CRITEX NEWSLETTER

Issue #4, Mars 2017

CRITEX is a 10-year program involving more than 20 partners, including (1) equipment specialists in charge of technical developments and (2) researchers associated to the national CZ observatories of RBV (réseau des bassins versants) or H+ (réseau hydrogéologique) networks. The success of CRITEX will lie in the ability of all groups to work together for a better understanding of the Critical Zone of the Earth and share common equipements through innovative research projects.

Editorial:

Welcome to the 2016 CRITEX's Newsletter !
You will find in this issue a report of the main events and achievements of the program in 2016, including a descrpition of each workpackage and interviews of Jean François Soussana from the National Institute for Agricultural Research and Alexandra Arènes, a landscape Architect that is fascinated by the Critical Zone Scientists…
Three highly significant events marked the year 2016 for the CRITEX program.
The first is the launch of the OZCAR (Observatoire de la Zone Critique : Applications et Recherche) national Research Infrastructure (RI). OZCAR gathers a number of national research networks observing the Earth's terrestrial surface. It aims at creating a plateform of scientific facilities and of scientific exchange enable our critical zone communities to adress new scientific questions that would be difficult to address without a common RI.
The second event is the development of the European CZ research. An ESFRI (European Strategy Forum on Research Infrastructures) proposal, called eLTER, is in preparation associating the Critical Zone and LTER communities in more that 25 European countries. It should be submitted to the European ESFRI Road map in 2018. This will mark an important step in the European construction of Critical Zone and Ecosystem sciences and will give a new dimension to our disciplines.
Last but not least, in 2016, Charlotte Le Traon has been appointed on the WP0 devoted to project management. Charlotte has spend almost all her time on finishing the web page of CRITEX that is now on line at https://www.critex.fr/. A big thank you to Charlotte!

2017 will be the end of the first phase of CRITEX (T1), corresponding to the acquisition of the equipments. The second phase (T2) is the operating and maintenance phase of the equipments. We have benefited from an extension of the T1 phase by the ANR, allowing us to be more flexible in the choice of the last instruments to be bought by the program. The T2 phase will give the opportunity to all partners and participants of the program to share Critical Zone questions on specific sites and couple the different approaches and techniques, ranging from geochemistry to geophysics and remote sensing.
In June 2017, an important moment of the project will be the mid-term evaluation by an international committee that will visit us.



We hope you will enjoy reading this issue of the CRITEX newsletter.

Jérôme Gaillardet
Laurent Longevergne
Charlotte Le Traon

OZCAR: Critical Zone Observatories: Applications and Research. OZCAR brings together the Allenvi-funded networks of observatories RBV (catchments), H + (groundwaters), CryObsClim (cryosphere), OPE (Andra perrenial obs.), the CNRS-funded Peatland network (Tourbières), Regional Spatial Observatory, and the BRGM-funded network of piezometers (ADES). OZCAR is a national Research Infrastructure (RI) shared by several research institutions (CNRS, INRA, IRSTEA, IRD, BRGM, ANDRA, and MétéoFrance) and French universities.
OZCAR IR's first mission is to promote integrated Critical Zone research on terrestrial surfaces and to be the unique national counterpart of the international Critical Zone initiative. With the network of the Zones Ateliers (French LTSER), it will represent the mirror structure of the European ESFRI eLTER project. OZCAR is organized in workpackages, one of which is "instrumentation and experimentation", and is therefore preparing the post-CRITEX era.

eLTER is a project aiming at providing Europe with an ambitious infrastructure promoting a holistic approach in the observation of terrestrial Earth's surfaces, associating geo, bio and socio-centered points of view. eLTER will be particularly important for understanding, predicting and moderating the impact of global change on geo-socio-eco-systems. Following the submission of the first version of the elTER ESFRI project by Germany in March 2015, eLTER was not selected but the ESFRI committee ranked it very positively and encouraged its resubmission by awarding it a one-year funded project "Advance_eLTER - Advancing the European Long-Term Ecosystem, Critical Zone and Socio-Ecological Research Infrastructure to ESFRI -". Advance_eLTER aims at preparing the submission of a second version of the eLTER ESFRI project for 2018. The Advance_eLTER project (Jan. to Dec. 2017) involves 28 partners for 15 countries. The French contact point is the CNRS with an INSU /INEE working group. Nicolas Arnaud, DAS INSU-SIC is in charge of one of the WP and belongs to the core group responsible for writing this project. The kick-off meeting was held in Leipzig on 1 and 2 February 2017. The project coordinators are Michael Mirtl, Herbert Haubold & Ingolf Kühn.

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Architecture and Critical Zone...

Alexandra Arènes is a landscape Architect. She accepted to answer to the questions of Jérôme Gaillardet.

Alexandra Arènes, could you tell us how the critical zone observatories can interest an architect?

AA: I am an architect specialized in landscape and urban planning projects, which concern the outside or the broader environment. My job consists in developing territorial prospect strategies for communities at different scales and in different landscapes (urban and natural) in France, and sometimes abroad.

There are several cross-cutting issues common to development planning questions and critical zone observatories. First, both are about habitability issues of the thin Earth pellicle that we all live on. Both are concerned with ecological and political questions, which impact the distribution of territories, and the visibility of natural phenomena. Finally, it is no longer a question of looking at a territory only horizontally or flatly, but in all its dimensions, and its strata. The territory constitutes an infinitely dense and complex spatial volume (the opposite of the idea of empty space) from canopy to underground basement. It represents a huge challenge in spatial representation (which may therefore interest architects). I went to see the Orgeval River Lab and some other equipments. It is another way of apprehending a landscape, by seeing invisible things that affect the management of territories. A journey through observatories could even be imagined to give the public access to these instruments and knowledge. I like the idea of a laboratory landscape. It is a subject on which I started to work for a mission of industrial site reconversion in the "chemical valley" in Lyon. And I also find this subject in the critical zone observatories.

JG: Could you give us some concrete examples for which the architectural question joins the critical zone science?

The development projects I am working on consist in rehabilitating old industrial sites (most often polluted) by renaturation processes; organizing urban development; revitalizing streams, etc. For this purpose, knowledge about ecosystem exchanges and soil processes is necessary in order to undertake actions of re-fertilization. But sometimes we do not have time to develop new solutions or to engage in substantive research because of the electoral calendars that dictate the project deadlines. There are time period, for example vegetation growing times, which are incompressible. It seems to me that one of the critical zone science stakes is also to make understand these temporalities which can be very long but also very short when the living processes are concerned. In the architectural world (in the broadest sense of spatial planning) and in the critical zone science, we need both to go on the field, to understand the human and nonhuman dynamics, to invent new tools to investigate processes. And based on this work, we must try to influence policies in the direction of sustainability.

JG: You work with Bruno Latour at a critical zone representation. What do you mean by "representation" and how do you work?

AA: After studying Political Arts at SciencesPo with Bruno Latour, I started a research project combining disciplines such as geography - cartography, the philosophy of nature, and geopolitics, through graphic means of visualization to imagine a renewal of our cosmograms (ie our ability to develop a common world). So it is also about political representations: how to make people feel concerned, to bring out issues to grasp politically those problems that impact our future, and the future of all species on Earth? For this we have set up a research program called Gaia-graphy: the representation of the Critical Zone, not limited to the surface of the globe. We want to bring out a common vision of this thin living pellicule of the earth, based on the Gaia hypothesis, which is the same as critical zonist land surveyors. We are at the beginning, but there has already been a concrete operation: we proposed a show, INSIDE, at the theater of Amandiers, performed by Bruno Latour and directed by Frédérique Ait Touati (she is scenographer, researcher at CNRS). This first act consisted in breaking the classical image of the Earth, which is too limiting to grasp ecological questions (too vast, too far), to make us enter (hence the title: INSIDE) in this particular fragile, living and complex film, and of which we have too few images to hang. The experimentation in the theater consisted in offering the public a diversity of "tables": dynamic maps, process diagrams, as well as a work of the stage space, sound and lights to test new formats to locate themselves.

J.G: What do you expect from CRITEX scientists?

AA: The gaia-graphy seeks to give a representation of the territories as they really are, that is to say superimposed, multidimensional, fluctuating, overflowing the limits assigned to them, etc., as can be seen by observing them through the sensors of your disciplines. So I would be very happy to discuss with CRITEX scientists about their perception of territories and Earth transformation through the critical zone instrumentation and accumulated data. I would like, for example, to ask them to describe to me how the processes they investigate would appear in the landscape if they were observable with naked eyes or if they were felt directly by our own senses.

Agricultural catchments : interview from Jean François Soussana

Jérôme Gaillardet and Laurent Longuevergne shared a meeting with Jean Francois Soussana, former INRA (National Institute for Agricultural Research) scientific director for Environment, now vice president in charge of international affairs, and Chantal Gascuel, her scientific join director.

JG: INRA is a partner in the CRITEX program and through its observatories, is providing a unique expertise on agroecosystem. How do you envision the future of environmental research in agricultural research catchments in France, particularly regarding instrumental aspects?

Agricultural catchments are constrained by different stressors related to agricultural management (tillage, grazing, fertilisers, etc.). The equipments deployed in the field provide a better understanding of the interactions and feedbacks between agroecosystems, soil and water resources at landscape level. The scientific challenges are: the determination of mass fluxes to the water and air compartments, the monitoring of internal catchment mass storage, the understanding of biogeochemical cycles at the landscape level which are useful for a better management of biomass production. The spatial and temporal high-frequency investigation is also a major challenge to understand how rapid events such as storms and droughts are impacting agrosystems as well as soil and water, relative to slow processes. We should also mention the deployment of multi-parameter approaches, particularly on contaminants (pesticides), the use of remote sensing techniques as a way for transfering knowledge gained from highly instrumented sites to management sites, or even larger regions, or issues such as soil carbon stock and water management in a changing world.

JG: France, through its various research institutions, is very rich in research infrastructures dedicated to monitoring and research of the critical zone (watersheds, soils, deep waters, glaciers) including the tropical critical zone. What is your feeling about this very complex and somehow confusing landscape of infrastructures?

It is complex but an important inter-institution work has been already done to structure research infrastructures in the recent years. So, we are moving forward! The water continuum has been well structured around OZCAR. There is probably still progresses to be done on soil research infrastructures that do not have the same visibility from the observational point of view, even if they are part of ANAEE, and OZCAR. In addition, a couple of communities are still poorly organized and need to be structured around national networks, for example ecotoxicology, which must build on existing infrastructures and complement them. Under the banner of the RECOTOX program we are trying to federate ecotoxicology data and observations from several watersheds. The articulation with the European roadmap is important in itself, and because it must allow a greater diversity of agro-pedo-climatic conditions.

LL: The critical zone is structured nationally within OZCAR research infrastructure, a national mirror of the growing European eLTER infrastructure. INRA has invested a lot of resources for decades in ANAEE, another European research infrastructure. How do you see the articulation between these collective efforts?

ANAEE aims at developing experimental approaches, in particular for understanding the effect of climate change on agroecosystems. It is using ecotrons, mesocosms and "in natura" sites. OZCAR proposes an observational approach of hydrosystems, at the landscape level. One could also talk about the Zone Atelier network or of the European ICOS infrastructure on the atmospheric part of the carbon cycle and greenhouse gas fluxes, in which INRA is also very involved. Environmental scientists thus have a wide range of services, and can target one or the other, or several complementary infrastructures to tackle their research questions. Beyond their articulation in terms of scales, approaches, and compartments of the environment, modeling platforms must cross these infrastructures, by simulating the functioning of ecosystems, including agroecosystems. This transversality is facilitated when the same region hosts several complementary infrastructures.

JG: People feel a desire to go back to the territory as an entity of action and decision. Do you think this is a good sign for environmental research and the ecological sensitivity of our stake-holders?

This is a good sign, as re-investing territories is required. We need to take into account the diversity of landscapes and the fact that the economic sectors contribute to shape them and participate in a certain steering of their evolutions. Agroecology aims at making better use of natural regulations within agroecosystems, particularly at the level of landscape and territory. Observatories are places for knowledge acquisition that must serve as benchmarks for these differentiated evolutions of territories.

CRITEX : 2016 hot moments

The **OZCAR research infrastructure (RI) kick-off meeting** was held at the Institut de Physique du Globe de Paris the 6th and 7th of February 2017. About 70 participants attended the meeting that consisted in presentations from each of the national nteworks and observing systems part of the OZCAR RI. Were presented RBV (Réseau des bassins versants) network (G. Nord), H+ (hydrogeological sites) network (O. Bour), CRYOBSCLIM (Cryosphere observatories, including alpine, Himalayan and andean glaciers) network (D. Six), OPE (the ANDRA-related environmental observatory, C. Galy), the SNO Tourbières (Network of peatlands, F. Laggoun), the OSR (Regional Spatial Observatory, T. Tallec and V. Simonneaux), the ADES (piezometers) network (N. Dorflinger). The CRITEX program (L. Longuevergne) and THEIA data center (S. Galle) were also presented. N. Arnaud talked about the European landscape and the recent progresses.

In addition to these presentations, 5 working groups brainstormed on selected cross-cutting themes: scientific grand questions, model-data interface, metadata-databases, instrumentation and experimentation, and future structuration of OZCAR at the national scale. For each of the working groups, facilitators and rapporteurs led discussions that clearly showed a shared enthusiasm to embark on the OZCAR adventure. Beyond the differences in scientific culture and practices of the different communities and disciplines appeared a clear desire to set up a common platform for solving scientific questions that cannot be solved otherwise, and to facilitate collaborations on critical zone science questions. The written summaries of these sessions will serve as a basis for writing the OZCAR position paper.

Kick off meeting off OZCAR, Feb, 6-7, 2017, IPGP, Paris. Front line: from right to left, Isabelle Braud (IRSTEA), Fatim Hankard (INSU) et J. Gaillardet (IPGP), OZCAR direction board.

Critical Zone at AGU 2017

Fall AGU 2017 was placed under the sign of the Critical Zone Science, with, in particular a Union session dedicated to the critical zone, a all-hands meeting and a pre-AGU workshop aiming at organizing CZ international initiatives. At AGU, several talks and posters reported works funded by the CRITEX program or by H + and RBV networks. Our colleague André Revil was awarded fellow of the American Geophysical Union (AGU). This distinction represents an important scientific recognition for this geophysicist specialized in porous media and imaging methods, and in particular for his recent work in hydrogeophysics and biogeophysics.

Future Earth's days in Paris

The French office of Future Earth organized a two day international meeting in Paris on November 30 and December 1, 2016. Christian Valentin represented the critical zone community and showed how the concept of critical zone allows us to approach the nexus "food, water and energy" concept. He developed the issues of nitrate residence times in temperate cultivated soils, of water and soil salinization by excess groundwater pumping in semi-arid zones, and the degradation of the entire critical zone as a result of the use of tropical peat bogs for the production of palm oil for energy purposes. The term nexus, close to the notion of a “hub”, is increasingly used (ANR, H2020, Future Earth, ODD, ...) to emphasize the imperative need for intersectoral and interdisciplinary approaches.

Presentation of the ANR HydroSlide project "High-frequency hydro-geophysical observations for deciphering landslide processes"

HydroSlide is a 4-years bilateral project funded by ANR (France) and FWF (Austria). Its objective is to propose better observations and quantification of water storage and flows in clay-rich landslides by time series analysis of hydro-geophysical measurements. In practice, the project should (1) result in a prototype of continuous time-lapse measurement of resistivity and chargeability (GEOMON-IP) of the porous medium, (2) propose a method for processing and interpreting IP and CS-AMT measurements in the context of continuous landslide monitoring, (3) correlate changes in the electrical properties of media with fluid changes and slope deformation, (4) and propose multi-physical modeling of water flows constrained by hydro-geophysical measurements (assimilation loops).

The project involves five partners (Institute of Earth Physics of Strasbourg and Geosciences Montpellier in France, Austrian Geological Survey and Department of Geophysics of the University of Vienna in Austria, and the Water Resources Section of the Technological University of Delft in The Netherlands) and will fund three doctoral PhDs and one post-doc. Research will be carried out on three hydrological sites (La Valette and Lodève in France, Pechgraben in Austria).

Two ERANET Projects in Montpellier

The OMERE observatory (INRA Montpellier) is involved in two ERANET projects involving the two monitored watersheds (France and Tunisia) of OMERE:

i) The **project "MASCC: Mediterranean Agricultural Soils Conservation under global Change"** funded (2016-2019) by the AO ARIMNET2 aims at identifying sustainable strategies for the conservation of agricultural soils adapted to the different agro-ecosystems of the (Western) Mediterranean region. This project, coordinated by D. Raclot (LISAH), is using highly instrumented catchments in 6 different Mediterranean countries (Spain, France, Italy, Morocco, Portugal and Tunisia), including the French and Tunisian catchments of The OMERE observatory. More information on http://mascc-project.org/

ii) The **project "ASSESS: Impacts and feedbacks between climate and Soil affected by EroSion: costs in terms of carbon storage in Mediterranean regions"** funded by the ERANET-MED AO (2017-2020) aims at better understanding the impact of soil erosion on the organic carbon balance of agricultural Mediterranean landscapes. The consortium consists of French teams (LSCE, ECOSYS, ECOPUB, LISAH), Tunisian (INRGREF / INRAT) and Algerian (Khemis Miliana) teams. This project, coordinated by B. Guenet (LSCE), is based on highly instrumented basins in 6 countries around the Mediterranean, including the French and Tunisian basins of the OMERE observatory.

CRITEX : Upcoming events

The **annual meeting of CRITEX Equipex 2017** will take place at the Escandille (www.escandille.com) resort, in the heart of the Vercors massif, at less than an hour from Grenoble downtown.
It is an important event, after the CRITEX meeting in Rennes in 2016. The 2017 CRITEX meeting will allow us to consolidate the links between the WP leaders and the Critical Zone Observatories. The meeting is organized by the CRITEX direction board and the Institut des Géosciences de l'Environnement (IGE) in Grenoble.
This year, we will focus on the first observations made with the high-frequency instruments, their potential, as well as the achievements or work in progress using the CRITEX instuments.
Invited speakers will be **Pr. Harry Verrecken**, Forschungszentrum Jülich, TERENO Network Manager and **Pr. Louis Derry**, Cornell University, in charge of the steering committee of the US-CZO program and Thierry Lebel from IRD direction.
Prior to the meeting, on May 10th, there will be a presentation of the CRITEX equipments led by IGE teams on the Grenoble campus.
The meeting is open to all provided a registration before April 17. Personnels funded by CRITEX are strongly encouraged to submit an abstract.
https://framaforms.org/inscription-journees-critex-2017-ige-1483375059

The **Goldschmidt conference,** the annual meeting of the geochemical and biogeochemical communities, will take place in Paris from 13 to 18 August 2017. The critical zone will be represented in several sessions. https://goldschmidt.info/2017/. Deadline for submission of abstracts: 1st April 2017.

The **BIOGEOMON** (International Smposium on Ecosystem Behavior) meeting will take place in the Czech Republic from 20 to 24 August 2017. It focuses on the biogeochemical functioning of ecosystems and the stoichiometry of biogeochemical processes at the watershed scale. http://www.biogeomon.cz/. Deadline for submission of abstracts: 10 March 2017.

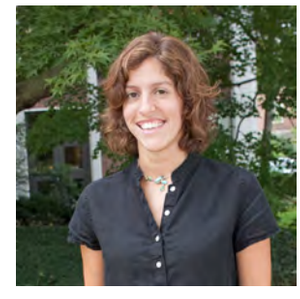
The third **AGU-SEG** meeting on hydrogeophysics in the Critical Zone will be held on the Stanford campus, California this summer July 24-27. It brings together the geophysical communities imaging the critical zone.
http://workshops.agu.org/hydrogeophysics/. Deadline for submission of abstracts on 26 February.

The 11th International **Geochemistry of the Earth's Surface (GES)** meeting will take place in China, Guiyang, from 11 to 16 June 2017. The symposium aims at covering recent advances in Earth science and the prospect of sustainable development. http: //www.datasonline.net/ges2017/ . Deadline for submission of abstracts on April, 14th.

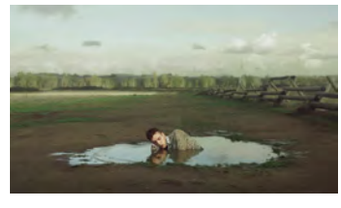
Joint ILTER Meeting: Nantes (France), 2-4 October 2017

France hosts in 2017 the annual international meeting of the Long-Term-Ecological-Research network (ILTER). The meeting will take place at the Westhotel of Nantes. It is co-organized by Zones Ateliers and OZCAR.
This meeting will allow international colleagues involved in the development of the European eLTER infrastructure to meet. The philosopher Bruno Latour will give a talk and explain his vision of the new relationships between humans and nature in the "new climate regime". We hope to see a broad participation in this meeting which will mark an important milestone in the co-construction of a national mirror to the ESFRI eLTER project.
The scientific committee brings together Vincent Bretagnolle, Marie Noëlle Pons, Hervé Fritz, Paul Blois and Jérôme Gaillardet.
Webpage: https://rza.sciencesconf.org/
Deadline for registration: July 21, 2017.

The **Darcy Lecture** (sponsored by the NGWA) will be given in 2017 by Kamini Singha, professor in the department of Geology and Geological Engineering and co-chairman of the "hydrologic science and Engineering program" at the Colorado School of Mines.
Her French tour will be marked by two importants lectures: June 1st, 2017 in Rennes and June 2nd at UMPC, Paris (place and timeslot to be announced).
Kamini Singha will develop her thinking about the role of water in the Critical Zone and how hydro-geophysics is inventing relevant tools to study the processes controling its circulation and availability in the sub-surface.
Contacts : damien.jougnot@upmc.fr, ludovic.bodet@upmc.fr, laurent.longuevergne@univ-rennes1.fr



The Critical Zone on stage



Published jointly in the journal Libération and the Revue du CNRS, an article by J. Gaillardet and N. Arnaud on the critical zone and its scientific vision.

http://www.liberation.fr/debats/2016/06/30/une-zone-si-critique_1463172

"Nothing like the scene to attempt a thinking experiment standing not on the Globe, but in this "critical zone" of which the scientists speak." (Bruno Latour). At the Nanterre Amandiers theater, November 18th, 2016: INSIDE, a conference-show by Bruno Latour and Frédérique Aït-Touati. Directed by: Frédérique Aït-Touati. With Bruno Latour. Pictures and videos by Alexandra Arènes, Axelle Grégoire, Sonia Lévy. Lights by Rémi Godfroy. Sound by Eric Broitmann, with the support of IRCAM.

RBV and H+ networks: news and views

Annual RBV meeting : "RBV days"

In 2016, the annual RBV Network meeting took place at Irstea Lyon-Villeurbanne, 19th and 20th of September.

Day 1, the meeting involved two invited speakers (“Grands Témoins”) Jean Braun from GFZ Potsdam and Agnès Ducharne from UMPC/IPSL that presented their work on “geomorphological models of the Critical Zone” and “Modeling the Critical Zone in climate models” respectively. In the afternoon, a field visit was organized in the instrumented periurban catchment of Yzeron. This is one of the rare urban and peri-urban sites in the RBV network (see below). A friendly diner in a famous brasserie from Lyon was organized in the evening.

Day 2, the preliminary results showed the importance of this program aiming at fostering multidisciplinary and multi-observatories research in the network. In the perspective of building bridges with the LTSER community represented by the Zones Ateliers Network, Jérôme Le Coz, from the Zone Atelier Basin du Rhone presented interesting results acquired by the “Observatoire des Sediments du Rhône, OSR” (Rhone river Sediment Observatory), highlighting the scientific common interests shared by the Zone Atelier and RBV networks. Collaborations already exist for example between Hybam (Amazon Basin monitoring program) and OSR that could clearly be extended and strengthened. Finally, a meeting of the steering committee of RBV was held in the afternoon where the European aspects were particularly discussed. The presentations and discussion reports are available on the intranet of RBV website (http://portailrbv.sedoo.fr/).

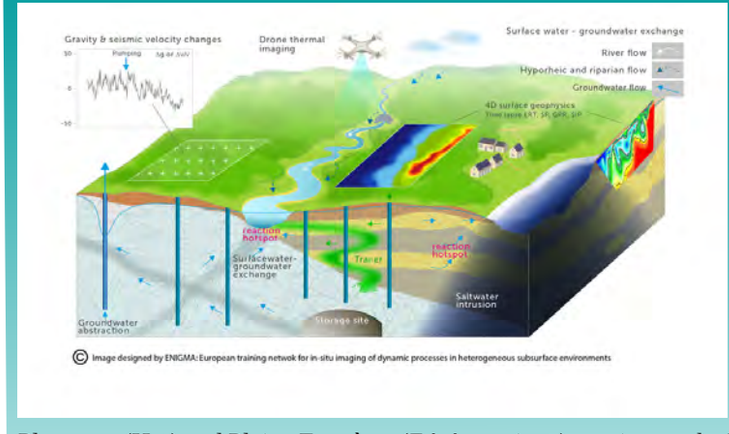
The 2016 annual meeting of the RBV network in Lyon (hosted by IRSTEA). Presentations by the two invited speakers (Agnès Ducharne, UMPC, left and Jean Braun, GFZ Potsdam, right). Journées du réseau RBV à Lyon (IRSTEA). Field visit in the Yzeron urban catchment (led by Flora Branger, middle). Luère Pass, Sept. 9th, 2016.

The Yzeron catchment is one of the experimental site of OTHU (Terrain Observatory in Urban Hydrology), itself incorporated into the ZABR (Rhone Basin LTSER). It is impacted by the growth of Lyon city, since the XXth century. This implies an increase of impervious surfaces in the downstream urbanized area, but also from satellite villages. There is also a decrease of agricultural activity. In the catchment, rain water is generally collected using combined sewer networks, collecting both waste water and rain water. In case of overload of the network, water is diverted to the river course via stormwater overflow devices (SOD).

Research questions addressed in the catchment deal with the impact of urbanization on the hydrological regimes, flooding in the downstream part of the catchment (Oullins city), the impact of rain water overflow from SOD on river morphology (incision, accumulation of sand) in river courses that are often intermittent, water quality (pathogen bacteria in particular) and the ecological wealth of small periurban river courses, in relation with their increasing use for recreation.

Initially focused on the Chaudanne sub-catchment at Grézieu-la-Varenne (2.7 km2), the experimental set up was extended since 2007 to the whole Yzeron catchment (150 km²). Observations collected in the catchment allow addressing the following research questions:

- Improve rainfall knowledge in this periurban zone
- Improve our knowledge of the water cycle in periurban areas, in particular through an integrated model including sewer networks



The H+ network of hydrogeological sites

In 2016, the H + observation network played an important role at the international level by being awarded the H2020 "Innovative Training Network", ITN project, ENIGMA (European Training Network for In situ imaGing of dynaMic processes in heterogeneous subsurfAce environments). This Marie Curie project will fund 15 doctoral PhDs based on the H + sites and their European equivalents, as well as 5 workshops and 1 summer school over the next 4 years (2017-2020). This is an important success considering the very competitive nature of this call at the European scale. ENIGMA is the only project chosen among the 30 ITN projects submitted this year that the CNRS as an institution is coordinating, all scientific themes combined.

In 2016, the actions of the H + teams in the framework of CRITEX project were as follows: gas tracing (WP 7.3 and 8.1) at the Agrhys (RBV), Ploemeur (H +) and Pleine Fougères (ZA Armorique), tracing on the Ploemeur site with radar tracking (WP 7.3), spatially distributed measurements of temperature by optical fiber (WP3) at the Orgeval (RBV), Agrhys (RBV) and Ploemeur (H +) sites, hydraulic tomography by periodic loading (WP 7.1 and 7.2) at the Ploemeur site, hydrogeophysical imaging by electrical resistivity tomography (WP 6.3), near-surface seismic Vp / Vs (WP 6.1) and proton magnetic resonance (W6.2) at the LSBB site, and approximation of gravimetric activities and inclinometry in the LSBB within the framework of the MIGA and CRITEX teams. H + also continued its scientific activities, including the organization of a prospective workshop on hydrogeophysical imaging in collaboration with the METIS laboratory (Paris, June 29-30, 2016), the organization of several sessions at the conference of the IAH (Montpellier, 26-29 September 2016) on Hydrogeophysics, Hydrogeodesis or even distributed measurements of temperature by optical fiber, and the organization of a hydrogeological workshop in Hyderabad (1-3 December 2016).

Monitoring landslides: a joint OMIV-CRITEX project....

Fluid circulation or long-term fracture alteration: which mechanisms control the behavior of large slope deformation? By Catherine Bertrand (Chrono-Environnement) and Jean Philippe Malet (EOST).

Landslides react in different ways to water-rock interactions and hydro-meteorological forcings depending on the lithologies and internal slope structures (fractures, heterogeneities). This is another application domain and methodological development for the Critical Zone community.

During Spring 2016, a large-scale instrumentation campaign was carried out on the unstable slope of Séchilienne (Romanche valley Alps) to quantify the interactions between precipitation, fluid flows in fractures and short and long-term destabilization of the rock massif.

The multi-technique instrumentation was carried out over 6 weeks with high frequency signal acquisition in order to document and quantify the role of fluids on the deformation of the slope in response to rain events. Changes in water storage and fluid circulation were studied by analyzing the spatial and temporal variation of the electrical resistivity of the subsoil (time-lapse electrical resistivity tomography on four profiles) and hydro-chemical properties (electrical conductivity, temperature, discharge, major ions and strontium isotopes). Slope deformation was quantified at several scales by analysing time series of terrestrial interferograms (GB-In-SAR) acquired every 10 min and by terrestrial laser scanning operated in continuous mode.

This scientific campaign associated several CRITEX teams (Laboratoire Chrono-Environnement / LCE, School and Observatory of Earth Sciences - Strasbourg / EOST, Laboratory of Hydrological and Environmental Transfers / LTHE), the Institute of Earth Sciences of University of Lausanne and the IRIS-Instruments geophysical company. It also benefited from the technical support of CEREMA / Lyon.

All the data acquired will be exploited by Pierre Nevers, who just started his PhD at Laboratoire Chrono-Environnement (Besançon) in collaboration with the Institut de Physique du Globe (Paris) and the School and Observatory of Earth Science (Strasbourg). The PhD aims at proposing a model for interpreting the links between fluid flow, fluid chemistry, deformation and alteration of this unstable slope.

This work is conducted under the flagship of the OMIV National Observation Service, which is monitoring four representative landslides in the French Alps in hard rocks / soft sediments. On each site, OMIV continuously provides open access to recordings of landslide kinematics, seismic response, and, recently, the hydro-geochemical characteristics of the fluids circulating in the massif (OMIV) http://eost.u-strasbg.fr/opomiv)

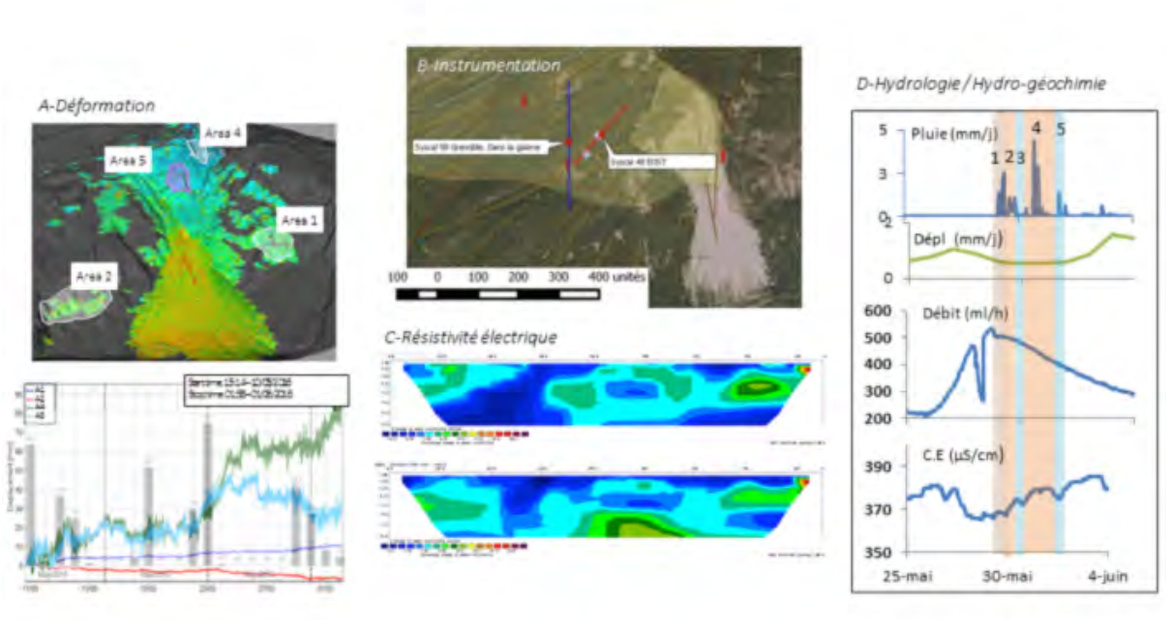


Figure: High-frequency monitoring of the hydrology and deformation of the Séchilienne unstable slope (Isère, France)
A- Spatial and temporal identification of several kinematic behaviors within the slope
B- Localization of two of the four profiles of electrical resistivity.
C- Fluid circulation signal in a fracture with a rapid transit: 4h after the beginning of the first rain event (first profile); 3h after the beginning of the second rain event.
D- Identification of the heterogeneous functioning of the drainage system (permeable volume / low permeability volume) with rapid transit (1-reaction time of the aquifer 20H, 2- piston effect with flushing of a more mineralized water, 3- Infiltration water inlet (dilution), 4- Effect of piston flows of more mineralized water due to a mobilization of a different or greater volume of water, 5- Contribution of the infiltration water of the second rain event (dilution).

WHAT iS CRITEX ?

CRITEX (https://www.critex.fr/) is an equipment project "of excellence" (EQUIPEX) funded by ANR within the framework of French governement program "Investment for future". It aims at developing and purchasing shared innovative instruments and methods to explore and monitor the Critical Zone, this thin Earth's envelope lying between the lower atmosphere and the unweathered rocks, supporting ecosystems and human societies. CRITEX is co-supported by the RBV and H + networks, both national infrastructure observatory networks (SOERE), certified by Alliance ALLENVI. CRITEX is one of the 36 EQUIPEX projects selected in the second round. It is, along with CLIMCORE and RESIF, one of the national projects that CNRS-INSU manages. CRITEX received € 5 million in phase 1 (equipment) and € 2 million in phase 2 (operation). The project started on 01/09/2012 for a period of 88 months. CRITEX kickoff meeting was held in Paris the 28 and 29 October 2012, the funding agreement was signed by the CNRS the 27 February 2013. Grant agreement N°. ANR-11-EQPX-0011 between ANR and the CNRS Regional division (DR3) was signed on March 28, 2013. The reception of the funds by the CNRS took place on April 15, 2013 and the funds were installed for year 1, tranche 1, on 22 May 2013. Funds are transferred from ANR to DR3, which in turn, transfers it to the various CNRS Regional Divisions involved in the project or to the research institutions other than the CNRS. This is done according to the timetable signed by the Prime Minister. The consortium agreement binding all CRITEX partners and specifying their contributions in terms of own knowledge was signed on 28 July 2014. The end of Tranche 1 will be effective on 30 July 2017. The last plenary meeting of CRITEX consortium (WP leaders and scientific teams of the RBV and H + observatories) was held in Rennes on 21 and 22 January 2016.

All CRITEX publications should include the following acknowledgments: "This work has been supported by research grants from the ANR project CRITEX ANR-11-EQPX-0011".

HIGH FREQUENCY MEASUREMENTS IN THE CRITICAL ZONE

WP1.1. Microwave scintillometry (J. M. Cohard, Hélène Barral, LTHE).

A protoptype of microwave scintillometer has been developed to explore the turbulent exchanges between soil surface and atmosphere. It has been set up on the Orgeval basin and monitoring since March 11th 2016 in parallel to classical infrared instruments. Data is recorded at the kHz frequency to allow (1) a clean signal extraction by digital filters and (2) qualification of the prototype data. The inversion codes to link raw data (signal variance) to the physical structure parameters Cn2 (optic refraction index), CT2 (temperature) and Cq2 (specific humidity) as well as actual evapotranspiration, sensible heat and latent heat fluxes, are also in the finalization phase. From August 15th to 17th 2016, days were cloud-free on the Orgeval basin, leading to a smooth net radiation curve. The dynamic of CT2 is larger than CQ2. Following a 6 mm rainfall on August 18th modifies the response of the scintillometers: as available energy is decreasing, convection and turbulent activity is also affected.

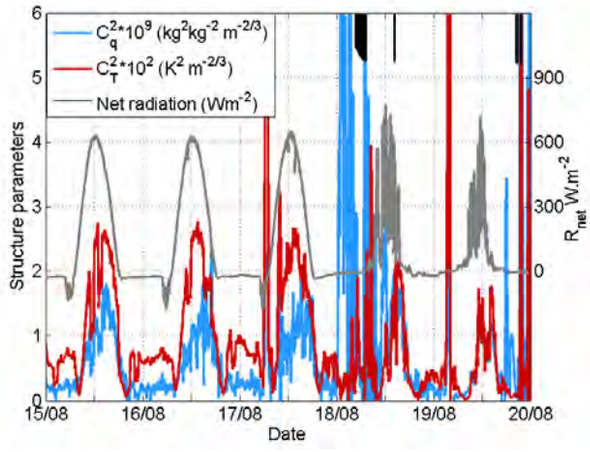


Figure: Structure parameters for temperature (CT2, red) and specific moisture (CQ2, blue) for a 5 day period in August 2016. Both time series are scaled for comparison. They are superimposed with net radiation (gray) and precipitation (black).

WP1.2. Surface-atmosphere fluxes from eddy covariance and infrared scintillometry measurements (B. Cappelaere, F. Arpin-Pont, J. P. Chazarin, J. Demarty from UMR HSM, L. Prévot de l'UMR LISAH from INRA et J. M. Cohard from UMR LTHE).

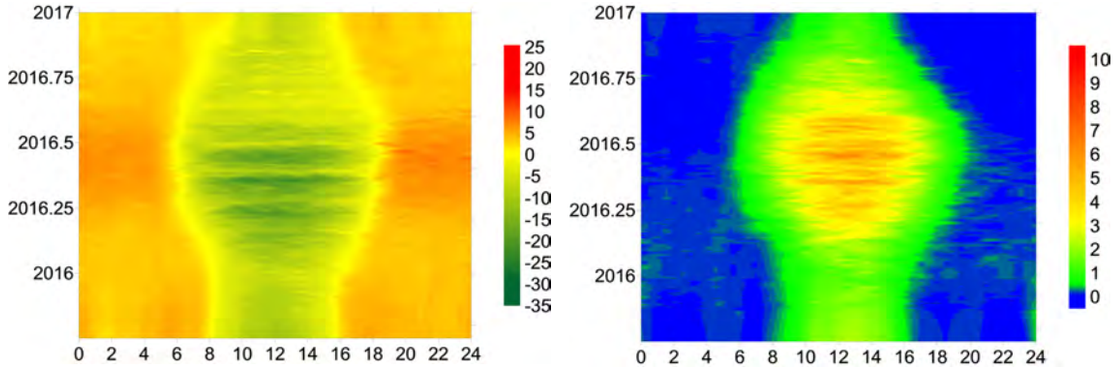
Teams involved in the observatories :

AGRHYS (UMR SAS): C. Flechard, O. Fovet, Y. Hamon, M. Faucheux; ORACLE (IRSTEA Antony): G. Tallec, P. Ansart, A. Guérin.

Main instruments to measure exchange fluxes (H_2O, CO_2, energy) between the surface and the atmosphere were deployed in 2014-2015 (see CRITEX newsletter NL # 3, March 2016). Therefore, 2016 was the first full year with continuous measurements at the Orgeval (ORACLE) and Naizin (AGRHYS) sites. On the Orgeval observatory, a long-range (~ 5 km) infrared scintillometer is associated with both an eddy covariance tower installed in an agricultural plot (corn crop in 2016) and a complementary radiative balance station sampling another crop. The IR scintillometer is also coupled to the microwave prototype scintillometer deployed as part of WP 1.1. On the Naizin observatory, an eddy covariance station monitors a permanent grassland field. The Orgeval setup experienced several breakdowns (sensors, power supply), which required factory returns and caused operation disruptions. In Naizin, since instrumental installation in the autumn of 2015, the recorded data is almost gap-free. Processing tools to estimate fluxes from raw data have been developed, and field observations have been interpreted as time series of energy and matter (H_2O and CO_2) fluxes.

The figure below highlights the temporal "fingerprints" of carbon dioxide (left) and water (right) fluxes in the Naizin prairie field, representing its seasonal variation (vertical axis, from autumn of 2015 to the end of 2016) of the daily cycle (horizontal axis). Particularly noteworthy are the effects of periodic grazing, especially in spring and early summer, as well as the impact of a dry period in late summer (limited photosynthesis and evapotranspiration), also evidenced by the vegetation index time series (not shown).

Training of the ORACLE team is still active and has been extended to new engineers and researchers in charge of the observatory. The local team has now a greater autonomy to lead instrumental operations and data processing.



Temporal fingerprints of carbon dioxide (right, in µmol m-^{2} s-^{1}) and water vapor (in mmol m-^{2} s-^{1}) fluxes in the Naizin prairie field (positive fluxes from surface to atmosphere)

WP2.1. Hydrogravimetry, the weight of water (J. Hinderer, EOST).

Three CRITEX iGrav superconducting gravimeters were delivered to the Strasbourg Observatory in July 2016. These "portable" superconducting gravimeters were set up in parallel for a test period with two Observatory-type superconducting gravimeters already in operation on site with the great help of Nolwen Portier (Engineer in geotechnical instrumentation financed by CRITEX). The intercomparison of these five gravimeters at the same place and over the same period will provide a unique and substantial dataset on a metrological point of view. Instruments quality is now validated; they will therefore be installed on selected hydrological observatories. A first gravimeter will be set up during spring on the OHGE Strengbach observatory located in the Vosges Mountains. A second one will be installed at the LSBB (low-noise underground laboratory) in Rustrel near Avignon as part of a joint project between the CRITEX and MIGA Equipex projects (gravitational antenna based on atomic interferometry). The CRITEX gravimeter will be located on the summit part of the LSBB, approximately 400 m above the iOSG gravimeter of MIGA. Both will measure temporal changes in the vertical gravity gradient, which will be linked to water infiltration into the karst of Fontaine du Vaucluse.

iGrav superconducting gravimeter (during a liquid helium filling on the left and installed on a pillar at the Strasbourg Gravimetric Observatory).

Hinderer, J., Hector, B., Mémin, A., & Calvo, M., 2016. Hybrid Gravimetry as a Tool to Monitor Surface and Underground Mass Changes, International Association of Geodesy Symposia, DOI 10.1007/1345_2016_253, © Springer International Publishing Switzerland

Hinderer, J., Hector, B., Séguis, L., Calvo, M., Boy, J.-P., Masson, F., Urbain, A., Ferhat, G., Bernard, J.-D., Littel, F., Viville, D., & Pierret, M.-C., 2016. Water storage changes in hard-rock basement areas using hybrid gravimetry; Results from tropical and temperate settings, 43rd IAH Congress, Groundwater and society: 60 years of IAH, Montpellier, September 2016.

Genthon, P., Hinderer, J., Mouhouyouddine, A., Hector, B., Ferhat, G., Yameogo, S., 2016. Basement aquifer tests monitored by gravimetry : a sensitivity study, 43rd IAH Congress, Groundwater and society: 60 years of IAH, Montpellier, September 2016.

WP2.2. Hydrogeodesy: Tiltmeters as a tool for multi-scale fractured reservoirs characterization (J. Schuite, Q. Courtois, L. Guillaumot, L. Longuevergne, O. Bour, Géosciences Rennes).

For hydrogeodesy, 2016 was dedicated to synthesizing, interpreting and evaluating all the surface deformation measurements collected at the Ploemeur (H +) site. Datasets are either issued from continuous records since 2006 (with long-base and GNSS tiltmeter stations) or from hydromechanical field experiments (short-base tiltmeter and mapping of vertical displacements of the soil by optical leveling). This significant dataset is mainly interesting because it covers a wide range of fractured reservoirs' mechanical and hydrogeological phenomena occurring at different space and time scales.

At the scale of 1 to 10 m, short-base (or pendulum) tiltmeters were deployed as part of an experimental and methodological development. The objective was to study the hydromechanical behavior of fractured networks (Fig. below) with an integrative vision of their response to low amplitude hydraulic perturbations. This was closely linked to the work of WP7.2; the reader can refer to the relevant paragraph.

At the ~100m scale, previous works demonstrate the interest of surface geodesy methods (tiltmeters and leveling) for imaging of hydraulically active structures from surface observations, such as sub-vertical faults (Schuite et al., 2015). Since then, a 3D numerical model revealed that the surface tiltmeters are particularly sensitive to contrasts of mechanical and hydrodynamic properties between the fault and the surrounding matrix. More surprisingly, we estimate water exchanges between fault and matrix by interpreting the ratio between tilt and piezometric head during a short hydraulic test of several hours. These results are gathered in an article submitted to Water Resources Research (Schuite et al., Submitted), and highlight tiltmeters as a powerful tool for fractured media hydrogeology.

At the reservoir scale (~ km), multi-annual tilt time series correlate well with quasi-periodic seasonal piezometric variations, except that the phase of tilt is 1 month in advance. These observations show that at this scale, the tiltmeters are sensitive to flux, which is of major interest for the problems associated with recharge. Among other studies, Quentin Courtois's M2 project dealt with the interpretation of these long-term signals. The results are very convincing since a very simple semi-analytical hydromechanical model allows description of both tilt and piezometric amplitude as well as the phase shift. It also shows that tiltmeters are sensitive to the recharge processes (local versus diffuse). Together with GNSS data, a conceptual model of lateral water transfers in fractured reservoirs was developed at seasonal time scales, which is built up on surface observations only. A future step will be to inverse deformation data and recover aquifer recharge.

All these works are gathered in the PhD dissertation of Jonathan Schuite (financed 50% by CRITEX, 50% by the Brittany Region) defended on sucessfully December 2nd, 2016.

Schuite, J., L. Longuevergne, O. Bour, F. Boudin, S. Durand, and N. Lavenant (2015), Inferring field-scale properties of a fractured aquifer from ground surface deformation during a well test, Geophysical Research Letter, 42, 10,696–10,703, doi:10.1002/2015GL066387

Schuite, J., L. Longuevergne, O. Bour, T. J. Burbey, F. Boudin, N. Lavenant, and P. Davy (soumis), Understanding the hydromechanical behavior of a fault zone from transient surface tilt and fluid pressure observations at hourly time scales, Water Resources Research.

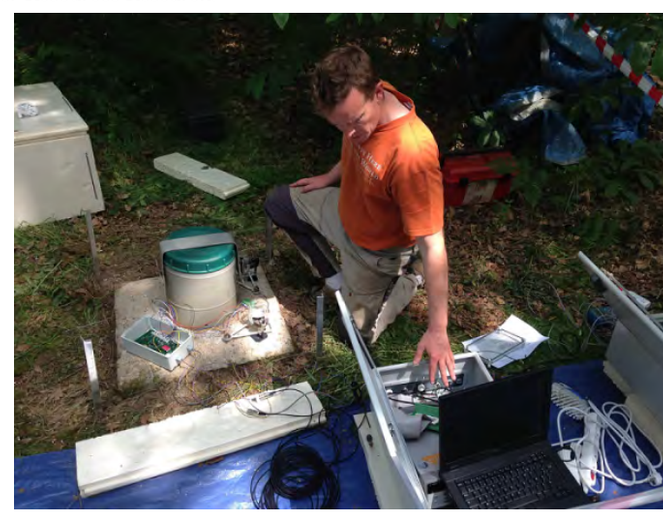
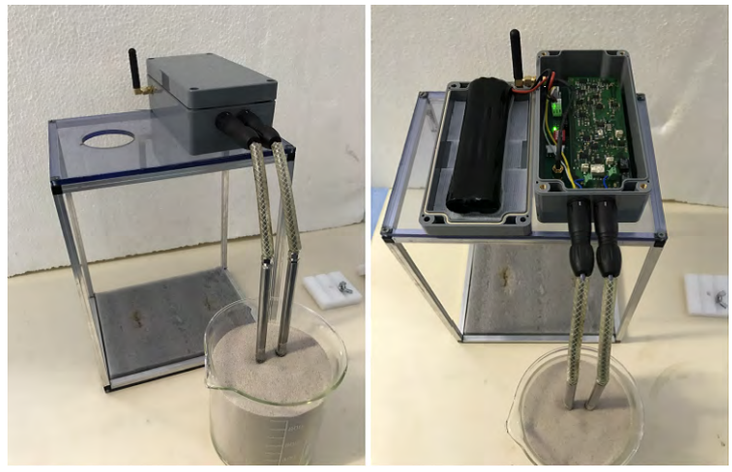


Figure: Setup of a hydromechanical experiment with periodic hydraulic solicitation of deep fractures and surface deformation measurements with pendular tiltmeters (between well and geophysicist's foot). Credit: J. Schuite.

WP2.3. Integrated soil moisture, salinity and temperature sensor HYMENET (X. Chavanne and J. P. Frangi, IPGP-Université Paris Diderot).

Developments are ongoing to correct - or at least to limit - any possible instrumental bias in the measurements. The electrode electrical contact has been improved; the temperature sensitivity of the electronic circuit has been reduced from 1000 ppm per degree to 200 ppm per degree. A simplified probe was also designed, benefiting from the experience and feedback of the first prototype. The new probe will be better adapted for field studies and other applications. The new measurement principle is identical (single channel probe), the geometry, though is updated and can moved at different depths (up to 70 cm) using extensions. The probe design minimizes flow perturbations (horizontal offset of the electronic device, same diameter for both electrodes and extensions). The electronic control and communication circuit is identical as previous probes: high acquisition resolution (16 bits), long time storage, basic data processing...with the possibility to operate in a wireless network. The autonomy is expected to be larger than 4 months at the sampling frequency of 15 minutes.



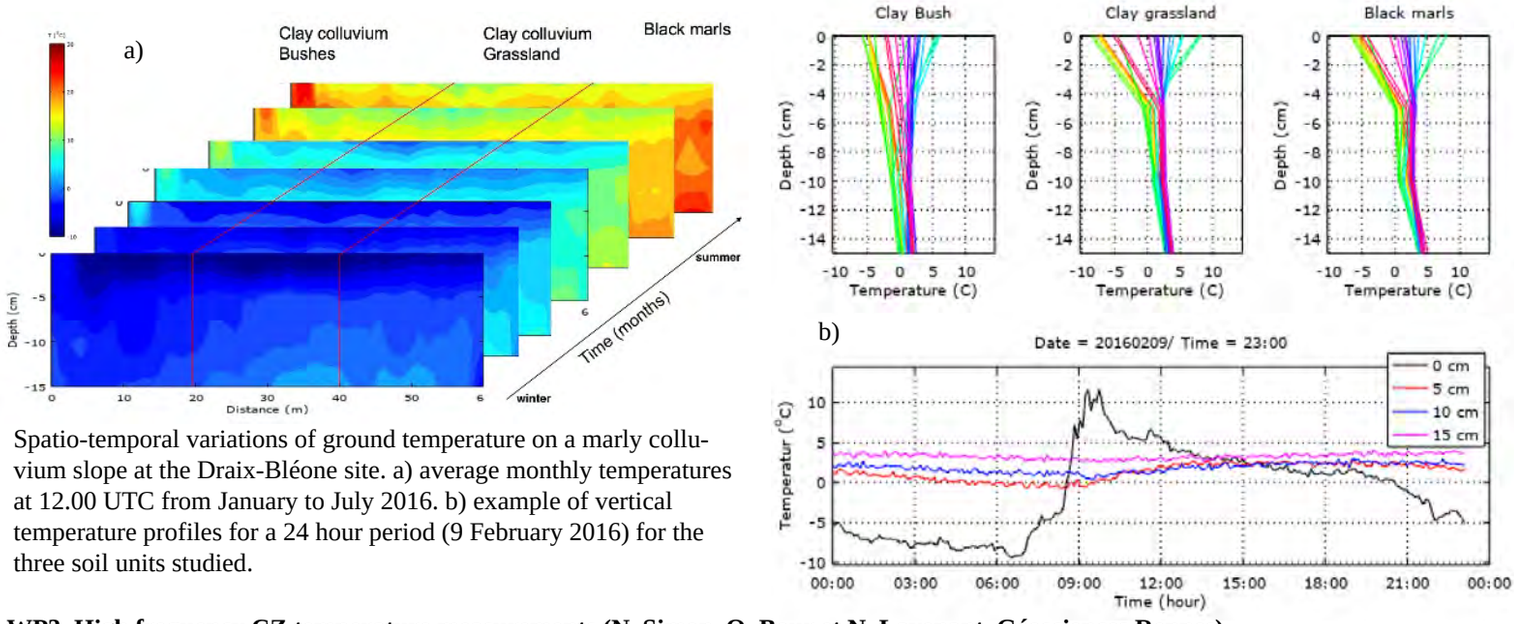
Simplified CRITEX moisture probes. Waterproof housing - with integrated circuits and battery, extensions and electrodes (in sand). Credit Oleg Antipov.

WP3. High frequency CZ temperature measurements. (J. P. Malet, EOST)

Since December 2015, a permanent observatory of water and energy fluxes by active and passive measurements of soil temperature through optical fiber is operated on the clay-shale slopes of the Draix-Bléone Observatory. The distributed measurements of temperature gradients in the near-sub-soil (up to -20 cm) are used to quantify the hydrological response of the slope (water storage and flows) to hydroclimatic forcings.

The measurement system is fully operational with an observation rate close to 97% achieved by efficient telemetry. Since June 2016, Kusnahadi Susanto, PhD student at EOST/University of Strasbourg, has been working on the interpretation of this data in collaboration with the Technological University of Delft (Netherlands). The first results indicate a differentiated response of the three soil facies to natural radiation and rainfall. The young researcher is currently developing data assimilation loops using the HYDRUS model to estimate spatial variations of water contents. A temporary campaign of time-lapse resistivity measurements will be conducted in spring 2017 to constrain the interpretations. This work will be presented at the next EAGE/DGG workshop 'Fiber Optics Technology in Geophysics' and at the EGU General Assembly 2017.

A similar long-term observation site will be deployed in 2017 at the Lodève site in order to quantify variations in surface water content around some boreholes and to interpret complex resistivity measurements (PIs) within the ANR HydroSlide project and the PhD project of Myriam Lajaunie which started in January 2017.



Spatio-temporal variations of ground temperature on a marly colluvium slope at the Draix-Bléone site. a) average monthly temperatures at 12.00 UTC from January to July 2016. b) example of vertical temperature profiles for a 24 hour period (9 February 2016) for the three soil units studied.

WP3. High frequency CZ temperature measurements (N. Simon, O. Bour et N. Lavenant, Géosciences Rennes).

Observatory teams: Kerrien-Kerbernez: M. Faucheux, O. Fovet and Z. Thomas; Orgeval, A. Rivière, A. Berrhouma and N. Flipo

In 2016, at Géosciences Rennes, the main objective was to develop different experimental setup and monitoring strategies to measure distributed temperature by fiber optics technology, focusing on the objective to characterize and quantify groundwater-river exchanges and their evolution linked to the hydrological cycle dynamics. On the Kerrien observatory (ORE AgrHys, RBV network), the long-term fiber optic monitoring revealed differential catchment behavior. Indeed, the increase in precipitation and piezometric levels at the beginning of January 2016 results in an increase in underground flows contribution to the riverbed. This change is well evidenced by specific sediment zone thermal anomaly, reflecting localized warm groundwater exfiltration. Different data processing methods have been evaluated to estimate flow velocity evolution in time. The optic fiber cable installed since December 2015 was removed in July 2016, after 7 months of acquisition. A new instrumental method was also developed to better quantify groundwater-river exchanges considering the localized thermal anomalies. The main innovation consists in applying the so-called active method, complementary to the passive method, still based on the simple optical fiber temperature system. It relies on the injection of an electric current into the steel reinforcement of the fiber which will lead to an increase in the fiber temperature. This temperature increase depends on the injected current electrical power, the thermal properties of the medium but also the fluid flow velocity dissipating the heat.

WP3. (follow-up)

The tests were very conclusive, highlighting the capacity to measure flow velocity ranging from 8.10-7 to 6.10-5 m/s with high sensitivity. This is consistent with the expected velocity range in sediment from the riverbed. This promising work is currently being evaluated and should be continued during 2017 to develop this methodology.

Figure: DTS units installed at the site of Kerrien (Agrhys CZO, Brittany) for a long-term temperature monitoring (7 months). Right panel: installation of fiber optic cable along the Avenelles basin riverbed, Orgeval CZO, Ile de France.

In October 2016, a 1500-m optic fiber cable was also installed on an Avenelles basin river (Orgeval basin, RBV CZO) in collaboration with the MINES Paris-Tech team. The objective is to follow the temperature evolution along the riverbed on the long term. These distributed temperature observations, coupled with the point MOLONARI devices (MOnitoring LOcal des échanges NAppe-RIvière, groundwater-river exchange local monitoring), should contribute to establish a thermal balance in the hyporheic zone and to characterize the hydrological functioning and groundwater-river exchanges at different scales along the catchment.

Finally, within the framework of the French-Québec "Resource and Societies" joint laboratory (LIA France-Quebec RESO), distributed optical fiber temperature measurements were carried out in Québec, in collaboration with INRS (Canada). INRS team has developed a heating cable to determine the subsoil thermal conductivity by thermal recovery tests (TRT). The optical fiber enables to obtain a distributed temperature measurement in thermal boreholes and thus, to validate methodology, in particular the use of this heating cable for geothermal applications.

WP4.1. RIPLE: Extreme event hydro-sedimentary monitoring. (Y. Michielin, G. Nord and M. Estèves, IGE Grenoble).

In 2016, the RIPLE development significantly progressed thanks to the recruitment of Yoann Michielin as an engineer. The River Platform for Monitoring Erosion (RIPLE) has been finalized in order to allow continuous and high frequency monitoring (~ 10 min) of water and sediment fluxes (fine and coarse) in mountain rivers. The scientific objectives are: (i) to contribute to the estimation of fine and coarse sediment mass balance; (ii) to investigate the fine sediment physical properties (size, shape, composition) in order to provide information on their origin, erosion conditions, transport and sedimentation processes in the river and (iii) to study their potential to transport other substances (nutrients, metals, microorganisms ...). For the platform design, priority has been given to non-intrusive instruments because of their robustness. The basic platform prototype (Fig. a) integrates the following instruments operated by a single acquisition system (Fig. b): radars for measuring surface water level and velocity, turbidimeters, conductivity probe, Hydrophone (Geay, 2013), digital cameras, automatic water samplers and echo sounder. Other instruments are progressively added, such as a SCAF (Wendling et al., 2015), an acoustic Doppler profiler and a spectrophotometer. A wireless telecommunication has been set up to allow remote platform operations and data transmission. The RIPLE platform has been designed to facilitate use and maintenance in difficult field conditions. The user interface allows data control, remote configuration and the sending of alerts (SMS, email). The flexibility of this in situ installation and the long-lasting power autonomy enable to move easily the platform from one site to another. An extended summary (Michielin et al., 2017a) describing the platform was accepted for the conference "Hydrometry 2017 Measurements and Uncertainties". In September 2016, the platform was installed on a bridge of the Romanche River at Bourg d'Oisans (45.1159 ° N, 6.0135 ° E) for a 1-year test period (Fig. a and b). This site was chosen for its scientific value and proximity to Grenoble. It is a mountain river with sediment transport by both bedload and suspended load, with various sediment sources. It is also isolated with an existing EDF hydrometric station (stage-discharge rating curve available). A few floods were observed during autumn 2016 (Fig. c). First results on surface velocity measurements, discharge estimation, turbidity measurements and detection of bedload occurrence will be presented at EGU 2017 (Michielin et al., 2017b).

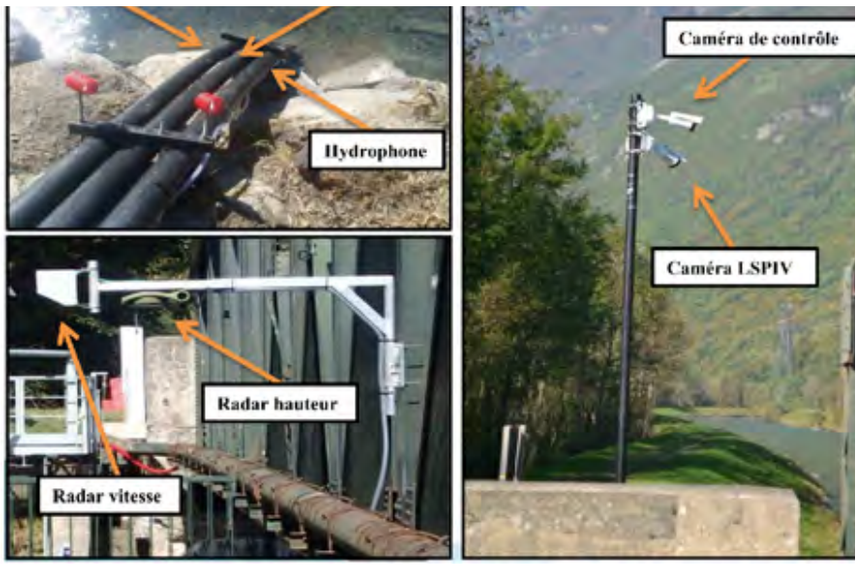


Figure a: Instruments deployed in the basic RIPLE platform prototype.

WP 4.1. (follow-up). Yoann Michielin's contract has been extended until May, 31st 2017. He will be able to finalize the platform and software interface development, to strengthen the data archiving, to write a complete documentation in order to ensure the transmission of knowledge to the IGE technical department and to write a scientific communication to enhance the work carried out. A first 3-day mission (October 2016) in collaboration with J.M. Martinez from HYBAM observatory (Fig. d) allowed a first characterization of the water optical properties of the Isère and Romanche rivers using radiometers and spectrophotometers. Another campaign is planned in spring 2017 to carry out a continuous monitoring during a few months in order to acquire data under variable suspended sediment composition and concentrations.

Fig. b: Solar panel, electronics (including acquisition system, Campbell CR6) and battery

Fig. c: Photo taken by the control camera on the site of the Romanche river on October 14th, 2016 at 14:07:35

Fig. d: Measurement of optical properties of water using radiometers.

Geay T. (2013) Mesure acoustique du transport de sédiments par charriage dans les rivières. Thèse de doctorat, Université Grenoble Alpes, 163 p.
Y. Michielin, G. Nord, M. Esteves, C. Aubert, P. Belleudy, J. Bois, C. Coulaud, T. Geay, N. Gratiot, C. Legout, B. Mercier and J. Némery, 2017a. Développement d'une plateforme de suivi hydrosédimentaire. Hydrométrie2017 : mesures et incertitudes, Lyon, 14-15 mars 2017.
Y. Michielin, G. Nord, M. Esteves, T. Geay, A. Hauet, 2017b. River Platform for Monitoring Erosion (RIPLE) in mountainous rivers, submitted to HS9.1/GM4.9/SSS12.22, EGU General Assembly 2017
Wendling V., Gratiot N., Legout, C., Droppo I. G., Coulaud, C., Mercier B. (2015). - Using an optical settling column to assess suspension characteristics within the free, flocculation, and hindered settling regimes. Journal of Soils and Sediments 15, pp 1991-2003.

WP4.2. Two new CRITEX "River Lab" equipments. Towards a new era of high-frequency chemical analysis in river. (Paul Floury, Gaëlle Tallec, Arnaud Blanchouin, Patrick Ansard, IRSTEA Antony and Laure Cordier, Jérôme Gaillardet, IPGP).

The "chemical house" has been renamed the "River Lab.". The prototype, installed at the Avenelles station on the ORACLE observatory (IRSTEA), has continued the acquisition of chemical composition data at the rate of an analysis every 40 minutes in 2016. Some breakdowns have occurred which have led us to modify the river sampling system. The exceptional floods of spring 2016 resulted in very high flows (see pictures below), exceeding 10 m3/s, was recorded by the River Lab. During a rain event, almost all concentration values dropped (see Fig.), suggesting dilution by the newly added water. However, the examination of the concentration-discharge relationship shows that dilution is not the single process (i.e. a Q^{-1} relation), because the concentration does not fall as much as the flow. This phenomenon of attenuation, called "chemostasis" by hydrogeochemists, proves that various water storage compartments are solicited during a flood.

The River Lab allows us the acquisition of unique databases that, when observed in detail, actually show hysteresis relationships between concentration and flow. Their careful analysis will allow us to enter the backstage of the potamochemical orchestra.

Laure Cordier, an assistant engineer in chemical analysis at IPGP, has been welcomed into the River Lab maintenance team. Laure's mission will be to take in charge the chemical maintenance of the River Lab ionic chromatography along with Patrick Ansart.

Beside, in 2016, two additional River Labs were purchased. A competitive market was set up with the help of the CNRS Paris Villejuif Delegation and the competence of Christophe Mariaud. Endress + Hauser Company was the only one to respond to the call and the contract was signed on December,12th 2016. The two new river labs will be set up on the Strengbach observatory (contact Marie Claire Pierret) and on the Naizin observatory (contact Ophélie Fovet) next spring and summer. This operation was co-funded by the INSU (SIC division) and the help of Patrick Régnier, Head of Endress + Hauser Solution Development. As compared to the Orgeval prototype, the new stations will carry out continuous dissolved silica and alkalinity analysis.

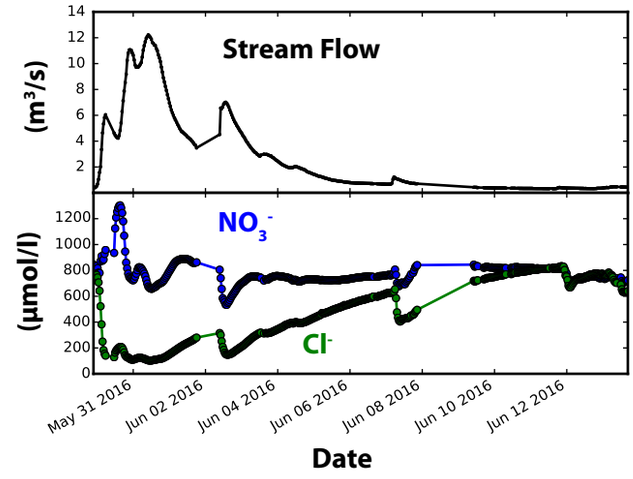


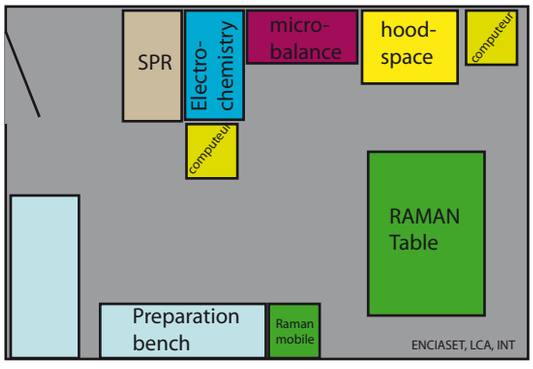
Figure: The exceptionnal flood event of June 2016 at Orgeval CZO. Credit Paul Floury.

WP4.3. Innovative sensor development (P. Behra, B. Dubeuil, LCA-INPS, F. Prévot, IPGP).

Since September 2016, Laboratoire de chimie industrielle (LCA, Toulouse) has acquired several instruments dedicated to the development of chemical sensors thanks to CRITEX project.

These different devices are set up in a dedicated room (Figure).

- a Raman spetrometer (LabRAM HR evolution (Horiba Jobin Yvon SAS), associated with a confocal microscope, BX41) for the characterization of materials and the study of molecular interaction mechanisms;
- a surface plasmon resonance system (MP-SPR Navi 200 OTSO, BioNavis), equipped with two optical channels and two lasers (670 and 785 nm), for studying the interactions between a ligand and a receptor layer adsorbed on a metal surface by measuring the refractive index in the interface vicinity;
- a quartz crystal microbalance with dissipation energy measurement (QCM-D E1, QSense) for measuring very low mass adsorption (a few ng/cm2) and studying molecular interactions, based on a quartz crystal frequency variation;



- a low-current potentiostat (SP 200, Bio-Logic) for developing sensors, based on electrochemical detection methods (E);
- a spin coater system making it possible to produce thin films (sensitive layers) for the sensors.

These technologies open up a wide range of detection methods (spectroscopic, refractive index, mass, electrochemical) and offer: (i) optimal performance in terms of sensitivity (trace amounts of a few pg/L to ng/L) and reliability (reproducibility, accuracy, accuracy of measurements); and (ii) the possibility of coupling the equipment in order to improve the sensor properties and detection methods developed in terms of selectivity.

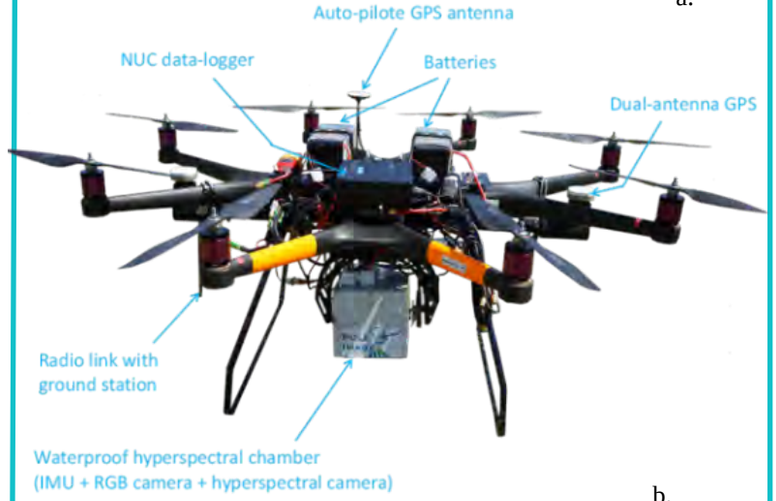
Two PhD works are currently in progress on new sensor development: (i) methodology development for the detection and quantitative in situ analysis of low concentration boron speciation in aqueous solutions (PhD student: Alan Castillo-Villa; grant: Conacyt, Mexico); and (ii) design of a dynamic generic sensor for in situ pesticides analysis in natural waters (PhD student: Huy Minh Do; grant: USTH, VIED, Vietnam).

WP5. IDEVA: Hyperspectral Drone: first data acquisitions and treatments (C. Delacourt, J. Ammann, M. Jaud & N. Le Dantec, LDO Brest, P. Allemand & P. Grandjean LGL Lyon).

A drone equipped with a sensitive hyperspectral camera in the visible and very near infrared is developed within the framework of CRITEX by the "Géosciences Océans" (UBO, IUEM, CNRS - Brest) and "Laboratoire de Géologie de Lyon" (Lyon 1, OSU Lyon, CNRS) teams. The objective of this drone is to complete the national and international offer in terms of hyperspectral satellite imagery for environmental problems, especially for rivers, coastline and vegetation. The drone is now entering its operational phase and the first tests have been successfully completed. A first acquisition was made around the Pye Lake in the north of Lyon city (Fig. a). Before the flight, two types of targets were placed on the ground. Their position were measured at the precision of ± 1 cm by DGPS. The first type of target is used to calculate the geometry of the image. The second type is a target with perfectly defined spectral properties and is used to calibrate the hyperspectral data obtained by the camera.

Fig. b shows a series of reflection spectra acquired over the study area: on vegetated areas, on Pye Lake, on sand and bare rock (Fig. b). The H20 spectrum acquired above the pond shows a strong absorption zone below 400 nm (band 33) and above 730 nm (band 211). The vegetation spectrum, with a significant increase in reflectance at 690 nm (band 190) and a peak between 520 and 600 nm, is characteristic of healthy vegetation. These first acquisitions and treatments show that the experimental protocol is totally operational both concerning the drone and for data acquisition. Optimizing positioning and elevation data management and their interfacing with the imaging data still need to be done. To do so, the drone has been equipped with new imaging (RGB camera) and positioning sensors (dual GPS antenna, radio receiver for GPS RTK) in order to improve the accuracy of the position and elevation data for reconstructing the hyperspectral image generated by the "pushbroom" type sensor.

a.



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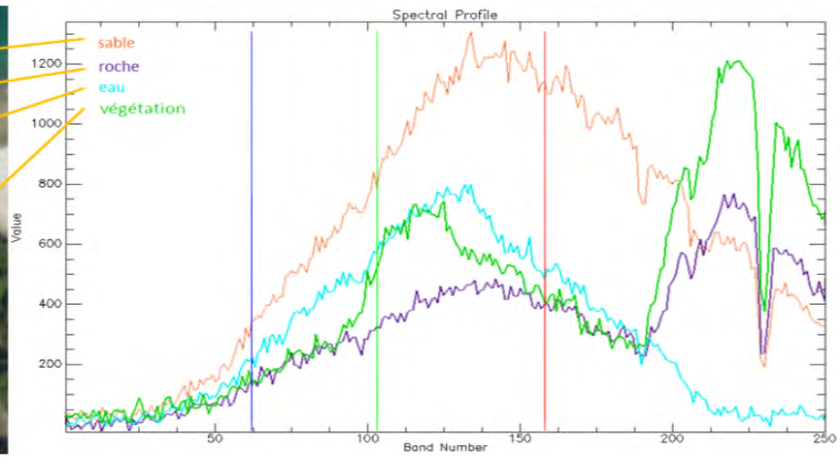


CRITEX : HOT MOMENTS AND HOT SPOTS IN THE CRITICAL ZONE: INVESTIGATION CAMPAIGNS

WP6.1. Seismic imaging of the CZ (L. Bodet, UPMC).

CRITEX's seismic is travelling abroad! Sylvain PASQUET, whose PhD and ATER at UPMC (2011-2015) contributed to the development of our approach on the PIREN-Seine (Orgeval) and H + (Ploemeur) sites, deployed this method in the Yellowstone National Park with the University of Wyoming (where he is currently a post-doc student). Thanks to the VP/VS ratio, Sylvain and his colleagues were able to clearly image degassing at the subsurface (see Geophysical Research Letters, December 2016).

CRITEX's seismic works also at lab scale! We have recently shown, using acoustic techniques, that a repetition of P- and surface-wave measurements would allow the monitoring of subsurface water content variations in the unsaturated zone. The paper published in "Vadose Zone Journal" was pinpointed as "Research Highlights" in September 2016.

CRITEX's seismic goes "time-lapse"! Following the laboratory experiment, Marine DANGEARD, PhD student at UPMC (2015-2018), validated experimental results on data recorded on both high and low water conditions in Ploemeur. P-wave first arrival times and surface-wave phase velocities differences appeared to be coherent with in situ measurements and estimations of saturation on this site. These first results were presented at IAH and EAGE conferences in September. In early February 2017, the method will be deployed "time-lapse" on the Orgeval site (downstream), to extrapolate local measurements of hydrodynamic properties in the vicinity of the river.

CRITEX's seismic gets wet! In October 2016, we were lucky to experience a strong rain event at the Sapine catchment (RBV) in Lozère thanks to Marie KUESSNER and Julien BOUCHEZ, previously met at the CRITEX meeting in Rennes in January 2016. Seismic measurements were carried out before and during the rain event, and complemented with water samples to be analyzed (we thank OHMCV and the Parc des Cévennes for the support). To be continued!

CRITEX's seismic will listen! The METIS laboratory co-funded with CRITEX the acquisition of a set of multi-component and broadband geophones to record seismic noise on hydrosystems (a project to be developed in the framework of the ITN ENIGMA which started in January 2017). First tests at Ploemeur and Guidel are coming soon, as part of a preliminary project with the University of Nantes and the CNAM, in parallel to the time-lapse active seismic measurements... CRITEX's seismic communicates! Meet us in Vienna@EGU in April for a synthetic presentation of our approach, its applications and perspectives.

When geochemistry meets geophysics in the Sapine Catchment, Mont Lozère, Cévennes, France. Crédit. D. Frings.

WP6.2. Magnetic Resonance Sounding (A. Legchenko, LTHE and J. F. Girard, EOST).

The development of a new module for signal processing and MRS data inversion within the SAMOVAR software was carried out as part of the CRITEX project. New developments improved the performance of the MRS method in different field conditions, and particularly in crystalline context where significant variations of the geomagnetic field may affect inversion results (Legchenko et al., 2016). This work was carried out in collaboration between IRD (UGA, IGE, Grenoble), EOST (Strasbourg) and the Avignon and Pays de Vaucluse University.The improved version of SAMOVAR was used in Benin as part of an IRD research project with the support from the African Union and the European Union.

The updated software was used to reprocess data obtained in 2012 in the framework of the ANR Hydrokarst G2 project (http://www.gm.univ-montp2.fr/spip.php?article1295). This study carried out on Larzac karst plateau (south of France) provides a new methodological support for MRS users. It contributes to the understanding of the water storage processes in the unsaturated zone overlaying karst formations, which has a significant impact on the overall karst hydraulic functioning (Mazzilli et al., 2016).

Finally, a field campaign was carried out in the Strengbach observatory (Vosges, Alsace) in April 2016 by IRD (UGA, IGE, Grenoble), the University of Strasbourg, IPGS and the Leibniz Institute for Applied Geophysics - LIAG (Hanover). This work has been funded by the HYDROCRIZSTO ANR project, allowed evaluation of MRS (NMR) logging method (NML), and applied to the investigation of the water content variability in fractured granite at the watershed scale (Girard et al. Al., 2017). Following this experiment, we propose a strategy to combine both NML and MRS methods, thus extending the instrumental pool available for the research programs carried out by the observatory OHGE (Strasbourg).

Legchenko A., J.M. Vouillamoz, F.M.A. Lawson, C. Alle, M. Descloitres and M. Boucher, 2016, Interpretation of magnetic resonance measurements in the varying Earth's magnetic field, Geophysics, 81(4), WB23-WB31, doi: 10.1190/GEO2015-0474.1.

Mazzilli N., M. Boucher, K. Chalikakis, A. Legchenko, H. Jourde and C. Champollion, 2016, Contribution of Magnetic Resonance Soundings for characterizing water storage in the unsaturated zone of karst aquifers, Geophysics, 81(4), WB49-WB61, doi:10.1190/GEO2015-0411.1.

Girard J-F., Duglosch R., Legtchenko A., Pierret M-C., Dumont M., Boucher M., Viville D., Müller-Petke M., Jodry C., 2017, Applicability of the Magnetic resonance in fractured granite aquifer: surface and borehole measurements in the Strengbach catchment, France, 79th EAGE conference, 12-15 june 2017 Paris.

WP 6.4. Induced polarization (C. Camerlynck and N. Florsch, UPMC)

WP 6.4 aims at characterizing the temporal and spectral induced polarization phenomena at field scale. This method shows large potentials, such as the estimation of permeability or electrochemical polarization linked to water chemistry.

The CNRS-EC2CO "Hydropolaris" project was funded in 2016 and aims at validating in-situ the complex conductivity/permeability relation estimated during laboratory experiments on core by field acquisitions. The first measurements were carried out in the Alsace plain in autumn 2016 on well-characterized saturated permeable soil and must continue in 2017.

In the framework of the internal call of RBV, a field campaign was carried out on the Houay Pano catchment (Laos) from October 24th to November 11th 2016 in order to correlate the river physicochemical variations with a hyporheic zone geophysical proxy (see Figure on the next page)

WP 6.4. (follow-up). Complex conductivity measurements in the spectral domain were acquired with a high-frequency monitoring protocol by automatic acquisition of an electrical sampling every 30 minutes (Jougnot et al., 2017). Another campaign will be carried out on the Orgeval observatory at the end of this winter, in the vicinity of the River Lab to compare geophysical data with the high-frequency physicochemical data acquired.

Finally, we are finalizing equipment acquisitions in 2017 by an optimal spectral conductivity measuring equipment. Tests will also be conducted this spring to adapt the complex conductivity measurements from the Phoenix system acquired by WP 6.5.

Jougnot, D., C. Camerlynck, H. Robain, G. Tallec, O. Ribolzi, J. Gaillardet, 2017. Spectral Induced Polarization of the groundwater physico-chemical daily variations for the stream-groundwater interactions, EGU General Assembly, Paris, 23-28 april 2017, Vienna

WP 6.5. Magnetotelluric electromagnetism with source controlled audio frequencies (CSAMT - P. Sailhac, GEOPS and IPGS)

A first CSAMT campaign has been carried out on the Strengbach observatory with the Phoenix T3 transmitter (acquired by CRITEX), to study the radiation diagram and receptor sensitivity (Ternisien, 2016). AMT processing algorithms were developped to interpret the data acquired on the same hydrogeological site. These algorithms are important to interpret data in the dead-band frequency domain corresponding roughly to depths between 40 and 100m. It can highlight preferential paths of circulation and water storage distribution in mountainous environments. Both subsurface models inferred from AMT and CSAMT imaging methods will be compared. A PhD has begun early 2017 to develop tools to interpret CSAMT in mountainous context (Myriam Lajaunie co-advised by P. Sailhac and JP Malet).

Considering the proximity of induced polarization and CSAMT methods, we will perform a joint test to use the T3 transmitter as a source for both WP 6.5 and 6.2. (with Christian Camerlynck).

Ternisien Z., 2016, Hydrogeophysical study of the Stengbach catchment basin with electromagnetic measurmeents, EOST Project Report, 2016, 39p.

Sailhac, P., J. Gance, H. Larnier, D. Viville, J.-P. Malet, Travaux en cours sur l'imagerie électromagnétique du bassin versant du Strengbach : développements en AMT et CSAMT. 25ième RST, 24-28 oct. 2016, Caen.

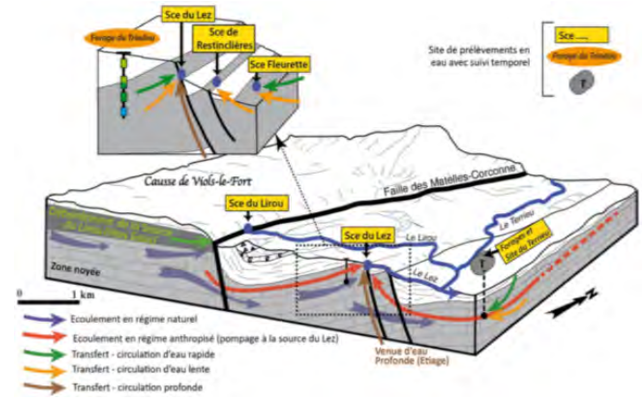
Lajaunie, M., P. Sailhac, J.-P. Malet, H. Larnier, J. Gance, S. Gautier, M.-C. Pierret, 2017, Multi-frequency electrical and electromagnetic measurements for imaging water flows: application to catchment and landslide hydrology. Geophysical Reasearch Abst. 19, EGU2017-12385, 23-28 April 2017, Vienna.

WP7.1. Deep monitoring of groundwater fluxes in karstic systems (H. Jourde and J.L. Seidel, HSM).

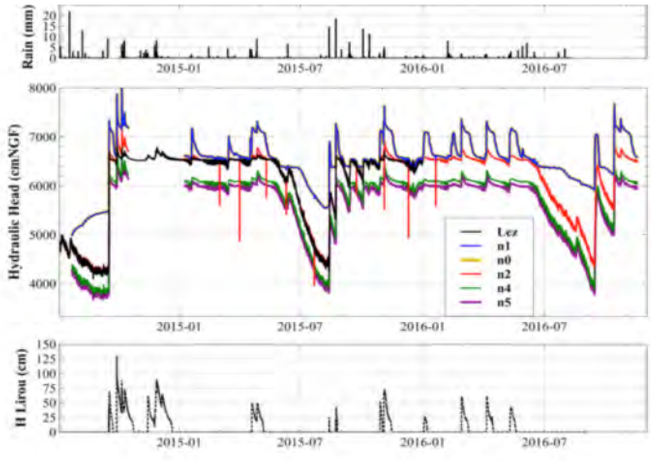
On the multi-scale observatory of groundwater hydrodynamics and flood dynamics in karst (MEDYCYSS observatory, SNO KARST, OSU OREME, IR OZCAR), the 335 m deep CRITEX bore-hole (Forage du Triadou, Fig.), strategically located 700 m north of the Lez spring and 150 m south of the Lirou intermittent stream has been used for both groundwater sampling at different depths and a continuous monitoring of pressure and temperature since July 2014.

Within this well, five compartments were isolated using packer systems for the continuous monitoring and the manual sampling of groundwater. The data (Fig.) show a consequent recharge and high interactions between surface water (when flow occurs in the nearby intermittent stream) and groundwater, particularly in the Valanginian upper compartment (n0, n1 and n2 levels on the Fig.), considered as aquitard.

The continuous monitoring allowed identifying a fast hydrodynamic response on the different compartments, synchronous with the hydrodynamic behavior registered at the main karst outlet (Lez spring). By constrast, the hydrochemical stability of groundwater highlights the differences between pressure transfer and mass transfer within the five compartments, pointing out slow groundwater circulation in the highly kartsified deep Berriasian-Kimmeridgian aquifer (n4 and n5 levels at -220 et -335 m depth respectively). The head gradient between the deep compartment and the Lez spring monitoring indicates that groundwater located in these compartments are not directly drained by the main karst outlet, and that deeper circulations towards other outlets may exist. The monitored hydrodynamic behavior, together with the physicochemical measurements, thus show a highly capacitive behavior of the deep compartments, which is a major result to satisfy the increasing water demand. These results highlight the complexity and the heterogeneity of such deeply kartsified Mediterranean aquifer, but also the large interaction with surface water, especially during extreme events.



Groundwater flow at the Lez aquifer scale and location of the CRITEX Triadou borehole [Leonardi, 2015]



Water depth in the Lirou river, precipitation and piezometric monitoring at the Lez spring and within the five compartments of the CRITEX Triadou borehole from July 2014 to Nov. 2016.

WP7.1. (follow-up) Geophysical monitoring of underground circulations (P. Pezard, G. Henry, GMontpellier).

Waiting for a new drilling to install both temperature and resistivity monitoring in a new borehole at the Strengbach basin (Alsace), the 2016 activity focused on the Argentona coastal site (Catalonya). New high temporal frequency resistivity (mHz and Time Laps Logging type) measurements have been realized to study the impact of the boundary conditions of the aquifer and to get ready for installing the double device for borehole monitoring.

At the end of July 2016, electrical conductivity measurements have been achieved every 20 min. during 27 hours in the Arg2Y well, giving information on the impact on the coastal aquifer salinity during two tide cycles.

WP7.1. (follow up) At this time scale, temporal changes of the electrical conductivity in sand is generated by temporal variations of salinity and/or of poral fluid temperature, while changes in clay are weak (e.g. at 5 m depth on Figure below). This test shows that permanent geophysical monitoring in well will allow to identify the origin of pore fluid variations from temperature or ionic charge. The full well monitoring has been set up with success early January 2017. It will provide, during several months and several times a day, information on the pore fluid variations into the aquifer.

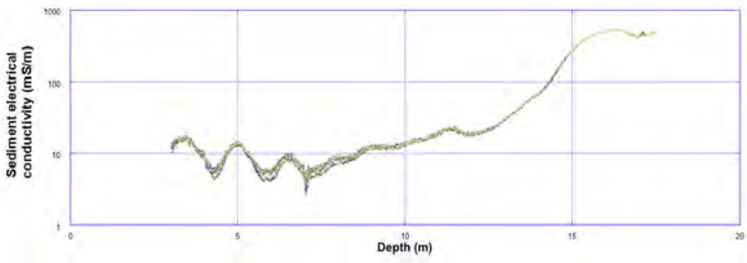


Figure: 100 electrical conductivity measurements recorded in the Arg2Y well with a GeoVista EM51 probe (30 and 31 July 2016). In the upper part of the aquifer, time changes of electrical conductivity of the medium are observed in sand (for the less conductive values of the section). Seawater intrusion, at the bottom of the aquifer, is significant from 12 m depth.

WP7.2. Automated winch for periodic hydraulic tomography (N. Lavenant, O. Bour, J. Schuite, L. Longuevergne, Géosciences Rennes)

Hydraulic tomography is a novel technique commonly used to determine hydraulic properties. It is developing quickly for its potential to reach hydro-dynamical parameters (eg hydraulic diffusivity). While constant flow pumping and hydraulic shocks are commonly used, some studies have shown that the shape of these disturbances has a direct influence on the resolution of this hydraulic property. This new approach involves the use of oscillatory water level variations at different frequencies in the source well. One of the advantages is to investigate the scale dependence on the properties linked to the chosen frequency.

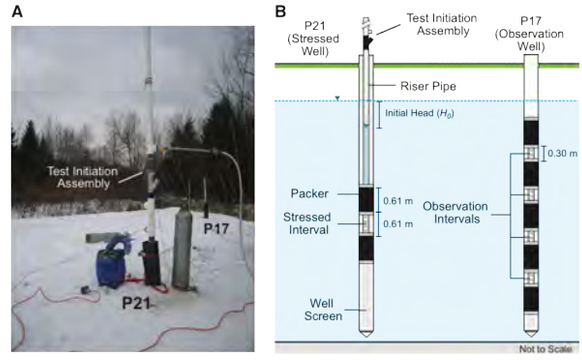
This periodic perturbation system was used to study the hydromechanical behavior of natural fracture behavior (Ploemeur site, SNO H +) in collaboration with M. Becker (California University, Long Beach). Indeed, pressure changes lead to fracture opening, which was recorded at the surface by pendular tiltmeters. Due to the oscillatory nature of the signal, new processing method were developed to extract low amplitude signals that could be detected and interpreted in terms of fracture mechanical properties and behavior. This new experimental approach is the result of a transversal development between WP 2.2 and 7.2 and is being thoroughly evaluated in a publication submitted to the Journal of Geophysical Research (Schuite et al.). Further works are underway to interpret the hydraulic tomography data acquired at the Kerrien-Kerbernez site (AgrHys, RBV CZO).

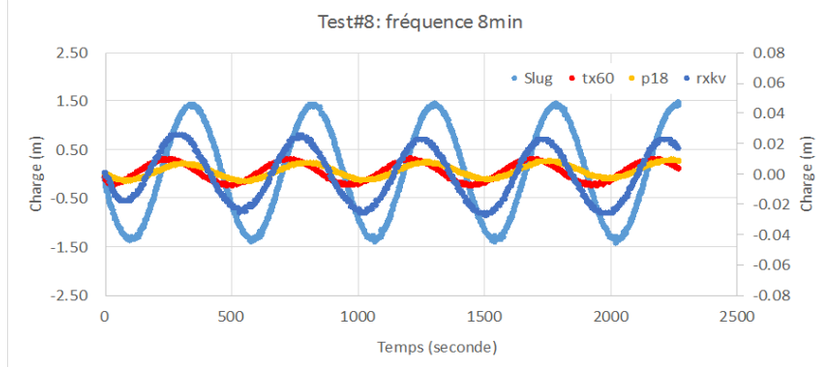
At the same time, a new tool was developed in Géosciences Rennes based on a numerically controlled mechanical winch that induces oscillatory variations in water level (see Figure). This prototype allows precise sinusoidal hydraulic stresses to be achieved at different frequencies and amplitudes. The interface was developed in Labview for an easy control of the winch and visualization of the periodic signal in real time. The acquisition and control system are operated remotely (~ 20m). Preliminary tests with this equipment were carried out in a highly heterogeneous and anisotropic granular medium at Saint Lambert site in Canada (as part of the LIA France-Quebec RESO "Resource and Societies" and in collaboration with D. Paradis and R. Lefebvre)

Tests at different frequencies have shown a good signal quality with this tool (Figures below). After this preliminary work, collaborations are planned with the INRS Quebec to develop hydraulic tomography methods and improve the aquifer hydraulic property characterization. Other applications are also planned on different sites within the H + CZ observatories.

Schuite J, L. Longuevergne, O. Bour, N. Guihéneuf, M. W. Becker, M. Cole, T. J. Burbey, N. Lavenant and F. Boudin, Combining periodic hydraulic tests and surface tilt measurements to explore in situ fracture hydromechanics, subm. to J. of Geophys. Res.

Schematic of the hydraulic tomography device on the Saint-Lambert site in Québec (Courtesy D. Paradis).





Pressure response in the observation well during the hydraulic tomography experiment on the Saint-Lambert site.

WP7.3. Tracer tests (T. Le Borgne, T. Labasque, O. Brochet, L. Aquilina, Géosciences Rennes).

The objective of WP 7.3 is to develop new experimental tools to characterize in situ reactive transport processes. This includes the design of a mobile laboratory to measure tracer concentrations and reaction products, a packer system for injection control, and innovative tracers for the characterization of microbial processes involved in biogeochemical reactions. After the development of the OSUR 4x4 truck in 2014 and 2015, a continuous flow analyzers of dissolved silicates, phosphates, iron, ammonium, nitrates and nitrites was purchased in 2016. Innovative reactive tracers are also under development to quantify the microbiological activity in situ.

The device of analysis in continuous flow (Fig.) once validated will be installed in the mobile laboratory CRITEX (Fig.) in order to complete monitoring devices dedicated to dissolved gases (WP 8.1). This analyzer will measure nitrates, nitrites, phosphates, silicates, iron and ammonium at a rate of 40 measurements per hour.

The innovative tracer is based on Fluorescein Diacetate (FDA). This molecule is degraded by microorganisms, the resulting degradation product being a fluorescein molecule that can be measured easily and at high frequency by a fluorimeter. In a first phase of laboratory characterization, we characterized the degradation kinetics of the FDA measured by the fluorescein. The innovative tracer was then tested during tracing experiments in the framework of the Master 2 course of Dorian Putigny. The results obtained allowed us to quantify microbial activity within the aquifer investigated. This method could subsequently detect hotspots of biogeochemical reactivity and plan remediation operations for polluted aquifers.

WP7.3. (follow-up)

Field campaigns using the CRITEX mobile truck:

- November 2016: hydrochemical monitoring in the river (LTSER Pleines-Fougères) in collaboration with ECOBIO and the OSUR Rennes
- December 2016: conservative and reactive tracing in drilling at the Ploemeur CZO site (H +)
- June 2016: Reactive and conservative tracing on the Naizin CZO - 3 weeks (project ANR Stock en Socle)
- November 2016: Hydrochemical monitoring and Gaseous drilling profiles at the Ploemeur CZO (H+).
- February 2016: campaign for hydrochemical measurements at the Ploemeur CZO (H +)

Figures: photos of stream analyzers acquired in CRITEX WP 7.3 and the CRITEX-truck on the right.

WP8.1. In-situ high-frequencymeasurement of dissolved gas: Labasque Thierry, Eliot Chatton, Luc Aquilina, Guillou Aurélie from Géosciences Rennes

1- The activities of WP 8.1 are mainly supported by Eliot Chatton's PhD work. A field mass spectrometer (MIMS) has been setup in the chemical truck and allows continuous monitoring of dissolved gasses at the sampling rate of 10 seconds, to estimate water age (Noble gases, Helium) and quantify biogeochemical reactivity (O2, N2, H2, CO2, CH4). This versatile tool might be used for various applications, in rivers, but also in wells to profile the different types of water. Several dissolved gas profiles in boreholes were carried out on Ploemeur H + hydrogeological site in order to characterize the recharge temperatures from noble gases, water age from helium (4He), as well as biogeochemical reactivity (Fig.a).

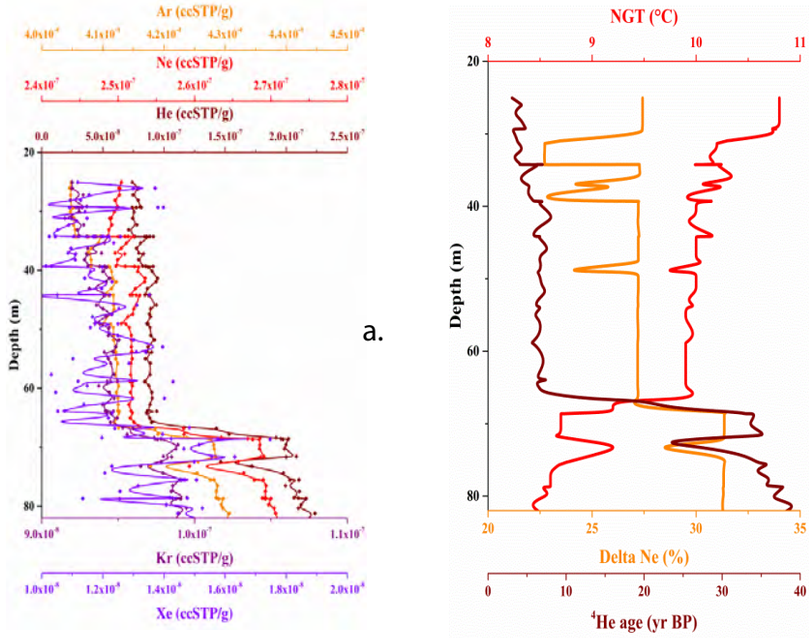


Figure a: Dissolved gas concentration profiles in borehole (F28 Ploemeur H +) and their interpretation in terms of recharge temperature, excess air and He age. Below the depth of 60 m, the recharge temperature is 2° colder, water is also older

2- A reactive tracing experiment was carried out between two boreholes on AgrHys / Naizin SOERE site within the context of the ANR “Stock en Socle” project. Dissolved gas concentrations were measured continuously using the MIMS for more than 100 hours. The use of dissolved gases as tracers allow characterization of flow structure, biochemical reactivity and reaction kinetics by subsurface layers (Fig. b).

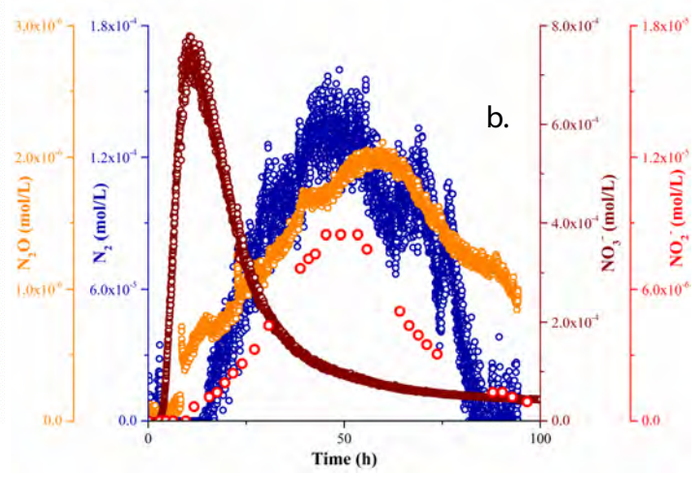


Figure b: Evolution of dissolved salts (NO3- and NO2-) and dissolved gases (NO2, N2) during a 100-hour tracing experiment within 2 boreholes.

Eliot Chatton, Thierry Labasque, Jérôme de La Bernardie, Nicolas Guihéneuf, Olivier Bour,and Luc Aquilina, Field Continuous Measurement of Dissolved Gases with a CF-MIMS: Applications to the Physics and Biogeochemistry of Groundwater Flow, 2016 ES&T

WP8.2. In situ high frequency measurements of water isotopes: the Picarro CRDS L2130i (Mathieu Sebilo, UPMC).

The CRDS has arrived.

It is measuring simultaneously the isotopic composition of H and O from the water molecule in the aim of tracing the origin of the water masses circulating in the Critical Zone.

The analysis can be conducted under two modes : injection (in the lab), or real time analysis.

in the injection mode, the water is introduced in a nebuliser and a combustion module, aiming at eliminating the dissolved organic matter and the potential interferences it could imply. The duration of a single analysis is 8 minutes and 10 injections are required par sample.

The real time measurements are made after a prefiltration step (0.2µm). One analysis is made each 10 seconds making it possible to analyse in quasi real time a typical flood event in a catchment.

Comparison tests between CRDS and IRMS are under way to evaluate the performance of the combustion module. Applications in rivers are rather rare and this aspect needs to be carefully tested.

The CRDS is intended to be installed in the field, in sites whose colleagues are interested. A technical training is required in the laboratory before the installation on field site.

WP8.3. Isotopic Integrative Sensors (B. Chague, P. Négrel, F. Gal, BRGM)

As part of the CRITEX project, a sampling system using integrative passive samplers in boreholes has been developed. This system aims at analyzing critical zone groundwaters (0-100 m depth) by creating a water flow in a passive sampler device constituted of Diffusive Gradient in Thin film (DGT)-type sensors. The chemical species of interest (metal elements, present at the trace level) are then pre-concentrated over a given period of time, which facilitates their measurement in terms of both concentration and isotopic composition, in the lab.

In details, the DGT traps the metal trace elements in a chelating resin after diffusion through a membrane and a gel. Since this type of sensor has been generally used in surface waters having a high flow rate, the objective of the WP was to generate a sufficient flow of water on the sampler surface in order to optimize element trapping. The size of the set up allows us to deploy it in boreholes with a diameter > 2 inches.

Different options and geometries have been tested and modeled for flow simulation (using a device with water agitation powered by a motor and a propeller, pumping ...). The economic model of the device is based on an assembly of commercially available equipments. A totally new mount was build (a patent is under submission). The device aims at recreating sufficient water stirring conditions to avoid the creation of a Diffusion Boundary Layer (DBL) on the DGT surface. This DBL would limit the pre-concentration capacity of the DGTs. The simulations allowed us to optimize the DGT position and the fluid velocity (inlet flow imposed by a small variable flow pump) in order to obtain the maximum flow at its surface and avoid the formation of a DBL. Thus, stirring conditions equivalent to those of agitated surface waters were created.

The first “real world” tests were carried out in a column simulating a borehole, including a pump, the DGT holder and a flowmeter. The first tests were carried out with tap water to simulate the water flow in the device and to determine its technical characteristics (current, voltage, flow, ...). The contamination blanks were also determined to ensure that the device is not polluting the sampled water.

We then carried out 6 days of system immersion on a BRGM piezometer. Daily samples obtained by conventional pumping method were compared to DGT analyzes for comparison. Finally, we carried out tests in the BRGM water well of the Coët Dan experimental catchment (Naizin, Morbihan, RBV network) using chemical elements for which we can make isotopic measurements by comparing the accumulated mass in the DGT to the water concentration. The first conclusion is that the isotopic determination is possible for uranium (U), strontium (Sr), neodymium (Nd), nickel (Ni) but not yet for copper (Cu) and zinc (Zn) at the moment. This is probably due to a contamination issue in the DGTs that should be further investigated. Overall, these results are extremely encouraging.

Please send us (gaillardet@igpp.fr or laurent.longuevergne@univ-rennes1.fr) any relevant information that could be used to write the next CRITEX Newsletter.