Progress in knowledge from synergy between modelling and observations

Isabelle Braud, UR RiverLy, Irstea, Lyon

Symposium: a tribute to Joël Noilhan

Toulouse, 21-22 March 2019

Outline of the presentation

1. General methodology
2. Example of process studies related to soil – vegetation – atmosphere interactions
3. Extension to catchment hydrology and hydrological processes
4. New directions in terms of observations and interactions between data and models: the OZCAR (Critical Zone Observatories) research infrastructure

Synergy between observation and modelling

<u>Objectives</u>: Process understanding

Data analysis and derivation of the perceptual models of the system functioning

⇒ Set up of dedicated models based on the current knowledge and available data

⇒ Use of the models in an hypothesis testing framework

Model evolution

⇒Improvement of input data and parameters

⇒Change in process representation

⇒Addition of new processes in the model

Results analysis: comparison between model outputs and observations and analysis of the discrepancies

⇒Problems with the parameters specification?

⇒Problems with the process representation?

⇒Processes not taken into account?

?

New data collection and analyses

Adapted from Braud et al., HESS, 2014

See also Clark et al., WRR, 2011

Understanding evaporation processes in a semi-arid environment
The EFEDA experiment 20-30 June 1991 Spain

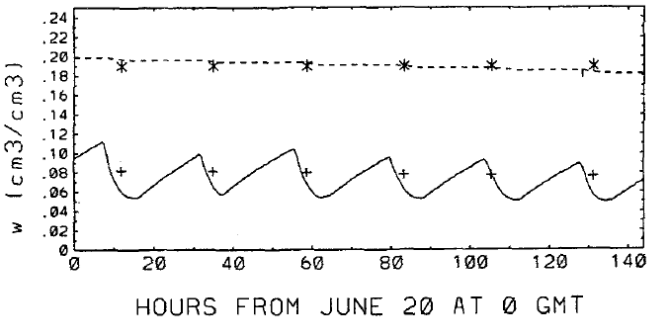
BARE-GROUND SURFACE HEAT AND WATER EXCHANGES UNDER DRY CONDITIONS: OBSERVATIONS AND PARAMETERIZATION

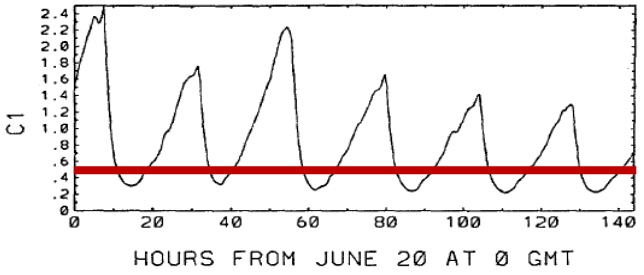
I. BRAUD, J. NOILHAN, P. BESSEMOULIN, P. MASCART
Météo-France/CNRM, 31057 Toulouse Cédex, France

and

R. HAVERKAMP, M. VAUCLIN
LTHE/IMG, CNRS URA 1512, INPG, UJF BP 53 X, 38041 Grenoble Cédex, France

(Received in final form 12 February, 1993)





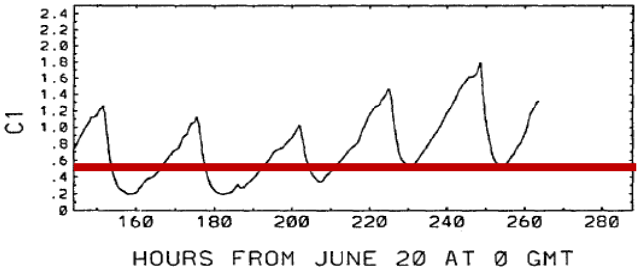


Fig. 9. Time evolution of C_1 when vapor phase transfer is included.

- Collaboration between atmosphere and soil science scientists
- Measurements: energy balance (Bowen ratio method), soil moisture, soil hydraulic properties
- Modelling of data that I had not acquired
- Improvement of ISBA to take into account vapour transfer in the soil

=> A more physically-based formulation of the transfer coefficient

Braud et al., BLM, 1993

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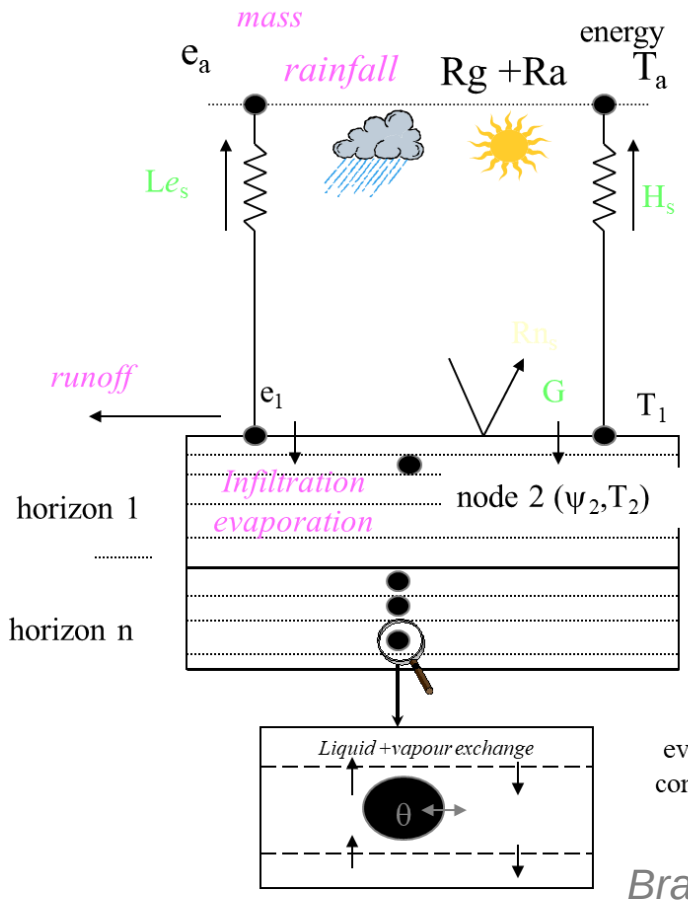
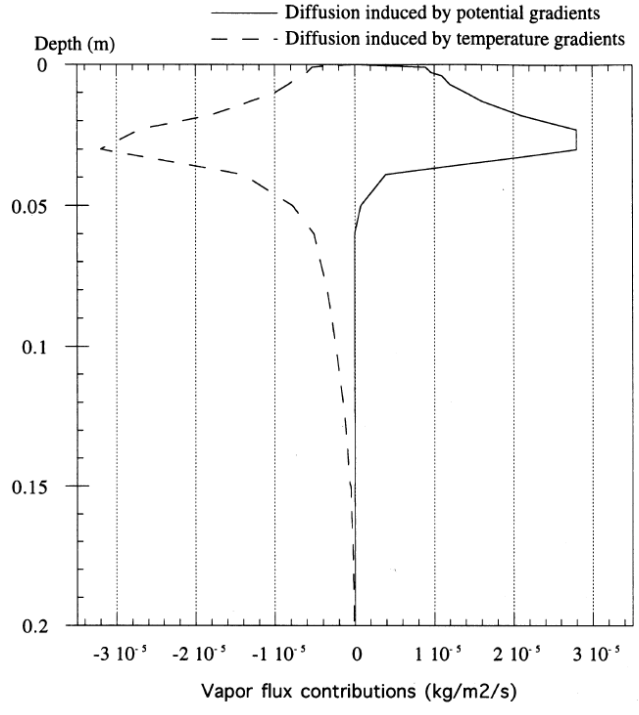
SiSPAT model



- Study of evaporation processes using the SiSPAT model including coupled heat and water transfers

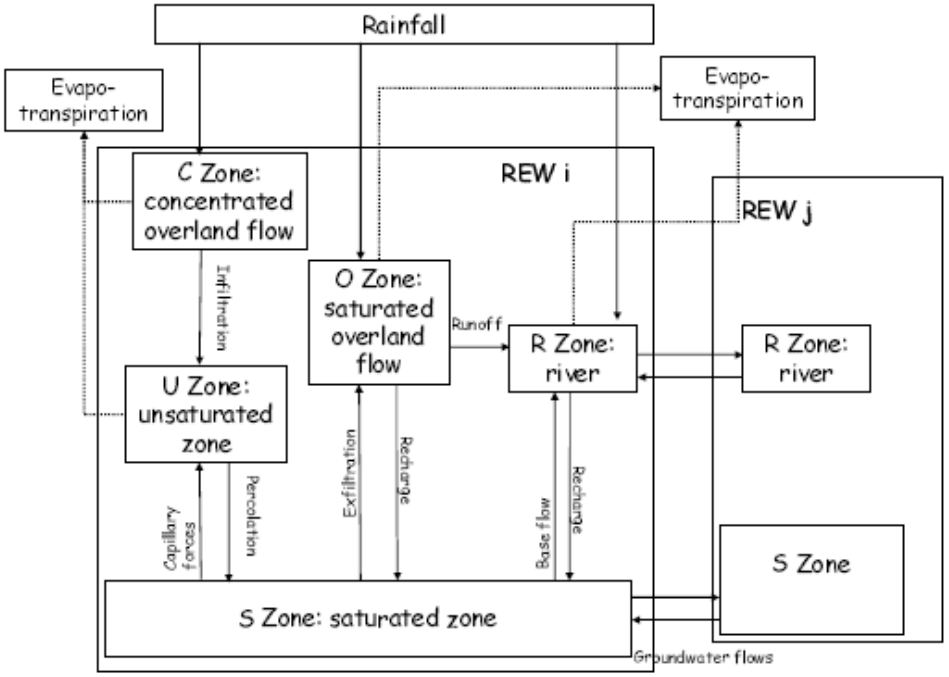
⇒ Soil water potential gradients, included in the new ISBA parameterization are influential

⇒ thermal gradients must also be taken into account



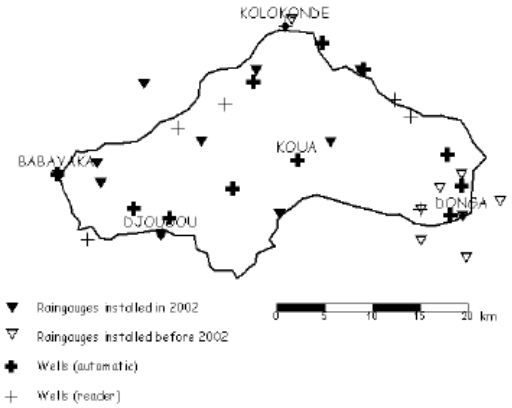
Braud et al., JoH, 1995
Boulet et al., JoH, 1997

Extension to hydrology: defining the AMMA-CATCH experimental set up



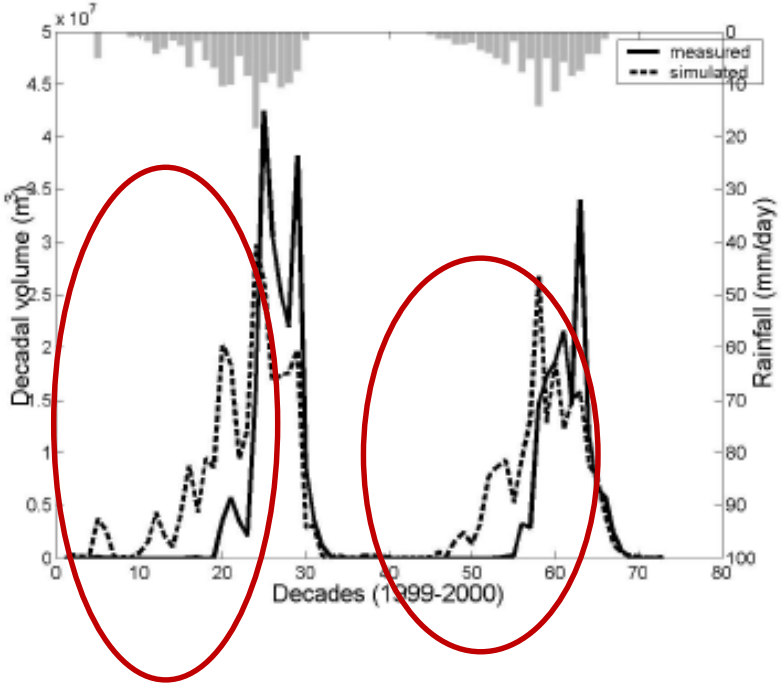
- Sudanian climate (Donga catchment)
- Starting hypothesis: groundwater is one of the main contributor to the discharge
- Research question: does the Representative Elementary Watershed concept provide a relevant representation of this functioning? (PhD thesis of N. Varado, 2004)

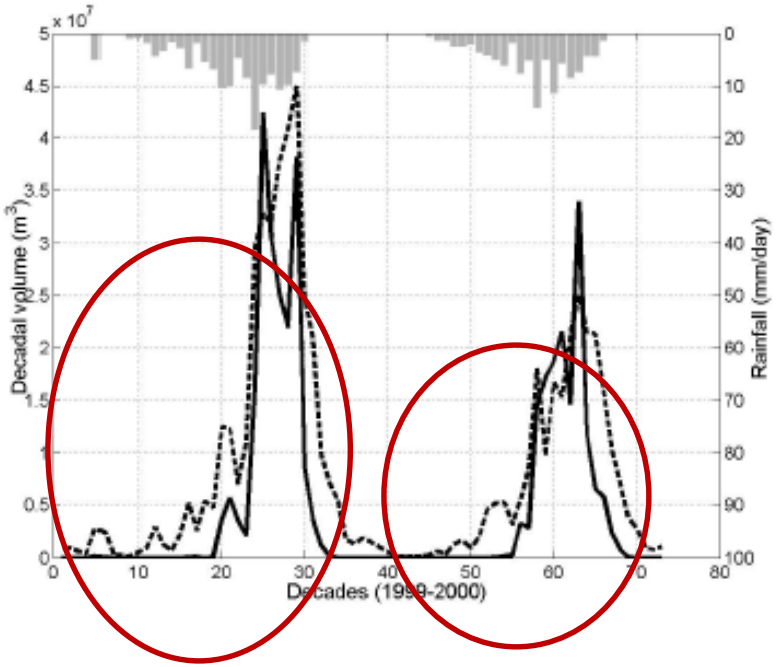
Characterization of soil surface hydraulic properties



Varado et al., 2006

Extension to hydrology: defining the AMMA-CATCH experimental set up





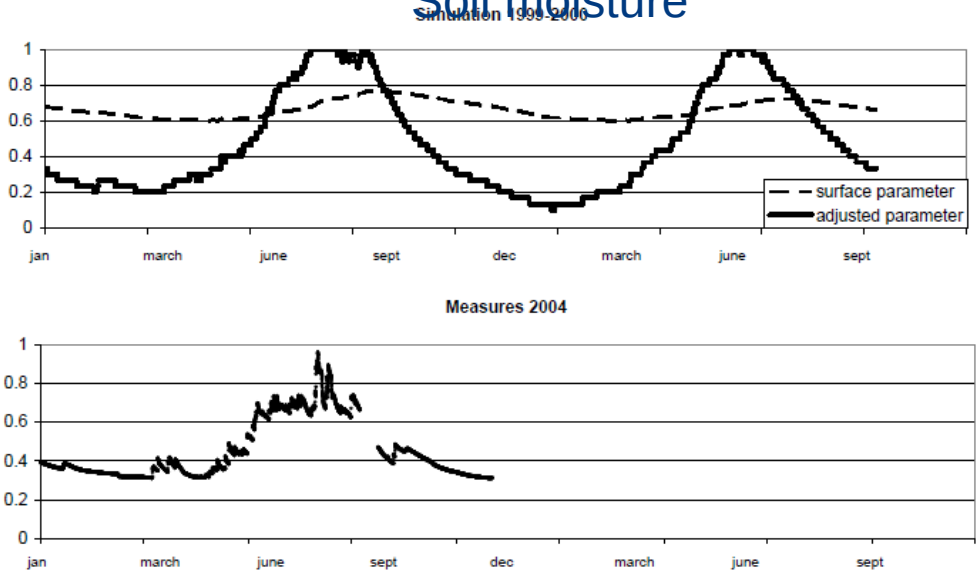
- First simulations quite deceiving as discharge starts too early and is overestimated
- Soil parameters (saturated water content and hydraulic conductivity) were adjusted to improve the simulation leading to a very low saturated water content 0.03, and a lower KS than the surface value

⇒ Highlight the importance of the deep soil that is poorly documented

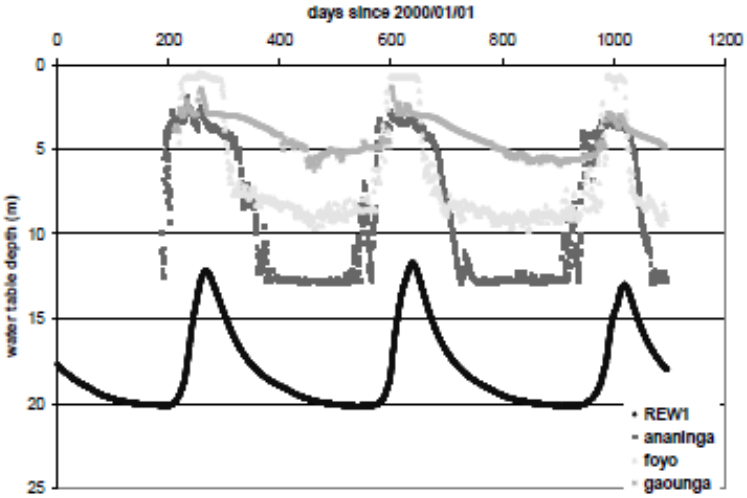
Varado et al., 2006

Model evaluation with collected data

Soil moisture



Groundwater table



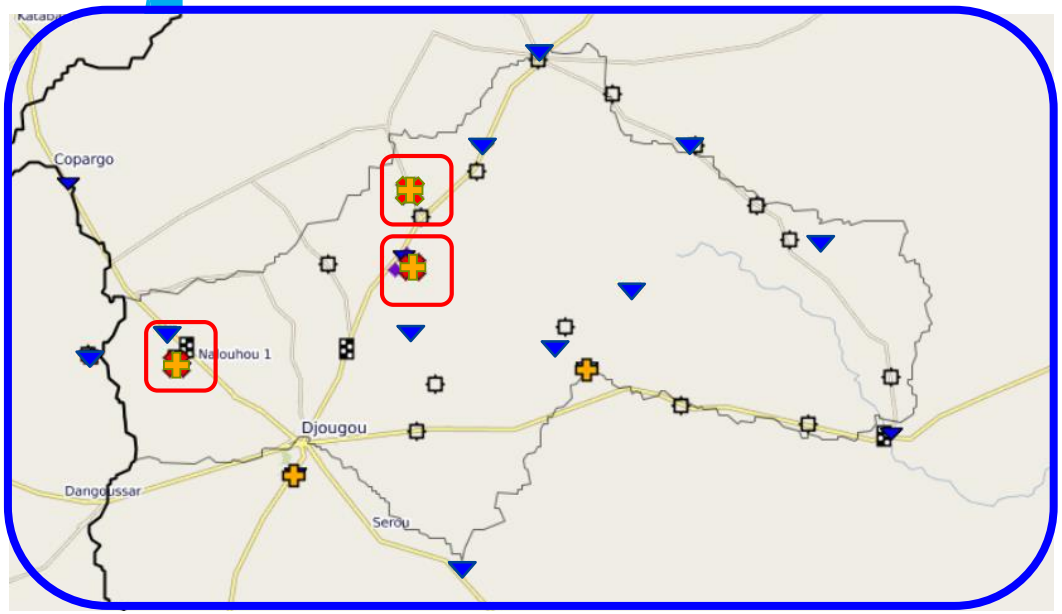
- Reasonable agreement for the simulation of soil moisture
- Groundwater table dynamics is poorly simulated

⇒ Highlight a limitation of the modelling approach that does not distinguish between deep and perched water table

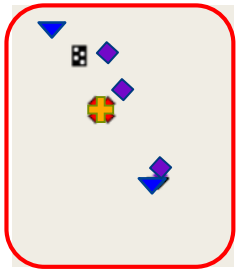
⇒ The contribution of deep groundwater is not the major contribution to discharge (cf Seguis et al., JoH, 2011)

Varado et al., 2006

Further investigation : more measurements



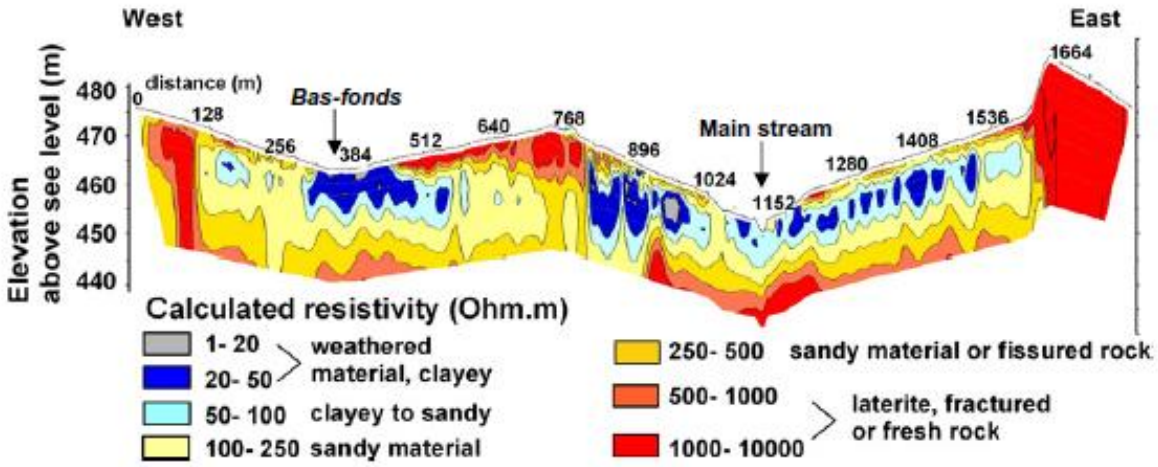
Local site



Type of measurement

- Rainfall
- Meteo (radiative budge
- Evapotranspiration
- Soil moisture
- Groundwater
- Discharge
- Vegetation

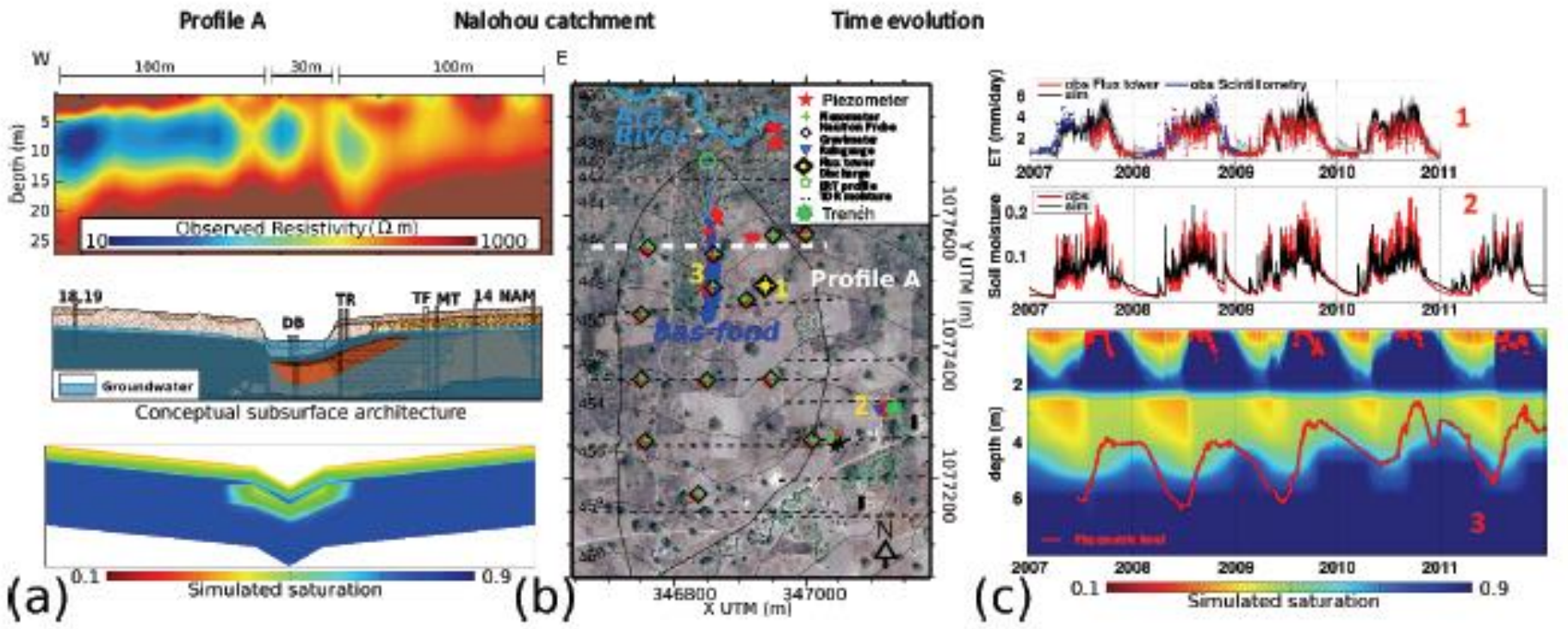
Courtesy of S. Galle



Seguis et al., JoH, 2011

- Documentation of additional components of the water balance: evapotranspiration (flux towers, scintillometers)
- Documentation of deep soil: geophysics, gravimetry

Further investigation : focus on the small Ara catchment



- Uptake by root tree is the main driver of groundwater discharge
- Inland valley (bas-fonds) landscape structures are key features of the hydrological functioning in these zones
- The ParflowCLM model is set up on the catchment to further investigate the role of deep soil structure on the catchment functioning

Hector et al., HESS, 2018; Gaillardet et al., VZJ, 2018

Perspectives: enhance the approach using data collected in observatories/research infrastructures

OZCAR

CRITEX

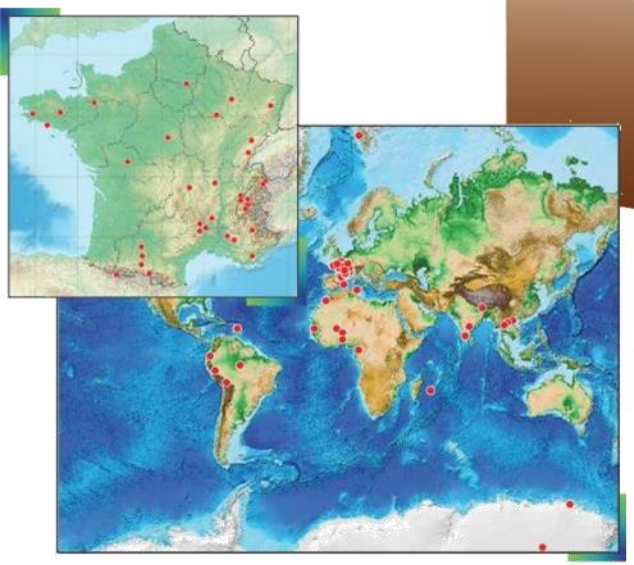
- OZCAR a network of networks
- With a common interest in the Critical Zone
- A common general question: how to monitor, describe and simulate the Critical Zone adaptation to a changing planet (climate change, land use changes, changes in practices)
- Computation of budgets, fluxes
- Highly instrumented sites and long term observation history

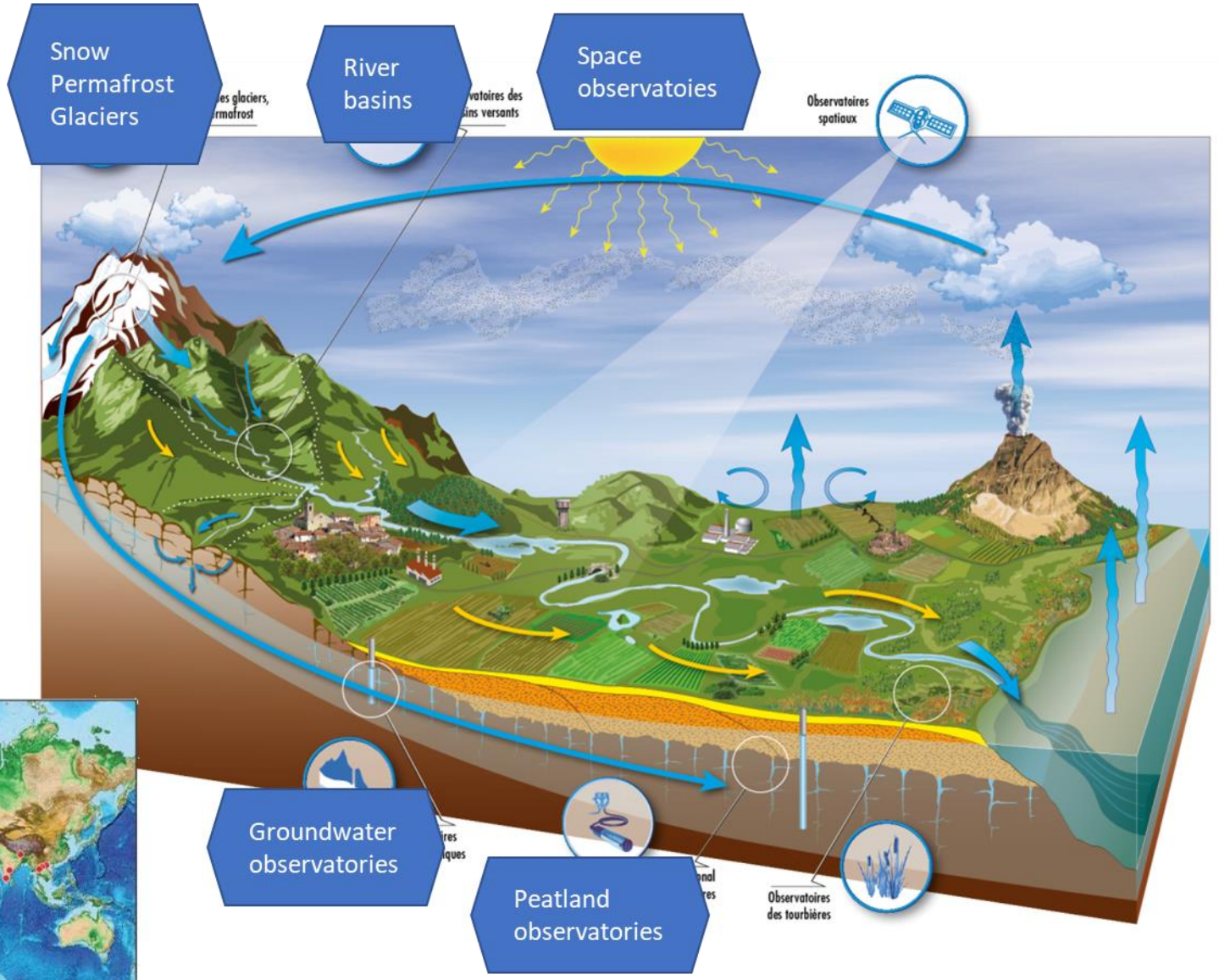
irstea

OZCAR Critical Zone Observatories network

eLTER

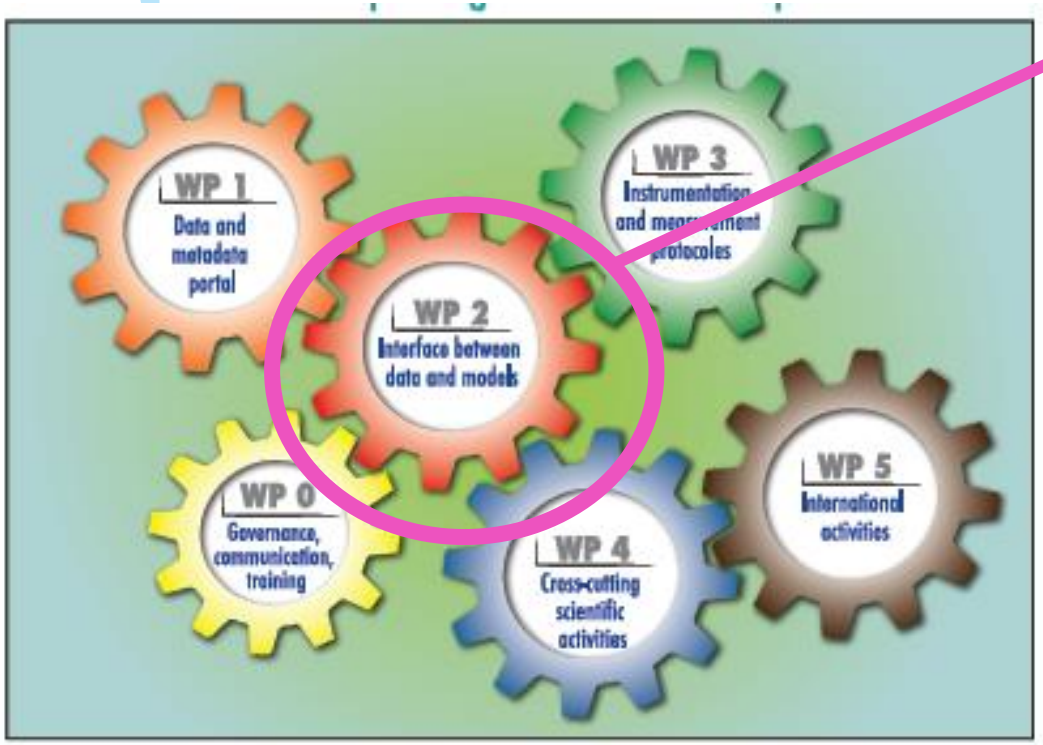
European dimension





Gaillardet et al., VZJ, 2018

OZCAR WP2: Interface between data and models



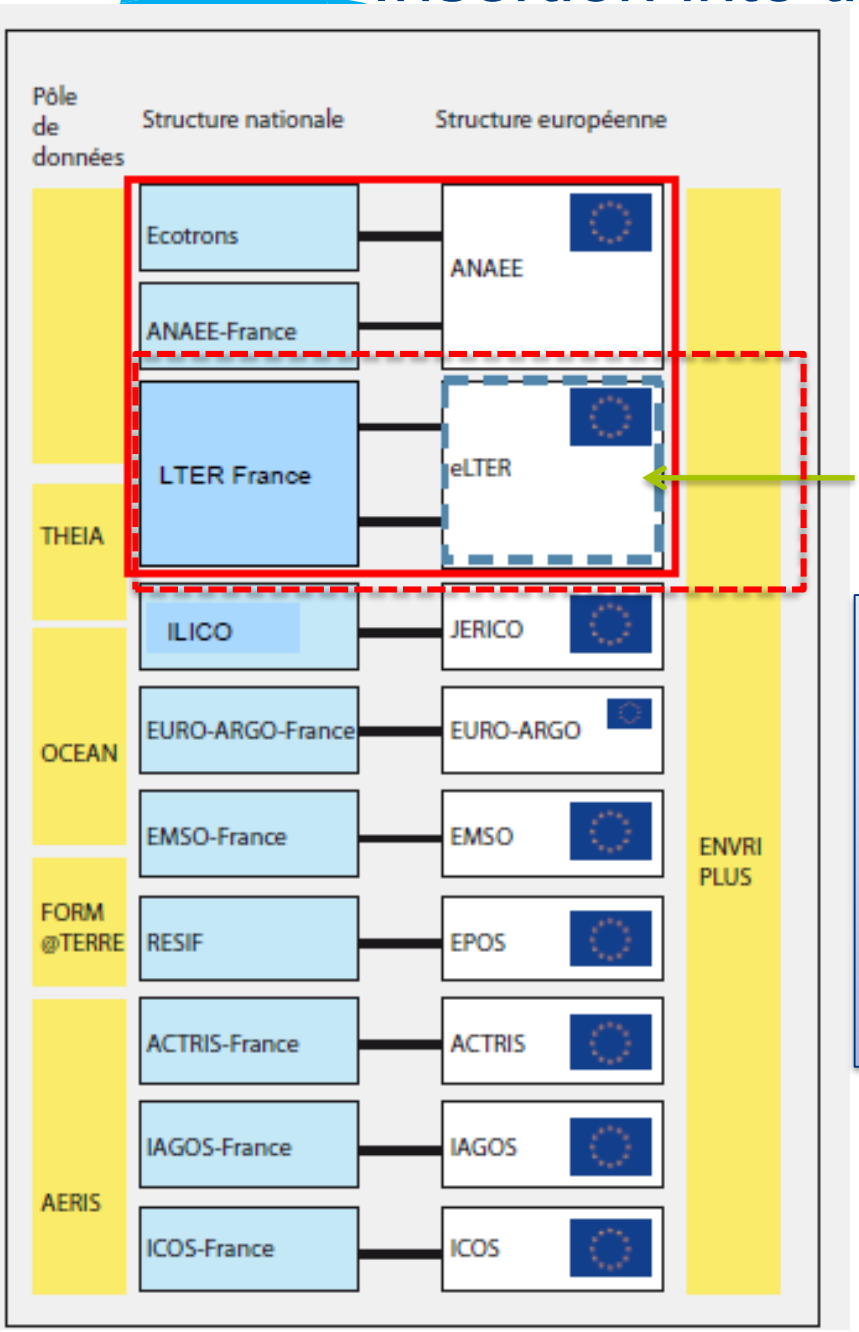
AMBITIONS

- Enhance the use of data in OZCAR by developing stronger links between data and model
- Enhance the use of satellite data in the community

REALIZATIONS

- Inventory of models used in the network and of the required data
- Postdoc aiming at applying the same model on several observatories (comparative analyses)
- Organize workshops on cross-cutting topics (machine learning, data assimilation)

Insertion into the european landscape



ESFRI: eLTER-RI labelled in septembre 2018

eLTER French mirrors: **LTER-France** including

- OZCAR-RI : Critical Zone Observatories
- RZA-RI: LTSER (long-term socio-ecological systems) network

THANK YOU FOR YOUR ATTENTION

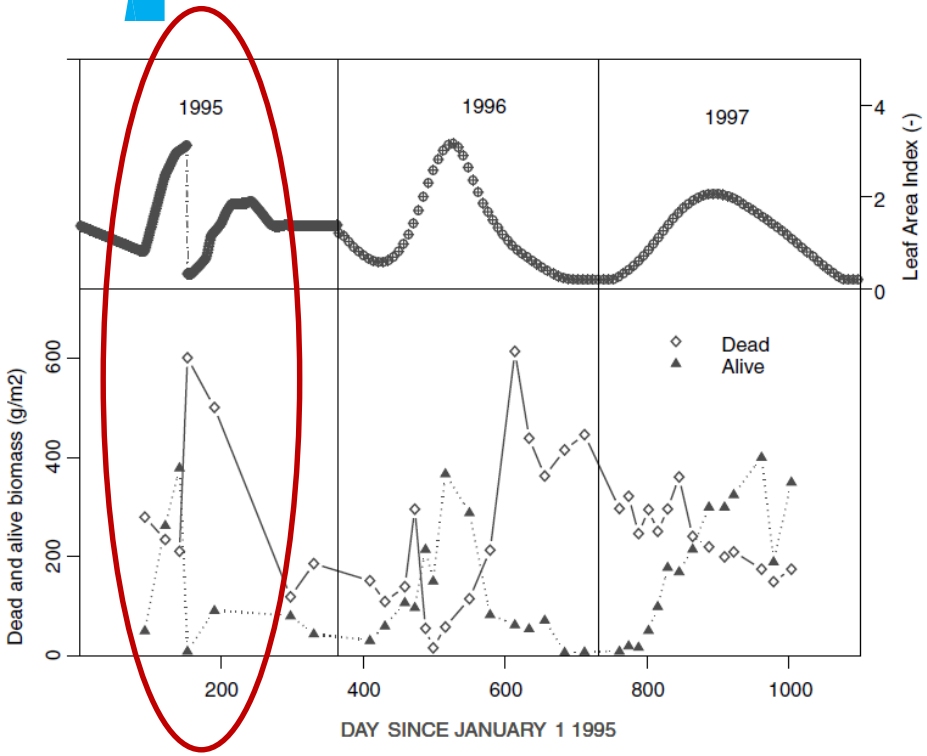
QUESTIONS???

OZCAR and its components are funded by the French Ministry of Education and Research, CNRS, IRD, INRA, Irstea, BRGM, ANDRA, Météo-France, several French universities and foreign institutions

eLTER

OZCAR

Mulch and litter processes: MuRex experiment
Use of the SiSPAT model to understand data



- A long term experiment to document soil, water, atmosphere, vegetation interactions

⇒ PhD thesis of E. Gonzalez: the validation of the SiSPAT model using these data

- But the farmer cut the grass unexpectedly, leaving a litter on the ground

⇒ What was the impact on the surface energy balance?

⇒ Led to the development of a specific version of SiSPAT called SiSPAT_mulch

⇒ Showed that the litter had an impact on the soil temperature and moisture

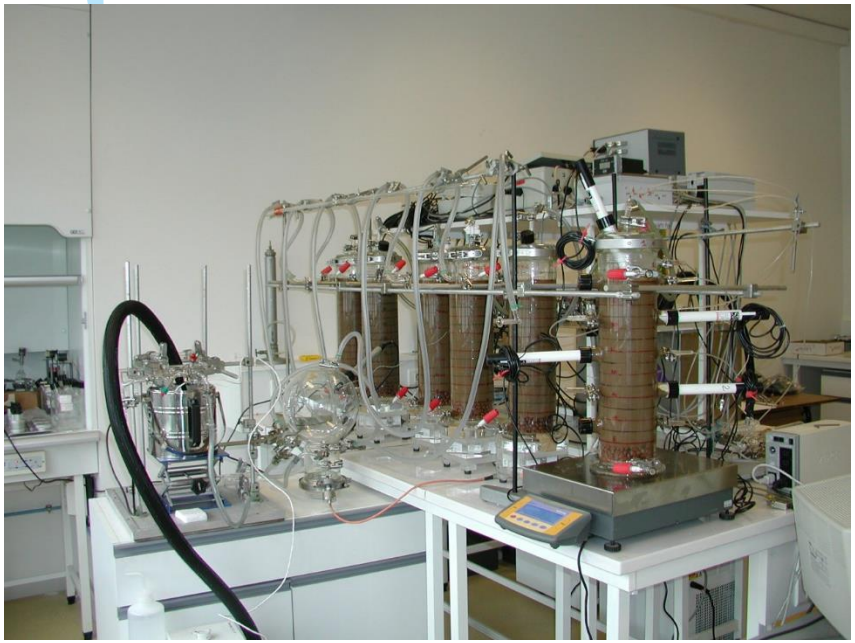
At that time, the study was considered as an academic exercise, without great potential

⇒ But the impact of litter on the water and energy balance was recognized and a litter layer is now included in the new version of ISBA: ISBA-MEB

Gonzalez-Sosa et al., AGFM, 1999
Gonzalez-Sosa et al., JoH, 2001

Partition evaporation – transpiration using stable isotopes

Bare soil evaporation



Transpiration by plants

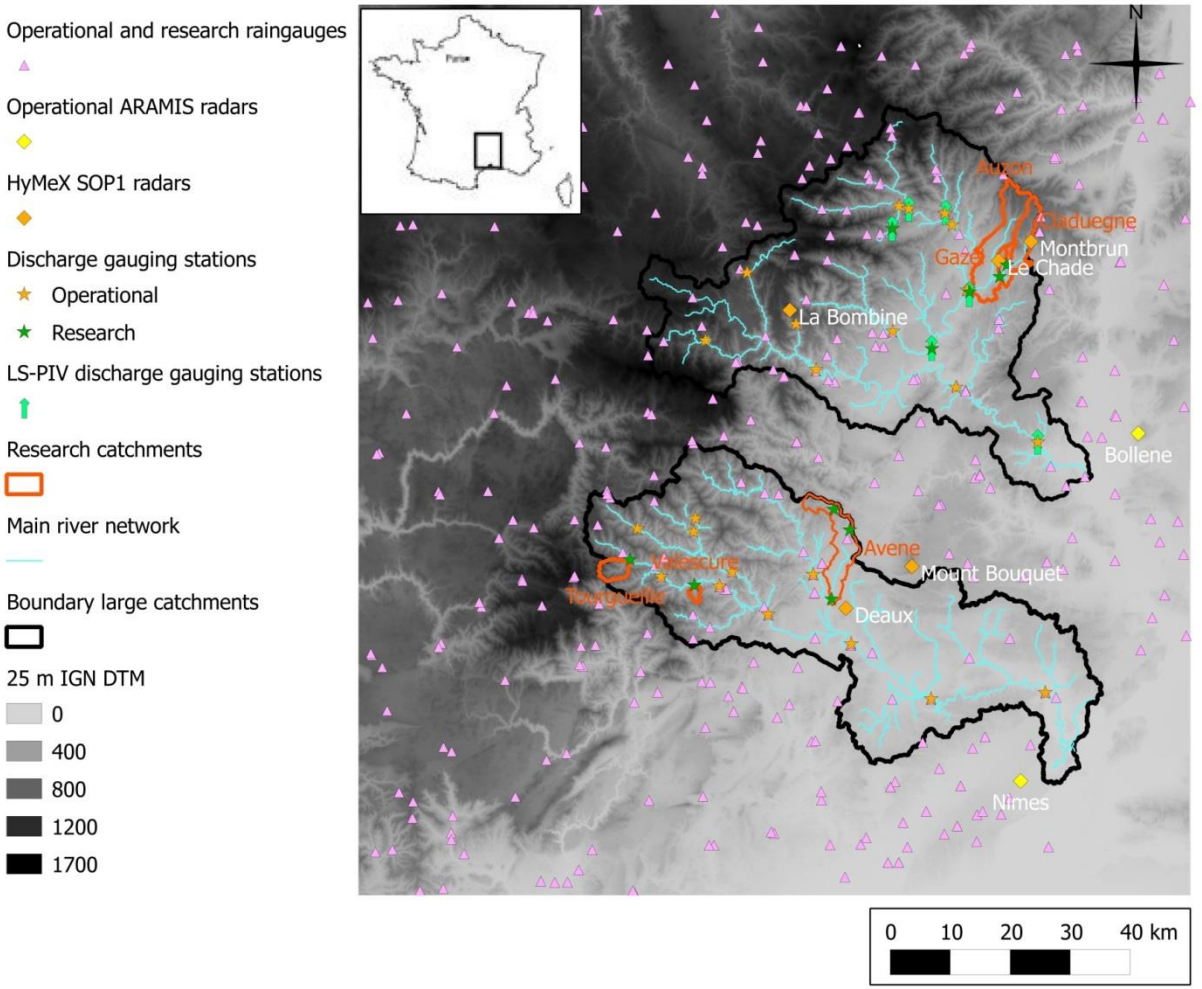
- Combination of laboratory experiments and modeling

⇒ Results on kinetic fractionation factor, that is very difficult to measure and that is very influential on the interpretation of measurements

Braud et al., JoH, 2009
Rothfuss et al., JoH, 2012

FloodScale: understanding hydrological processes during and between flash floods in the Mediterranean region

➢International HyMeX program (Hydrological Cycle in the Mediterranean Experiment-2010-2020) and enhanced observation period (ANR FloodScale project 2012-2015)



=> An opportunity to go towards documentation of hydro-sedimentary processes in a range of nested scales.
=> Selection of various small catchments in various geology, land use

Braud et al., HESS, 2014