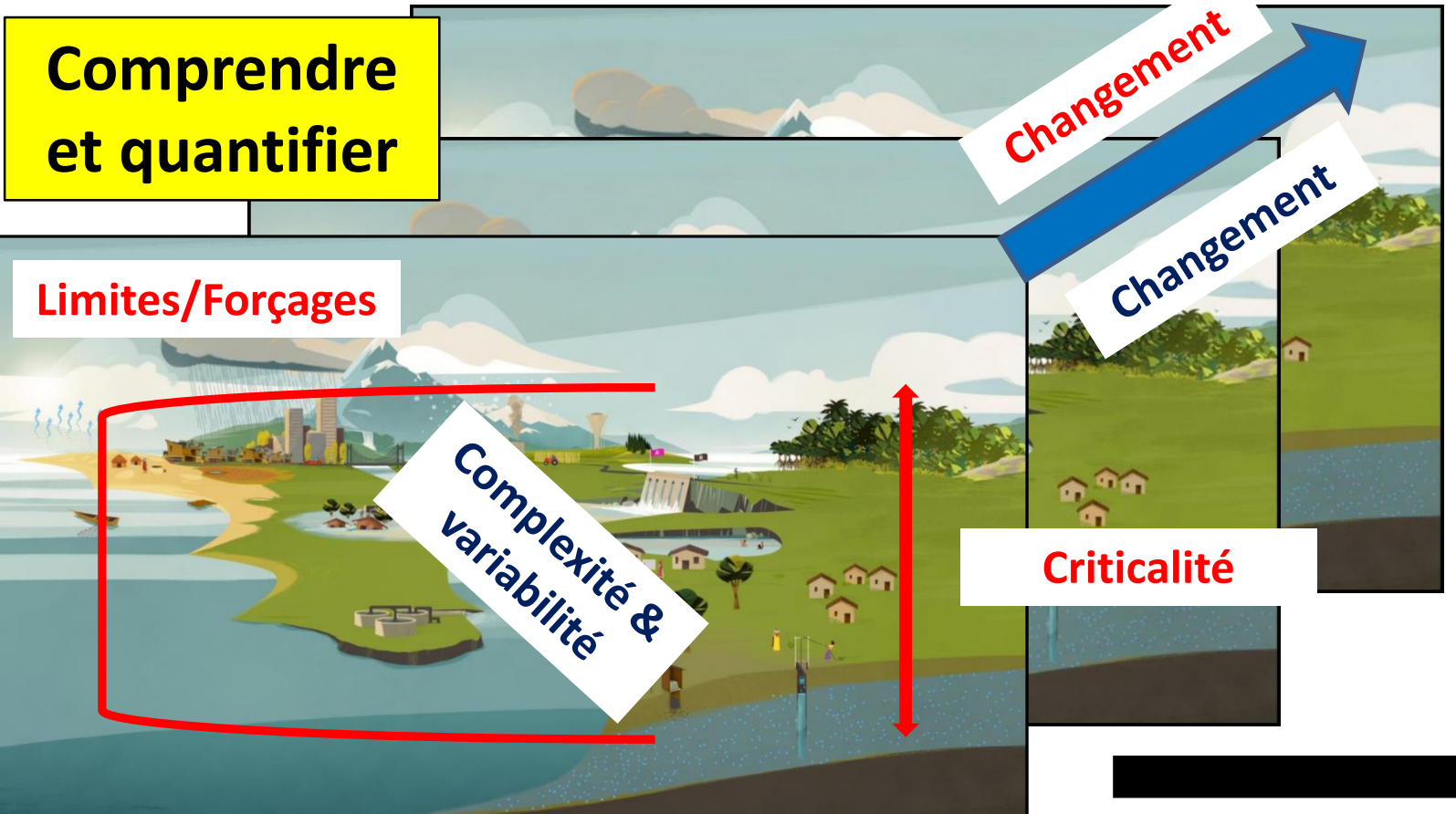




Enjeux
et fronts de science

Non-stationnarités Incertitudes

Comprendre et quantifier



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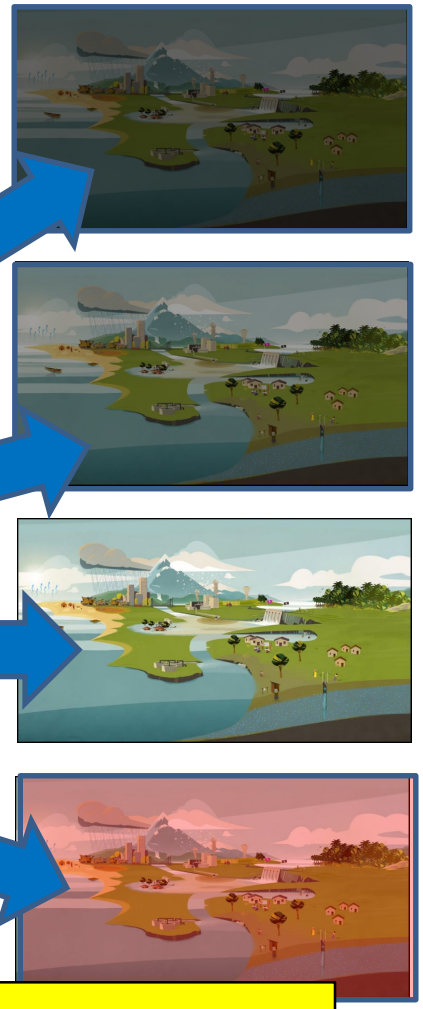


=> Bascules?

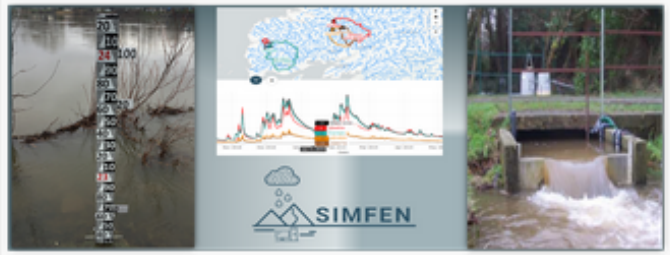
Prospective Choix Trajectoire

2030

...

https://geosas.fr/simfen/

Lettre n°1 - janvier 2021



Edito

En tant que chercheurs et enseignants en hydrologie et en géomatique, nous avons la préoccupation depuis plus de vingt ans de développer des méthodes qui ont une pertinence et une utilité vis-à-vis d'enjeux opérationnels et sociétaux ; et de former des étudiants, futurs professionnels, à ces méthodes pour permettre la diffusion des résultats de la recherche. La convergence des approches en hydrologie, en hydro-informatique et sur les services web permet d'aller bien plus loin dans le sens de la science ouverte et du dialogue science-société, au service d'une meilleure connaissance partagée du fonctionnement hydrologique régional, et donc de sa gestion multi-acteurs. Cette sortie du laboratoire de recherche, accompagnée et encouragée par la Région Bretagne et l'Agence de l'Eau Loire Bretagne, en dialogue avec la DREAL et des professionnels aux points de vue complémentaires, est un défi un peu risqué, que nous avons souhaité relever en tant que scientifiques du service public. Les réflexions sur l'ergonomie, la vulgarisation des principes de modélisation sous-jacents, la communication sur les incertitudes, l'anticipation des usages, les retours pertinents et stimulants des premiers utilisateurs du service en libre accès, les perspectives de prolongement vers d'autres simulations (statistiques, hydrochimiques ...) et d'applications (baies littorales, écohydrologie, sciences citoyennes...) sont autant d'étapes et de perspectives passionnantes.

L'équipe SIMFEN

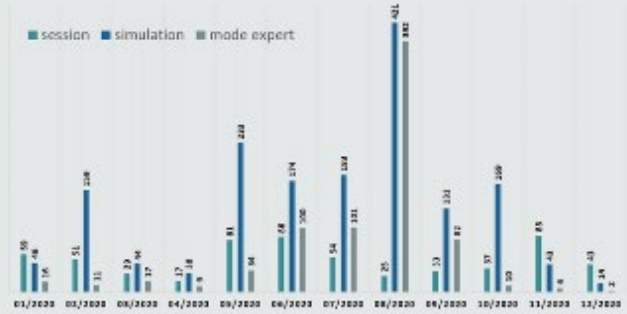
Actualités

La version 2 du portail cartographique de SIMFEN est disponible, plus d'information...

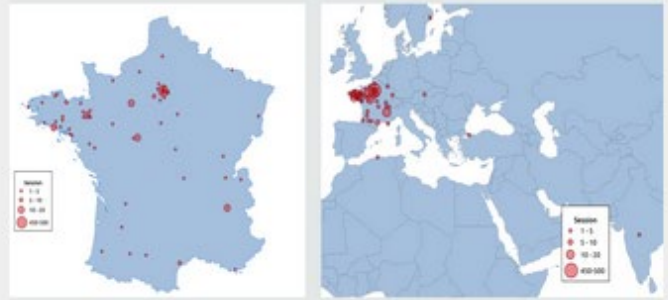
Liste de diffusion

Inscrivez-vous et participez à la liste de diffusion de la communauté SIMFEN

Évolution des utilisations



Localisation des utilisateurs



Emplacements des simulations

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