European Commission

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Project Acronym: ENIGMA

Project title: European training Network for in situ imaGing of dynaMic processes in heterogeneous subsurfAce environments

Mid-term report

Part B of the Periodic Report

Period covered by the report: from [01/01/2017] to [31/12/2018]

Periodic report: *[*1st*]*

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This deliverable "Midterm Report "was created by using the "Template mid-term (interim check) report" provided by the MSCA. The initial instructions are in italic grey.

1. Explanation of the work carried out by the beneficiaries and Overview of the progress

• Explain the work carried out during the reporting period in line with the Annex 1 to the Grant Agreement.
• Include an overview of the project results towards the objective of the action in line with the structure of the Annex 1 to the Grant Agreement including summary of deliverables and milestones, and a summary of exploitable results and an explanation about how they can/will be exploited.
(No page limit per workpackage but report shall be concise and readable. Any duplication should be avoided).

1.1. Objectives

List the specific objectives for the project as described in section 1.1 of the DoA and described the work carried out during the reporting period towards the achievement of each listed objective. Provide clear and measurable details.

Scientific and technological objectives

There were four main scientific and technological objectives for the ENIGMA ITN project. These objectives correspond to the different scientific workpackages of the project. **Therefore, the description of the work carried out during the reporting period towards the achievement of each listed objective will be detailed by workpackage in the section 1.2 (Explanation of the work carried per WP).**

- Scientific objective 1: design novel in situ experimental strategies for quantifying subsurface process dynamics by coupling innovative experimental methods and inverse modelling approaches

  This scientific objective was addressed in the workpackages:
  o WP3 Enhance our capacity to monitor temporal changes in the spatial distribution of subsurface water content and fluxes
  o WP4 Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids
  o WP5 Design inverse modelling strategies for imaging dynamic processes in complex subsurface structures

- Scientific objective 2: explore in-situ flow, transport and reaction processes to address current open scientific questions based on highly instrumented experimental sites where the new results, data and open source codes will be made available to academia and industry through a common on-line database

  This scientific objective was addressed in the work package:
  o WP2 Explore coupled dynamic processes in highly instrumented sites

- Technological objective 1: develop and validate innovative environmental sensing techniques with the required sensitivity, as well as spatial and temporal resolution to monitor dynamic processes

  This scientific objective was addressed in the work package:
  - WP3 Enhance our capacity to monitor temporal changes in the spatial distribution of subsurface water content and fluxes
  - WP4 Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids

- Technological objective 2: transfer the obtained knowledge of process dynamics in heterogeneous porous and fractured media to operational models for predicting the evolution of subsurface environments.

  This scientific objective was addressed in the work package:
  - WP2 Explore coupled dynamic processes in highly instrumented sites
  - WP5 Design inverse modelling strategies for imaging dynamic processes in complex subsurface structures

1.1.1. Milestones

The nine Milestones described in the Grant Agreement required before January 2019 have all been reached.

i.   Website completion

The delivery date was February 2017. This milestone was reached on time.

ii.   Recruitment completion

The delivery date was January 2018. This milestone was reached in December 2017; as agreed in December 2017 with the Project Officer Luisa Marconi, the report for the corresponding deliverable was submitted on the Participant Portal in January 2018.

iii.   Development Plans

The delivery date was January 2018. This milestone was reached on time. ULG (University of Liège) collected all the PCDP on a common file shared with the EPM (European Project Manager).

iv.   State of the art review

The delivery date was April 2018. This milestone was reached on time according to the ESRs presentations during the meeting in Lausanne in February 2018 (and also confirmed with the posters session during the Summer school in Cargèse in June 2018).

v.   Workshops 1,2,3 held

The delivery date was April 2018. This milestone was reached on time indeed the workshop 3&4 were held in Lausanne in February 2018.

vi.   Experimental plans

The delivery date was July 2018. According to the posters session and the discussions during the Summer school in Cargèse, this milestone was achieved in July 2018. The experimental/laboratory plans were collected by the Coordinator and a common calendar is available on the Enigma website

vii.   Summer school held

The delivery date was July 2018. This milestone was reached on time indeed the summer school was held from June 25th to July 07th 2018. More information about the Summer school on the dedicated website: https://cargese2018.sciencesconf.org/

viii.   Year 1 report

The delivery date was September 2018. This milestone was reached on time (the corresponding deliverable is on the home participant portal).

ix.   1st round of experimental campaigns completed

The delivery date was September 2018. This milestone was reached on time according to the different presentations and posters during the meetings and to the common calendar (available on the Enigma website).

1.1.2. Training

Workshops and summer school

The four training courses described in the Grant Agreement, expected to occur during the period covered by this report (January 2017 – December 2018) were held in Liège, Belgium and Ploemeur, France in October 2017 and in Lausanne, Switzerland in February 2018.

i.   Workshop 1 - *Advanced subsurface characterization methods: theory and field practice* held in Liège (Belgium) in October 2017.
The corresponding deliverable report D6.3 – D16 is on the Participant Portal and has been approved.

ii.   Workshop 2 - *Multi-scale investigation of fractured media* held in Ploemeur (France) in October 2017.
The corresponding deliverable report D6.4 – D17 is on the Participant Portal and has been approved.

For the trainings due before the Progress report deliverable, when they were some changes about the dates, the explanations are in the Progress report.

iii.   Workshop 3 - *Predictive modelling and upscaling of flow and reactive transport in heterogeneous aquifers* held in Lausanne (Switzerland) in February 2018.
The corresponding deliverable report D6.5 – D18 is on the Participant Portal

iv.   Workshop 4 - *Advanced inverse modelling and stochastic representations of heterogeneous porous and fractured media* held in Lausanne (Switzerland) in February 2018.
The corresponding deliverable report D6.7 – D20 is on the Participant Portal.

The workshop 3 & 4 and the meeting 3 were concentrated in February 2018 in Lausanne in order to optimize the ESR travels. This decision and its explanation were previously communicated to the Project Officer Cathy Souto-Enriquez and were accepted.

v.   ENIGMA Summer school- *Sensing and modelling flow and transport processes in heterogeneous subsurface environments* held in Cargèse (France) in June/July 2018.
The corresponding deliverable report D6.6 – D19 is on the Participant Portal.

As indicated in the Grant Agreement as milestone 3, supervision arrangement and career development plans have been agreed on for each recruited researcher with PCDP (Personal Career Development Plan).This milestone was reached in January 2018. ULG (University of Liège) collected all the PCDP on a common file shared with the EPM (European Project Manager).
The PCDP were updated during autumn 2018 for all the ESRs for 2018/2019.

The European Commission raised some questions about the co-supervision of ESR5 by CNRS with contribution of UMR Metis as joined third party, asking for more details regarding the time spent on each of the premises. In order to clarify this point, an Amendement is currently in progress.

1.1.3. Deliverables of the first reporting period

The deliverables required until December 2018 are all on the Participant Portal (summary in Table 1& Table 2).

Table 1: Status of the deliverables required before January 2019 – part a

WP No	Del Rel. No	DelNo	Title	Lead Beneficiary	Nature	Dissemination Level	Est. Del. Date (annex I)	Receipt Date	Approval Date	Status
WP7	D7.11	D35	Supervisory Board of the network	CNRS	Other	Confidential, only for members of the consortium	28 Feb 2017	05 Dec 2017	06 Dec 2017	Approved
WP7	D7.12	D36	Consortium Agreement	CNRS	Report	Confidential, only for members of the consortium	28 Feb 2017	21 Feb 2017	30 Oct 2017	Approved
WP7	D7.2	D26	Setup of the ENIGMA website	CNRS	Other	Public	31 Mar 2017	15 Mar 2017	30 Oct 2017	Approved
WP1	D1.1	D1	NEC - Requirement No. 1	CNRS	Ethics	Confidential, only for members of the consortium	30 Jun 2017	08 Jun 2017	30 Oct 2017	Approved
WP1	D1.2	D2	EPQ - Requirement No. 2	CNRS	Ethics	Confidential, only for members of the consortium	30 Jun 2017	22 Nov 2017	22 Nov 2017	Approved
WP6	D6.3	D16	1st workshop	ULG	Report	Public	31 Jul 2017	20 Nov 2017	13 Dec 2017	Approved
WP6	D6.4	D17	2nd Workshop	CNRS	Report	Public	30 Sep 2017	20 Nov 2017	13 Dec 2017	Approved
WP7	D7.3	D27	Completion of the recruitment process	CNRS	Other	Public	30 Sep 2017	18 Jan 2018		Submitted
WP7	D7.7	D31	Progress report	CNRS	Report	Public	31 Jan 2018	30 Jan 2018		Submitted
WP6	D6.5	D18	3rd Workshop	ULG	Report	Public	28 Feb 2018	20 Feb 2018		Submitted
WP6	D6.6	D19	ENIGMA summer school	CNRS	Report	Public	30 Jun 2018	08-oct-18		Submitted
WP6	D6.7	D20	4th Workshop	UNIL	Report	Public	31 Oct 2018	07 Mar 2018		Submitted

Table 2: Status of the deliverables required before January 2019 – part b

WP No	Del Rel. No	Del No	Title	Lead Beneficiary	Nature	Dissemination Level	Est. Del. Date (annex I)	Receipt Date	Approval Date	Status
WP7	D7.8	D32	Mid-term report	CNRS	Report	Public	31 Oct 2018			This is the Mid-term report
WP3	D3.2	D7	Field test of novel techniques for quantifying water content spatial distributions and temporal fluctuations	UNINE	Report	Public	31 Dec 2018	03/12/18		Submitted
WP3	D3.3	D8	Report: Critical assessment of emerging techniques for in situ monitoring of water content and fluxes	UCPH	Report	Public	31 Dec 2018	03/12/18		Submitted
WP5	D5.1	D12	Validated algorithms for fully coupled 3-D inversion for tomographic datasets	EKUT	Report	Public	31 Dec 2018	07/01/19		Submitted
WP5	D5.2	D13	Report on joint inversion procedures for multiple and disparate datasets (soft and hard data) with realistic subsurface structure reconstruction methods	ULG	Report	Public	31 Dec 2018	20/12/18		Submitted
WP6	D6.2	D15	Training Needs Assessment Plan	UCPH	Report	Confidential, only for members of the consortium	31 Dec 2018	20/12/18		Submitted
WP6	D6.8	D21	Mid-term training progress reports by supervision committee	ULG	Report	Confidential, only for members of the consortium	31 Dec 2018	20/12/18		Submitted

Explanation of the delays for the previously submitted deliverables

For the deliverables due before the Progress report, when they were some shifts regarding the dates, the explanations are detailed in the Progress report, already submitted on the Participant Portal.

Explanation of the delays for the submitted deliverables D6.6-D19 & D7.8-D32

- *WP6:* D6.6-D19 ENIGMA Summer school

This deliverable was submitted after the Summer school, which ended on July 07th. There was some delay before the submission due to the EPM work stoppage.

- *WP7:* D7.8-D32 Mid-term report

After discussion with the Project Officer Luisa Marconi, the common date found to hold the Mid term review meeting is in February 2018 (month 26) in Barcelona. The mid term report is due one month before the mid-term meeting. Therefore this mid term report will be submitted in January 2019.

1.1.4. Meetings during the first reporting period

As indicated in the Grant Agreement, regular meetings have been organized to prepare and manage the Enigma project. The details for the three first meetings organized before the Progress Report are in the Year 1 Progress report, submitted on the Participant Portal. After the Year 1 Progress report submission date, there were two other meetings:

- Meeting n°3 in Lausanne between workshops 3 & 4 in February 2018

See the complete minutes of the meeting in Annex 1 and the corresponding pages on the Enigma website: https://enigma-itn.eu/project-overview/meetings/enigma-meeting-n3-lausanne-9-10-february-2018/

- Meeting n°4 in Cargèse during Summer School in July 2018

See the complete minutes of the meeting in Annex 1 and the corresponding pages on the Enigma website: https://enigma-itn.eu/project-overview/meetings/enigma-meeting-n4-cargese-30-june-2018/

1.2. Explanation of the work carried per WP

1.2.1. Work Package 2: Explore coupled dynamic processes in targeted highly instrumented sites (Leader Beneficiary/Coordination of WP2: JUELICH)

Explain the work carried out in WP2 during the reporting period giving details of the work carried out by each beneficiary involved.

- Scientific objective 2: explore in-situ flow, transport and reaction processes to address current open scientific questions based on highly instrumented experimental sites where the new results, data and open source codes will be made available to academia and industry through a common on-line database

CSIC Barcelona/ESR1 Kevin De Vriendt: The first year was centered around numerical modelling, more specifically on the impact of heterogeneity and connectivity on mixing and reactions in coastal aquifers. The aim of the work so far has been to highlight the importance of how different types of heterogeneity can result in complex mixing patterns that contribute to reactions that may explain the formation of karsts in coastal landscapes. On top of this, looking at the basic mechanism of mixing in heterogeneous coastal aquifers may also provide insight into the fate of anthropogenic pollution before being discharged into marine environments. In addition, preparatory work has been performed for the experimental work that will be carried out next year during the Rennes-secondment. In this study, we will be using fluorescence probes and chemiluminescence reactions in order to visualise reactions across the salt/freshwater interface. Research on the highly instrumented sites will come into focus more in the second and third year of the work.

Leipzig/ESR2 Guilherme Nogueira: During the first year, high resolution time-series analysis of ground water levels and different tracer tests (total of eight) were carried out in the riparian aquifer of the Selke River to acquire a better picture of the system dynamics in different hydrological conditions (Figure 1). By adding dissolved oxygen (DO) as an extra parameter to be measured within a tracer test, we were able to easily show how oxygen consumption rates vary throughout the year and within the aquifer sections. Flow directions, transport parameters, as well as mean groundwater travel times varied considerably according to river discharge. Time-lapse ERT imaging of tracer injection also supported the evaluation of arrival and mean travel times, as well as preferential flow paths within the aquifer.
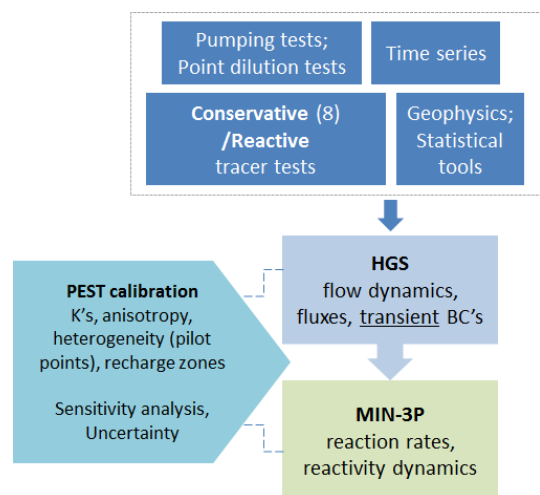

Figure 1. General scope of ESR2 research

UNINE/ESR3 Álvaro Pardo Álvarez: This first year has been mainly used to learn the necessary modelling tools to reach the project goals. Therefore, not much fieldwork has been carried out so far. Last March, three in-stream piezometers were installed in the Emme site for dissolved gas

relative concentrations analysis. After that field action, I was on secondment in Leipzig for 4 months. Within those months, I also attended the CMWR conference in St. Malo, France, where I presented my modelling advances and future goals of the project.

The core of my fieldwork will be conducted next January, when a big, month long pumping-test is planned at the Emme site. We will take advantage of it to measure temperature, tracer and hydraulic data over very different hydraulic scenarios. This will allow us to come up with the perfect database to carry out promising experiments on surface and subsurface water flow and solute exchanges.

ITASCA/ESR4 Justine Molron: In the first year, two experiments were completed at the SKB Äspö tunnel Hard Rock Laboratory (HRL) in Sweden. The objective was to develop a new approach for better assessing the safety of the bedrock barrier around canisters for nuclear waste disposal. The first experiment (November 2017) was to investigate the possibility to use the surface ground penetrating radar (GPR) to identify fractures close to tunnel walls at depth. I spent 1 month in Lausanne to process and interpret GPR data. During 3 months in Rennes, I constructed a 3D GOCAD model to visualize fractures and to support decision making. After discussions with SKB, ITASCA consultants, CNRS and UNIL partners, the position of 3 new boreholes of 9 meters depth were finalised (Figure 2). Based on the results, the second experiment (November 2018) was designed to involve surface GPR monitoring during pumping and tracer tests in the three new boreholes. The goal is to image the flow of water in fractures and their connectivity.
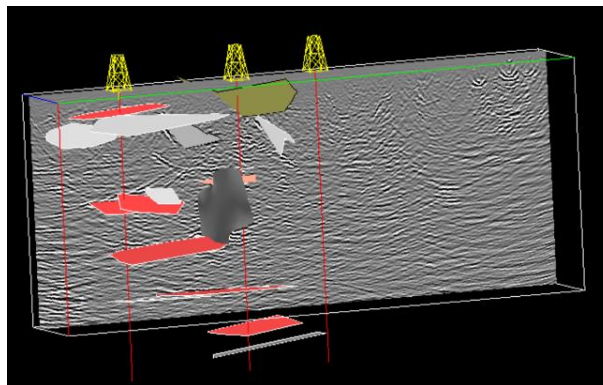
Figure 2. Fracture visualisation on 3D GPR sections from the first GPR survey and determination of three borehole positions for the GPR monitoring during tracer test experiment.

- Technological objective 2: transfer the obtained knowledge of process dynamics in heterogeneous porous and fractured media to operational models for predicting the evolution of subsurface environments.

CSIC Barcelona/ESR1 Kevin De Vriendt: During my secondment next year (Rennes), we will begin by looking at a homogeneous porous media to confirm the non-unique mixing rates across the saltwater mixing zone using a 2D sand tank (Figure 3). Using chemiluminescence reactions in an optically indexed matched media, we hope to observe simplified first-order reactions that will highlight zones of enhanced mixing. Once this is established at steady state, we will attempt to add transient forcings in the form of tidal fluctuations to see how mixing is impacted. Without the use of index matching, it is also possible that we use fluorescence probes to measure the products of reactants as it is discharged out the sand tank as an analogue to submarine

groundwater discharge. All numerical models used for visualisation, prediction and studies were carried out using Comsol Multiphysics.
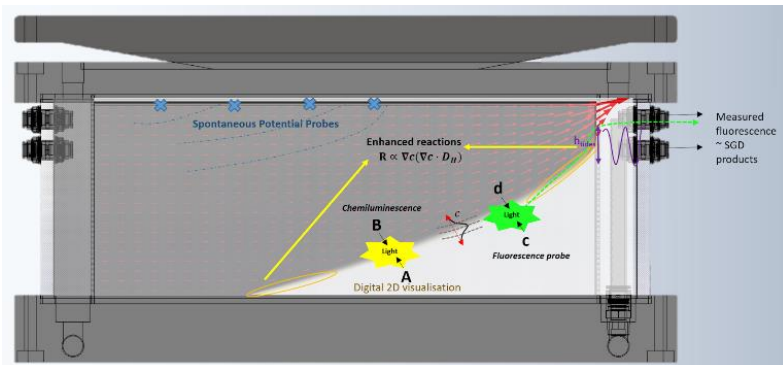

Figure 3. Conceptual schematic of reactions and measured variables expected during sand tank experiment.

<u>Leipzig/ESR2</u> Guilherme Nogueira: During the secondment at UNINE (three months), work on a numerical flow model in HGS has been initiated. This model will be calibrated with assistance of PEST using the different tracer tests and time-series of hydraulic heads and oxygen from the field site. The aim is to obtain further insights of system behaviour under different scenarios of temperature, distributed heterogeneity and river morphology, but also to get a better sense on how highly instrumented sites can help contribute for calibration of such models, and to improve their capacity and reliability. In the following steps, a reactive transport model will be set up (possibly coupling MIN3P with the established flow model) for better assessing the reactivity behaviour of the river-groundwater continuum with respect to redox-sensitive compounds, such as nitrate.

<u>UNINE/ESR3</u> Álvaro Pardo Álvarez: Throughout this year, I have learnt how to use the two numerical models that I will employ in my PhD project: HydroGeoSphere (fully integrated physically based hydrogeological model) and one of the OpenFOAM (CFD code) multi-phase solvers interFoam (IF). This latter model is adjusted by applying a very basic, manual calibration. However, HydroGeoSphere (HGS) requires further adjustment of the parameters. This is achieved through an automated calibration using PEST (Model-Independent Parameter Estimation and Uncertainty Analysis).
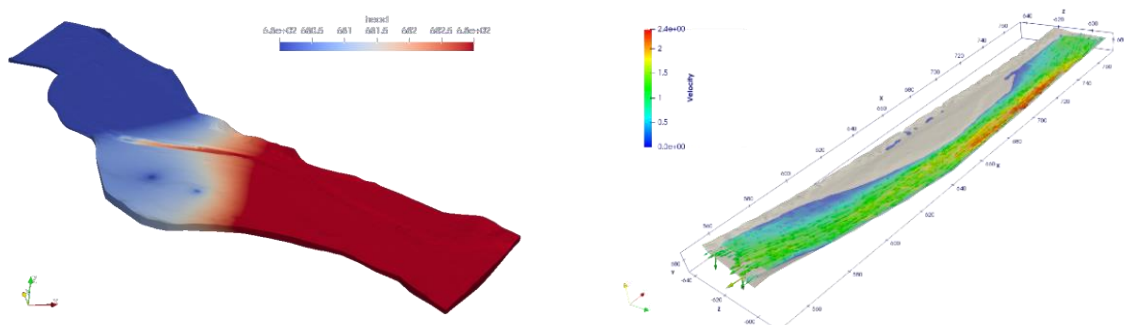

Figure 4. The right image corresponds to the HGS model setup to test the performance of the system due to the future pumping test in the Emme site. The left image shows an interFoam simulation. The image is included in the poster presented at the CMWR Conference 2018

I aim to couple HGS and IF (Figure 4). CFD hydraulic heads would be the most suitable approximation of realistic surface flow boundary conditions for integrated hydrogeological

modelling. Although this coupling has not been implemented yet, the required steps have been already specified, which implies that the first goal of the project is close to be achieved.

<u>ITASCA/ESR4</u> Justine Molron: This past year, I have created a 3D statistical Discrete Fracture Network (DFN) model based on deterministic, borehole and tunnel data from SICADA database (SKB) and GPR data acquired during the first experiment. During my secondment in Rennes (CNRS), I have learned how to create a stochastic DFN model with the 3DEC numerical modeling code. With these two achievements and the last GPR experiment, next year I will work on the conditioning of DFN models to deterministic data and create a stochastic geo-DFN (Figure 5). Finally, hydraulic data will be introduced to build a hydro-DFN (hydrogeological properties and the connectivities between fractures).
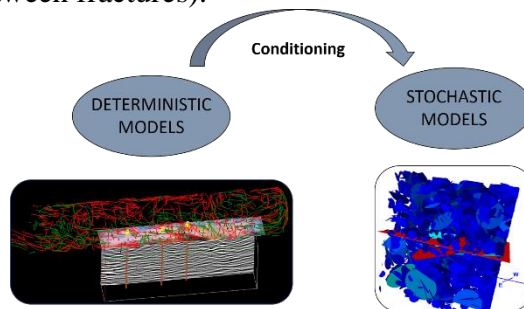
Figure 5. Conditioning of stochastic DFN models to deterministic data (borehole, tunnel and GPR data)

1.2.2. Work package 3: Quantify temporal changes in subsurface water content and fluxes distributions (Leader Beneficiary: UCPH)

Explain the work carried out in WP3 during the reporting period giving details of the work carried out by each beneficiary involved.

● <u>Scientific objective 1: design novel in situ experimental strategies for quantifying subsurface process dynamics by coupling innovative experimental methods and inverse modelling approaches</u>

<u>CNRS/ESR5</u> Lara Blazevic: A central objective of this work is to understand the co-eval changes between seismic information and water storage/flow in the critical zone. A first approach consists in estimating the near-surface pressure- and shear-wave velocities, from refraction tomography and surface wave dispersion analysis, respectively. Several rock physic models were tested to infer their ability to provide more quantitative informations about saturation, both from laboratory and field experiments at Ploemeur hydrogeological observatory (Brittany, France). In September, we carried out a controlled infiltration experiment on the Ploemeur site which was monitored by hydraulic, high resolution seismic and electrical resistivity methods. As the methods are sensitive to different physical properties and have different resolutions, we will first analyze the data sets independently and test different rock physics and petrophysical models, before continuing with clustering and joint inversion.

<u>CNRS/ESR6</u> Behzad Pouladi: A new model has been developed to describe temperature profile in boreholes, which is dedicated to the high resolution measurement ability of Distributed Temperature Sensing (DTS) data. The model has been validated by a numerical model, and tested on experimental data acquired in November at the Ploemeur hydrogeological observatory (Brittany, France). Unexpected high dynamic temperature changes in boreholes where observed, which can be linked to fracture flow variations and also tidal-related geomechanical processes. Long-term temperature monitoring has also been set up.

<u>UCPH Copenhagen/ESR7</u> Joel Tirado Conde: Monitoring of thermal dynamics in the subsurface using fiber optic distributed temperature (FO-DTS) sensing and thermal infrared (TIR) images from drone flights for the top part of the media (surface and upper 20 cm, unsaturated zone) and temperature profiling in boreholes for the groundwater temperature. The field campaigns have been carried out every 3-4 months with special attention to seasonal changes. Integrated modelling of the main field site, in 2D, to study the expected outcomes of the field measurements as well as to interpret the thermal signal in groundwater - surface water flux exchange processes.

<u>Muquans/ESR8</u> Anne-Karin Cooke: One year of monthly vertical gravity gradient survey with a relative gravimeter has been carried out at the geodetic observatory in Karstic environment on the Larzac Plateau, France. The potential of gradient monitoring for soil moisture distribution detection and the uncertainty of the methods are being investigated.

● <u>Technological objective 1: develop and validate innovative environmental sensing techniques</u> with the required sensitivity, as well as spatial and temporal resolution to monitor dynamic processes

<u>CNRS/ESR5</u> Lara Blazevic: We designed and carried out a controlled infiltration experiment on a 5 m² plot, and acquired high resolution seismic and electrical resistivity data along two orthogonal lines. 10 full geophysical datasets were acquired after each step of 400 liter of injected water. We will track the spatio-temporal evolution of the geophysical response and compare it with water content observations from a vertical TDR probes in the subsurface and injected volumes. As the methods have different resolutions, we will also study their individual applicability to monitor hydrodynamic processes in the critical zone.

<u>CNRS/ESR6</u> Behzad Pouladi: Following the quick temperature change observations, we designed a framework for real time flow profiling in a wellbore using DTS temperature data to analyze fracture. The framework is written in form of programing script, which may be published to be used by other researchers. Reflexions on the combination of DTS and precise point temperature observations are also ongoing.

<u>UCPH Copenhagen/ESR7</u> Joel Tirado Conde: The combination of FO-DTS and TIR imaging for the upper part of the media in combination with the profiling in boreholes is giving insights on the groundwater upwelling processes occurring on land while most of the existing studies focus on the water exchange with surface water bodies. In a stream valley wetland environment, these processes can occur around small scale concentrated areas (hot spots) and are evolving in time due to changes on the hydrological/environmental conditions so the resolution of the methodology applied must be high enough to capture them. Focusing on seasonal differences in the collected data, we expect to increase the knowledge on the dynamic behaviour of such systems.

<u>Muquans/ESR8</u> Anne-Karin Cooke: Survey protocols to monitor vertical gravity gradients for hydrological signal detection have been developed and applied and are being evaluated. The data is being interpreted with available hydro-meteorological data. The development and coupling of a hydrological model for the site with a gravity forward routine has been conducted for joint analysis. So far, ESR8 has already assisted in AQG testings at Muquans, Talence and at the Larzac observatory and is going to be trained in the operation of the instrument to be prepared for the soon to be conducted field evaluation. The operability and sensitivity at the level of $10nm.s^{-2}$ have been shown by Muquans in a publication this year (Ménoret et al., 2018).[2]

1.2.3. Work package 4: Create new methods for tracking the transport and reactivity of chemical species in subsurface (Leader Beneficiary: UNIL)

Explain the work carried out in WP4 during the reporting period giving details of the work carried out by each beneficiary involved.

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[2]Ménoret, V., Vermeulen, P., Le Moigne, N., Bonvalot, S., Bouyer, P., Landragin, A., & Desruelle, B. (2018). Gravity measurements below 10^{-9} g with a transportable absolute quantum gravimeter. *Scientific reports*, *8*(1), 12300.

- <u>Scientific objective 1: design novel in situ experimental strategies for quantifying subsurface process dynamics</u> by coupling innovative experimental methods and inverse modelling approaches

<u>UNIL Lausanne/ESR9</u> Alejandro Fernandez Visentini: Electrical Resistivity Tomography (ERT) has proven a useful technique for assisting hydrological studies by showing success in providing qualitative and structural constraints in different contexts. However, when used to quantitatively monitoring tracer tests, the method systematically under- and over predicts the plume's total mass and spatial dispersion, respectively. In great part, these failures arise when transforming the geophysical data (electrical conductivity for ERT) into the tracer concentration via some petrophysical relationship. Such relationship is by definition applied at the scale of a Representative Elementary Volume (REV) of the subsurface -in practice equated with the resolution scale of the ERT- within which a homogenous conductive phase (tracer) distribution is assumed. However, strong heterogeneity exists in the plume's mass distribution at smaller scales, evolving by the action of spreading and mixing and controlling an effective electrical response of the medium that is then spuriously interpreted in terms of the applied petrophysical relationship. Thus, there is the need of developing a scaling framework that accounts and corrects for these time-varying sub-resolution induced errors. Currently, the relationship between the conductive phase distribution and the effective electrical conductivity is being investigated both theoretically and experimentally for a simple case of a 2-D layered medium, aiming at providing the basis for studying more complex and realistic scenarios (Figure 6).
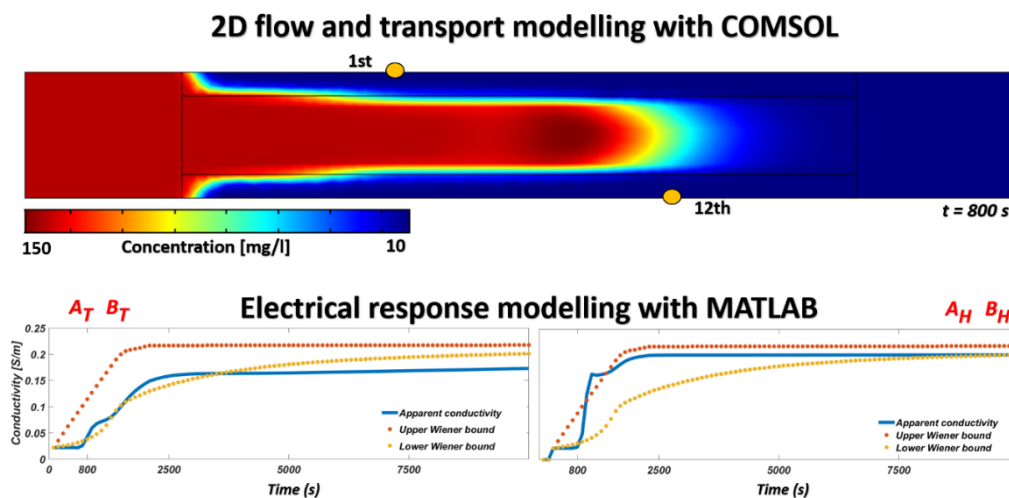

Figure 6: Top. Flow and transport numerical simulation in a simple 2-D layered medium that has two thin low permeability channels (top and bottom) and a thick high permeability channel (middle). Bottom. . Simulated effective electrical conductivity as measured between points labeled as 1st and 12th, by exciting the sample along the vertical direction (left) and horizontal direction (right). Extracted from poster presentation at 2018 Cargese Summer School of Flow and Transport

<u>FZJ Jülich/ESR10</u> Peleg Haruzi: Numerical study of time-lapse GPR full-waveform inversion to detect tracer plumes was carried out. Prior to a field test, GPR-FWI was tested for its potential to detect tracer plumes and to better plan the experimental setup. Detailed hydrogeological model was generated based on past measurements (point measurements, and GPR-FWI and ERT transects) of hydraulic cond., porosity and electrical cond., taking into account preferential paths

with spatial variability at decimeter scale – which is the scale GPR-FWI can resolve. Synthetic transport simulation allows synthetic time-lapse GPR-FWI crosshole imaging in order to reconstruct the plume. Resolution of plume reconstruction was tested (and is ongoing) for high and low electrical cond. contrasts, high electrical cond. limitation (due to signal attenuation), ideal transmitter-receiver separation for rel. permittivity and for electrical cond. parameter estimation, and time-lapse approaches.

ULG Liège/ESR11 Richard Hoffmann: Compared to common solute tracer tests, joint heat and solute tracer experiments also allow estimating heat advection and conduction, bringing additional information when imaging the dynamical subsurface processes. However, in complex and heterogeneous environments, it is extremely difficult to generate realistic models explaining heat and solute transport data sets. As a pre-step to inversion, the roles of parameter uncertainty and spatial heterogeneity using Monte-Carlo simulations were explored. An existing joint heat and solute tracer data set is used for prior uncertainty investigation and global sensitivity analysis (Figure 7). Deterministic models fail to predict the complementary tracer behavior, due to excessive smoothing (Figure 7a). In contrast, the variability of Monte-Carlo simulations realistically represents the complexity of field data and its analysis allows accepting or rejecting some prior hypotheses about heterogeneity (Figure 7). These pre-inversion validations are a requirement for classical inversion and direct predictions (e.g. Bayesian Evidential Learning) and will be further investigated.
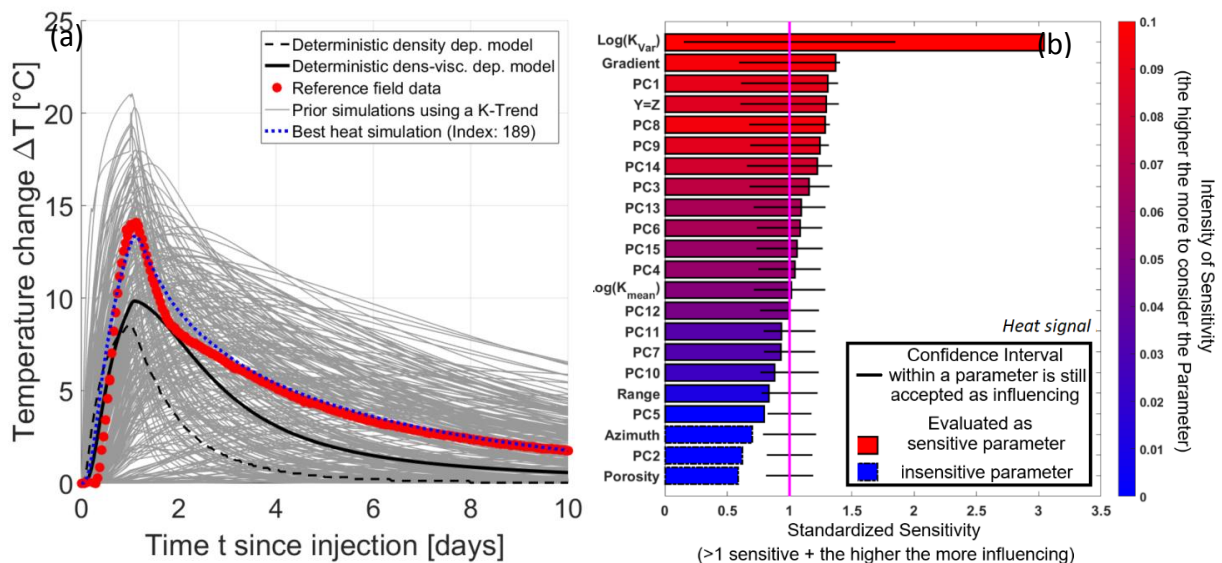

Figure 7: (a) One picked out observation point (3 m away of injection) of the joint heat and solute tracer data set showing the comparison of applying a deterministic model and Monte-Carlo simulations to generate 250 surrogate models as prior for further method validations. (b) Results of applying a distance based global sensitivity approach (method validation) to find a prior describing the experiment most realistic compared to common deterministic approaches.

FZJ Jülich/ESR12 Satoshi Izumoto: A soil column experiment with induced calcite precipitation has been performed in FZJ to investigate how the spectral induced polarization (SIP) response of calcite precipitation depends on solute concentration in collaboration with Yuxin Wu of the Lawrence Berkeley National Laboratory in the United States. The results implied that the SIP response of calcite is highly sensitive to the solute concentration near the precipitates, which may explain previously reported conflicting results. The results were presented at the 5th International

Workshop on Induced Polarization in Newark, USA. A manuscript has been prepared about this experimental work, and will be submitted to a peer-reviewed journal in January 2019.

- **Technological objective 1: develop and validate innovative environmental sensing techniques** with the required sensitivity, as well as spatial and temporal resolution to monitor dynamic processes

UNIL Lausanne/ESR9 Alejandro Fernandez Visentini: Conservative fluorescent tracer tests were performed in the laboratory using a novel experimental setup that consists in the coupling of a 2-D millifluidic setup equipped with a fluorimetric setup, and a geoelectrical monitoring setup (Figure 8). Experiment outputs: (i) high-resolution 2-D concentration (electrical conductivity) fields evolving over time in an artificial porous medium (from the millifluidic and fluorimetric setup), and (ii) effective electrical conductivity of the system evolving over time (from the geoelectrical setup).
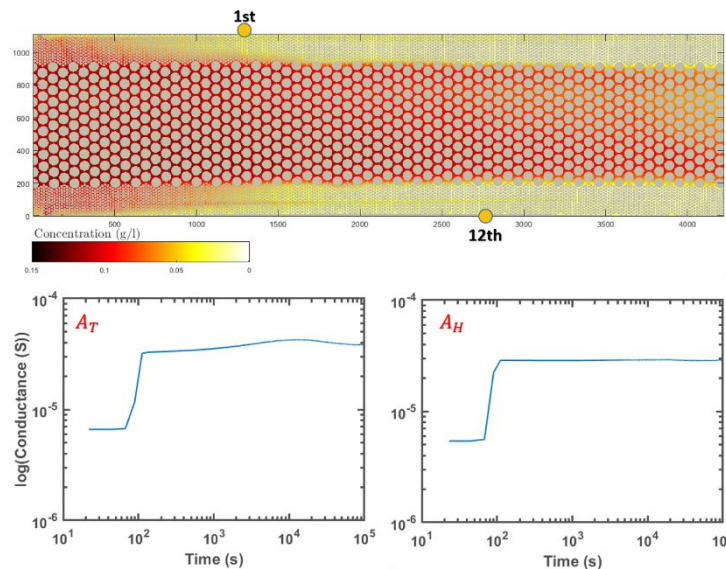
Figure 8: Top. Image capture of concentration field in a 2-D layered artificial porous medium that has two low permeability channels (top and bottom) and a thick high permeability channel (middle). Bottom. Effective electrical conductance measured between points labeled as 1st and 12th, by exciting the sample along the vertical direction (left) and horizontal direction (right).

FZJ Jülich/ESR10 Peleg Haruzi: Field experiment of time-lapse GPR-FWI to validate the numerical study findings was delayed because of late approval of the experiment, and later postponed because the setup of the experiment in Krauthausen needs to be modified. The current plan is to have small tracer tests of saline, desalinated and heat tracers, and one big experiment of saline tracer.

ULG Liège/ESR11 Richard Hoffmann: In April 2018, an innovative multi tracer experiment using jointly a dye tracer, heat and a dissolved gas cocktail, (He-Xe) was performed in a chalk aquifer nearby Mons, Belgium. A flowmeter test and optical well imaging assisted to identify an open horizontal fracture between two 7.55 m distant adjacent wells (Figure 9a). Using a dipole configuration for injecting heat for 70 hours, added by two solute pulses and complement by fiber optics, resulted in a strong heat delay and temperature rebound interpreted as double porosity and matrix effects of the chalk (Figure 9b,c). A dipole and push-pull configuration for injecting jointly a dye and the dissolved gases as innovative sensing technique (live time on site observed within a CF-MIMS system) shows, that the higher the tracer diffusivity, the higher the confronted flow heterogeneity. This advanced heterogeneity observation is important for further dual-domain transport modelling in conjunction with Monte-Carlo based direct prediction approaches (e.g. parts of Bayesian Evidential Learning).
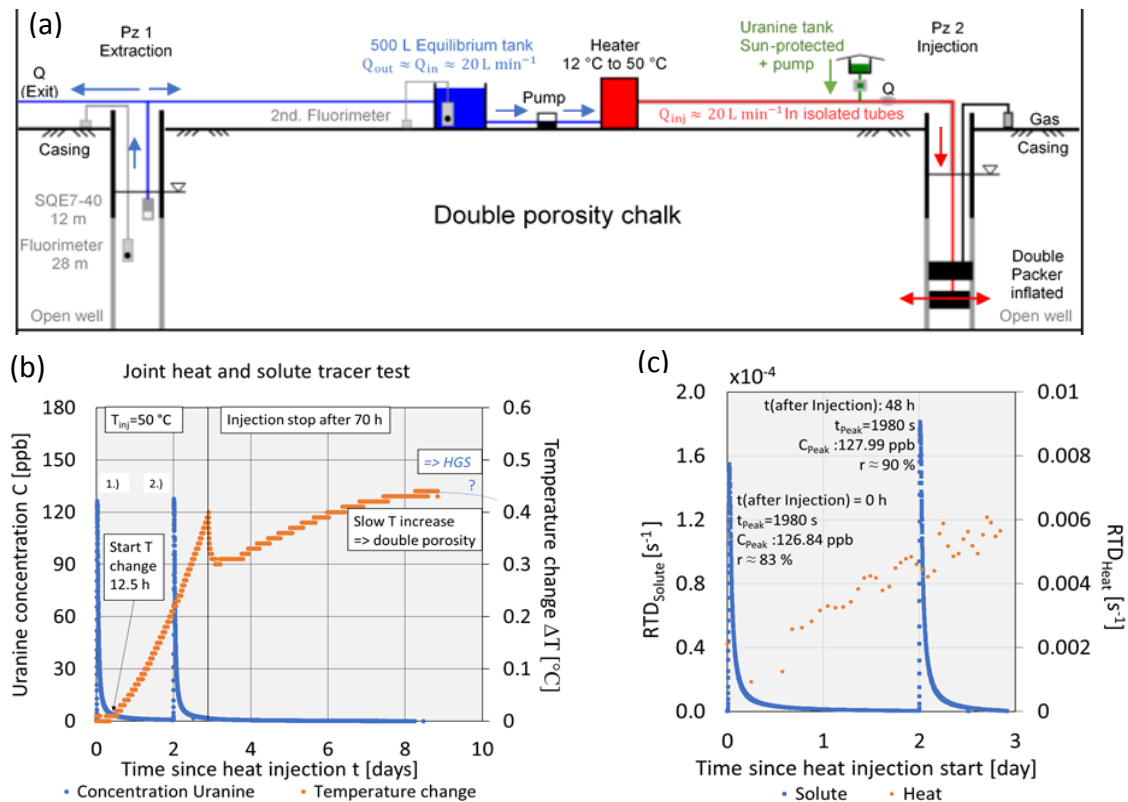
Figure 9: as example, an illustration of the Joint heat and solute tracer test is presented. (a) The tracer test dipole configuration (b) Observed heat and solute output signals showing an interpreted induced heat delay due to matrix interactions. (c) Heat and solute tracer signal comparison using a Residence time distribution function (normalized areas to 1).

FZJ Jülich/ESR12 Satoshi Izumoto: A novel laboratory setup combining a millifluidic-cell and an SIP measurement system has been developed to quantitatively investigate SIP response and biochemical reactions. The first test measurements were conducted during the first part of the secondment at the CNRS Rennes. The results showed that the SIP response of calcite precipitation can be successfully measured in combination with visual observation of calcite precipitation. The results will be presented at the American Geophysical Union 2018 Fall Meeting in Washington, USA.

1.2.4. Work package 5: Design inverse modelling strategies for dynamic processes in complex subsurface structures (Leader Beneficiary: EKUT)

Explain the work carried out in WP5 during the reporting period giving details of the work carried out by each beneficiary involved.

• <u>Scientific objective 1: design novel in situ experimental strategies for quantifying subsurface process dynamics</u> by coupling innovative experimental methods and inverse modelling approaches

<u>UT Tübingen/ESR13</u> Veronika Rieckh:

A modeling and inversion framework for monitoring solute tracer tests with the help of geoelectrical monitoring is developed in the project. Various forward solvers were tested for their appropriateness: The coupled PFLOTRAN-E4D system of PNNL, an implementation of DUNE, developed at the University of Heidelberg, and self-written matlab codes. The latter turned out to be most efficient for problems of the intended discretized domain size ($\approx 10^6$ cells/elements). A variant using Finite Element discretization (with streamline diffusion for the stabilization of advection-dominated transport) was compared to a Finite Volume scheme, which turned out to be more efficient, and slightly more diffusive. The chosen scheme can solve steady-state flow, transient transport and geoelectric monitoring using 4650 combinations of 144 electrodes, covering one day of simulated time, in 160 minutes computing time on an 8-core workstation. A different variant directly solves temporal-moment generating equations for concentrations and electrical-potential perturbations in 10 minutes computing times. A survey on ensemble-Kalman methods for nonlinear parameter estimation was performed, leading to the conclusion that the ensemble Kalman smoother with multiple data assimilation is the best candidate for fully coupled inversion of the ERT-signals obtained during salt tracer tests. This method will be implemented and tested by virtual examples in the first quarter of 2019.

In spring/summer 2018, field experiments were conducted at the hydrogeological test site Lauswiesen (Figure 10). Appropriate sampling methods as well as geophysical measuring protocols were established. As this project, aims for a high resolution of the subsurface repeated tracer tests are required. The current data set includes a test with the tracer injection over the whole length of the borehole in two directions; one with the enforced flow in the direction of ambient flow and one with the reversed flow field. Additionally, three tests with flow in the ambient flow direction were performed, in which the tracer injection was limited to one of three distinct depth intervals each. The measurement protocol involves drawdown observations, tracer breakthrough curves in up to 19 locations, and ERT monitoring using 144 electrodes in 4650 configurations.
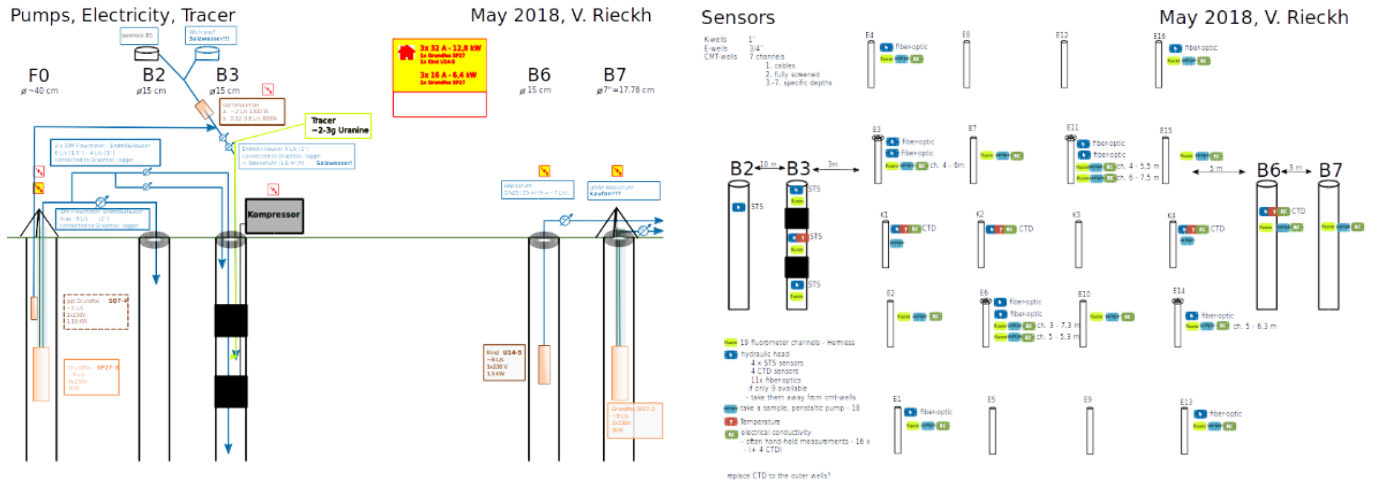
Figure 10. Set-up of the field experiments at the Lauswiesen site.

CSIC Barcelona/ESR14 Andrea Palacios: Time-lapse cross-hole electrical resistivity tomography (CHERT) was conducted in the Argentona experimental site. The experiment captured short-term and long-term salinization events in the coastal aquifer. This type of time-lapse geophysical survey is commonly used to study dynamic processes, but was never used before for seawater intrusion purposes. The time-lapse inversion includes a geostatistical operator that improves the imaging quality. It removes the rounded shape anomalies commonly found in the inversion of cross-hole measurements. In order to maximize the resolution of the time-lapse reference model, surface and cross-hole datasets were combined in joint inversion. Figure 11 shows the system put in place for this experiment and some results.
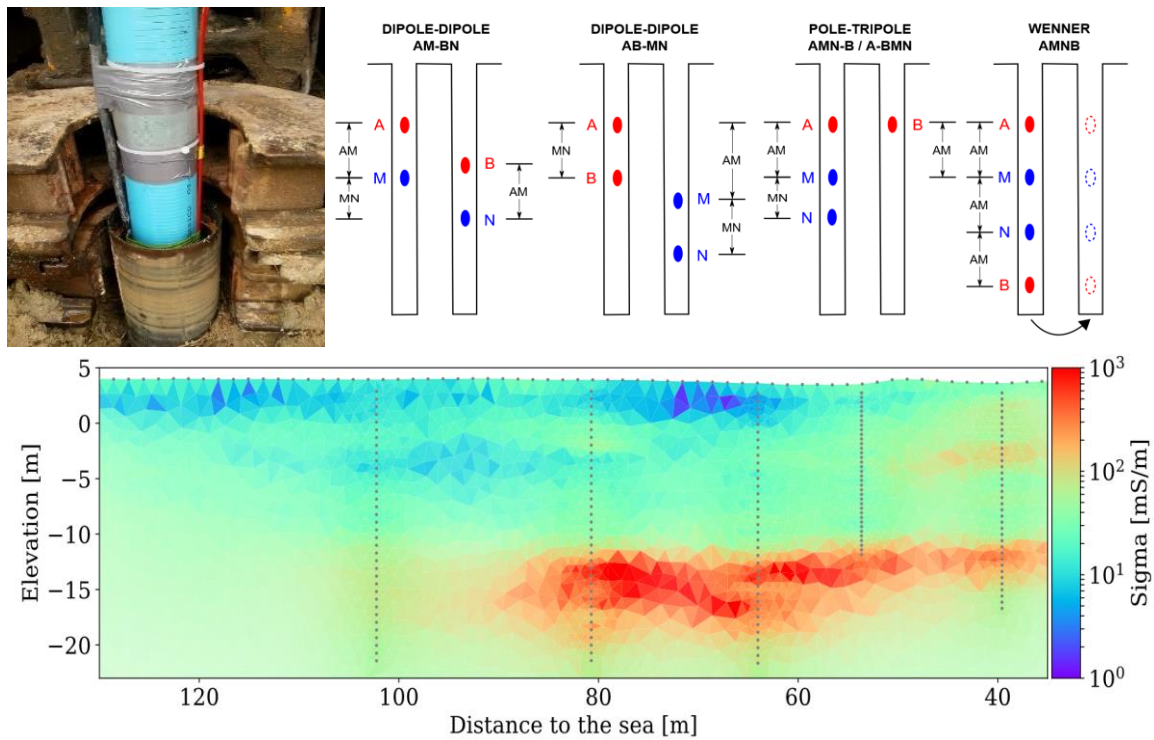
Figure 11. (Upper left) Stainless-steel meshes (electrodes) permanently fastened around PVC piezometers for time-lapse CHERT experiment during piezometer installation. (Upper right) Electrodes configurations used in the survey. (Bottom) Result from the inversion of surface and cross-hole ERT. Grey dots represent the electrodes around the boreholes and on surface. This cross-section is used as reference model in the time-lapse inversion.

ULG Liège/ESR15 Jorge Lopez Alvis: A probabilistic inversion framework to integrate realistic prior information on structure was proposed. The method aims to estimate structural uncertainty given geophysical data (cross-borehole ground-penetrating radar). To reduce computational demand (which is particularly important for high dimensional data) we propose to use features of the data. Finally, we apply different feature extraction techniques and propose a score to compare their performance. Figure 12 shows how an adequate selection of features can discriminate different structures (in the form of different training images used for multiple point geostatistical realizations) even in a two-dimensional space. A paper entitled "Updating structural uncertainty using features of geophysical data" is in preparation.
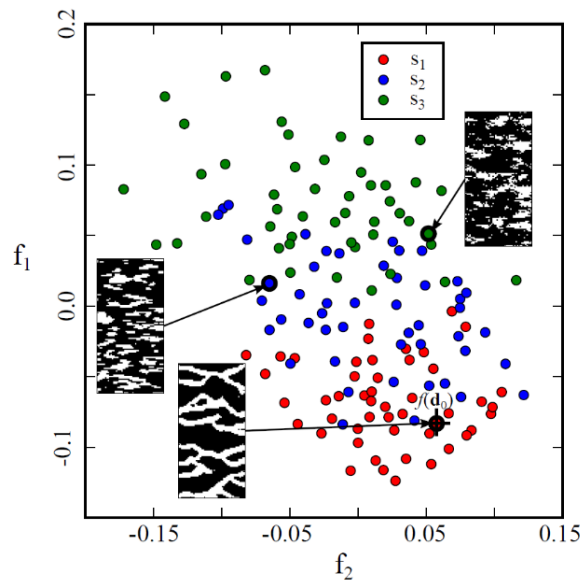
Figure 12: Feature extraction on ground-penetrating radar traveltime data resulting in a two-dimensional feature space (f_1 and f_2). Examples of realizations for each value of a structural parameter, which represents three different geological scenarios (s_1, s_2 and s_3).

- **Technological objective 2: transfer the obtained knowledge of process dynamics in heterogeneous porous and fractured media to operational models** for predicting the evolution of subsurface environments.

UT Tübingen/ESR13 Veronika Rieckh: The project of ESR13 aims at identifying static aquifer properties of heterogeneous porous media from joint geoelectrical and hydraulic observations of dynamic hydraulic tests rather than at predicting the evolution of the subsurface. The evolution of subsurface properties is strictly related to the test itself.

CSIC Barcelona/ESR14 Andrea Palacios: Geophysical properties (bulk conductivity) are related to hydrological properties (water conductivity) through petrophysical relations. Looking for the petrophysical relation that best represents the Argentona site is a very important part of the work. Modeling of flow and transport through porous media will include density-dependent flow models, to reproduce the changes in salinity/conductivity observed in the CHERT results. First forward modeling efforts reproduce the changes interpreted from the CHERT data, but inverse modeling is needed to make the model fit the experimental data.

ULG Liège/ESR15 Jorge Lopez Alvis: Bayesian evidential learning (BEL) has been explored as a method to integrate flow and transport simulations and geophysical forward models. By generating Monte Carlo samples of the predictions (e.g. transport of a contaminant) and the data (e.g. ground-penetrating radar data) one can search for a direct statistical relation between the two. However, prediction and data for subsurface problems are usually high-dimensional (number of spatial points multiplied by the number of time steps) and their relation is often non-linear, therefore statistical techniques for dimension reduction and linearization are necessary. Currently, an optimal combination of such techniques for a transport problem monitored by ground-penetrating radar is being searched.

1.3. Impact

In the Grant Agreement, there are three principal sections developed in the Impact of the Action part.

1. In the context of the first section "Enhancing the career perspectives and employability of researchers and contribution to their skills development", Enigma ITN has already achieved the main objective: a top-level doctoral training has been launched. The recruitment of 15 young researchers is now complete. Their training is now ongoing with the different beneficiaries.

2. In the context of the second section "Contribution to structuring doctoral / early-stage research training at the European level and to strengthening European innovation capacity", Enigma ITN has already achieved several objectives. Here are some examples :

   a. As the 15 projects have now started, the network is developing interactions between the Enigma members and a global collaboration.
   b. Common decisions have been taken within the network about the datasets. There is an ongoing reflection about data formatting, data storage strategies in the existing databases, and link creation between the databases. One beneficiary already created a new database access within the H+ database:
       After discussions between ESR11, ESR15, EPM and T.Hermans (Liège), A.Battais (Rennes IT engineer), ULG has now a functional database for the data that will be collected in Hermalle (link to the web access of this page).
       CSIC is also discussing with the H+ database IT engineers to create a database repository for Argentona (CSIC experimental site).
   c. Moreover, the training courses during the workshops were also opened to other students, for instance in Ploemeur, there were 19 other participants, in Lausanne 6 and in Cargèse 67.
   d. Industrial partners contributed to the training events: Itasca and Muquans presented their ongoing work to the ESRs during the workshop 2.
   e. Other partners contributed to the Cargèse ENIGMA Summer school, for instance: Jef Caers (Stanford University) gave a lecture, John Selker (Oregon State University) gave a lecture and organized several workshops…etc.
   f. Interactions have been launched thanks to the network (during the workshops, the meetings, the summer school…), for instance:
       - the ESR11 Richard Hoffmann learned about the mobile chemical laboratory developed by the University of Rennes. In the framework of ENIGMA, the mobile lab was made available to him for some of his tracer test experiments.
       - ESR4 Justine Molron worked with a lot of partners (SKB, Niklas Linde and people from UNIL, researchers from CNRS…) and another Itasca PhD student D.Doolaeghe for the experiments at Aspö.
   g. Within the network, several collaborations are being set up in order to facilitate complex experiments, for instance:

- ESR14 Andrea Palacios has performed a series of electrical resistivity tomography (ERT) surveys in one of the Danish field sites, and the inversion for temperature and its comparison and discussion with the thermal data collected by ESR7 Joel Tirado Conde are planned.
- A possible joint pumping test experiment including ESR 8 Anne-Karin Cooke and ESR 3 Alvaro Pardo Alvarez at the Emme site in Switzerland is currently in discussion for four weeks in January/February 2019 with potential participation of ESR7 Joel Tirado Conde.

3.   In the context of the third section " Quality of the measures to exploit and disseminate the project results", Enigma ITN has already achieved several objectives:

   a. To ensure the visibility of the network, a website has been created with all relevant information, updated news about the events… This website is also a way to highlight the ESRs contribution to conferences or Student Chapter or to publish their videos from the field or about posters trough their personal webpages.
   b. The 15 young hired researchers already participated in four workshops (for more details please see the corresponding reports already on the Participant Portal).
   c. The ESRs were also trained to use the H+ database and have started to participate to discussions about the data formats and data storage. Moreover, the network is working on developing the formats and sites adapted for several ESRs projects data on the H+ database. In addition, links to other databases used by the ESRs (Tereno or Hobe) are planned to be gathered and published on the website.
   d. The question of the intellectual property (IP) has not been addressed at this stage of the project. This will be discussed during workshop 5 in Barcelona.
   e. After discussion within the network, instead of a newsletter, less adapted to the network dynamics, a common calendar, available on the website, is updated by the EPM in order to share with the whole network the ongoing experiments/secondments/events of the different network members.
   f. The Enigma ITN members are actively communicating about the project and their research. The coordinators and the supervisors advertised about the project during scientific international conferences (AGU, EGU…). The website has been created. The ESRs created and now they update Enigma pages on social networks (for more details please see 2.1 about dissemination).

2. Update of the plan for exploitation and dissemination of result

Include in this section whether the plan for exploitation and dissemination of results as described in the DoA needs to be updated and give details.

2.1. Dissemination and public engagement activities:

- A website was created for the Enigma project to disseminate the project's purpose and to communicate information about the network, job offers, events and workshops. The website is regularly updated online, it is available at https://enigma-itn.eu/.
For each ESR and their project, dedicated webpages are now online in the menu "People" → Research Fellows and Research Projects.

- There were informal discussions and advertisements during well-known scientific events which are detailed in Annex 2:

  - At EGU 2017 (European Geosciences Union) in Vienna (Austria), a flyer was distributed and an informal meeting was organized.
  - At AGU 2016 and AGU2017 (American Geosciences Union) in San Francisco and New Orleans (USA) flyers were distributed and informal meetings were organized.

The corresponding flyers are in Annex 2.

- About the social networks: Damien Jougnot (CNRS Paris), the tutor appointed to the ESRs during the Enigma meeting n°3 in Liège and the ESRs, created Enigma profiles and groups on social networks :

Please have a look at:
- the Enigma ITN profile created by Damien Jougnot and the ESRs on ResearchGate!
- the hashtag #ENIGMAITN created on Linkedin and Twitter by the ESR to communicate about their activities!

- For the Summer School in Cargèse, Corsica (June 2018): A website was created: Cargèse2018 website and flyers were distributed during the AGU 2017 (see Annex 2). The network had the opportunity to interact with international well-known lecturers and with PhD students from different universities and companies. During this summer school, several videos were made with the ESRs presenting their posters. These videos should be available online early 2019.

- The ESRs participated in several scientific conferences(for the details, please have a look at the Dissemination and Communication section on their personal webpages on the Enigma website): the details of all dissemination and communication activities is available in Annex 3.
Another example: ESR10 Peleg Haruzi is a member of the "RWTH Aachen SEG Student Chapter" and a member of the board: see the Chapter website: https://rwthseg.wixsite.com/rwth-seg/board

- Several ESRs made some field videos. These videos are available on their webpage on the Enigma website: for instance, have a look at ESR4 video, ESR5 video (or at the soon available ESR13 video).

- The network H+, coordinated by the CNRS in France, published an article in the *Geologues* periodical of the French Geological society about the experiments of the H+ network, its database, and the Enigma network.

- The network is gathering information and competencies to use in common the H+ database for the data collected by the ESRs going on the field. For instance, the Hermalle site used by the ESRs at University of Liège is now created on the H+ site : http://hplus.ore.fr/en/enigma/data-hermalle

3. Deviations from Annex 1 of the Enigma ITN Grant Agreement [Description of Action]

As Enigma ITN beneficiary, did you encounter some issues that resulted in deviations from your initial project (described in the Annex 1- Description of the Action of the Grant Agreement)?
If it is the case, please explain the reasons for deviations from the Grant Agreement Description of Action, the consequences and the proposed corrective actions.

	Issues/ deviations	Reasons	Consequences	Corrective actions
Beneficiary 1-CNRS	ESR6 Behzad Pouladi was hired only starting on 01/12/2017.	There were a lot of issues and delays with the French visa for Iranian students.	ESR6 could not attend the first workshops in October 2017.	The training provided in Liège and Ploemeur were also provided later to ESR6 with direct hands-on during several field experiments in Rennes.
Beneficiary 2-CSIC	ESR1 Kevin de Vriendt was hired only starting on 16/12/2017	The initial selected candidate stopped answering to the supervisors emails during September 2017. A new series of interviews were launched by CSIC in order to find a new candidate.	ESR1 could not attend the first workshops in October 2017.	The training provided in Liège and Ploemeur were also provided later to ESR1 in Barcelona or in Rennes during visits.
Beneficiary 3- JUELICH	• The project of ESR12 was rescheduled without consequences for the work within the consortium. The novel experimental approach that combines spectral induced polarization (SIP) measurements with well-controlled millifluidic experiments has been successfully established as planned. However, initial testing has not focused on biofilm distribution as planned, because of increasing evidence that the SIP response of biofilms in porous media is more related to indirect effects related to pore space alteration (e.g. calcite precipitation). Therefore, an intermediate experimental step focused on calcite precipitation without microbiology has been added for system testing, and independent assessment of the "abiotic" SIP response. Work will progress as planned after this intermediate step. • For ESR10: Two different tracer tests are planned, on a small scale and on a bigger scale. Due to a delayed authorization from the municipality, and learning from the results of the detailed modeling of the Krauthausen test site, the first tracer test has been postponed to early 2019.			

Beneficiary 4-LEIPZIG	ESR2 Guilherme Nogueira was hired only starting on 03/11/2017.	ESR2 received a German visa only mid/end of October, which makes impossible to give him an UFZ contract before November and the German embassy needs his MSc certificate which was provided after 15 September	No consequences for ESR2, thanks to the corrective actions.	In order to allow him to attend the first meetings in Liege and Ploemeur, UFZ decided to offer ESR2 the possibility to come to the workshops with an "external guest invitation" by the UFZ. By doing so, they could fully cover ESR2 travel costs and accommodation.
	The PostDoc Dr Nico Trauth working in collaboration with Jan Fleckenstein and ESR2 found another position.		No consequences for ESR2.	Another Postdoc replaced Dr Nico Trauth in the team : Dr. Christian Schmidt
Beneficiary 5-ULG	Nothing to report			
Beneficiary 6-EKUT	Nothing to report			
Beneficiary 7-UCPH	Nothing to report			
Beneficiary 8-UNIL	Nothing to report			
Beneficiary 9-UNINE	Nothing to report			
Beneficiary 10-Muquans	Nothing to report			
Beneficiary 11-Itasca	Nothing to report			

3.1 Tasks

Each beneficiary can describe some specific Enigma ITN achieved tasks not previously indicated. Please also include explanations for tasks not fully implemented, critical objectives not fully achieved and/or not being on schedule.
Explain also the impact on other tasks on the available resources and the planning.

	Issues/deviations	Reasons	Consequences	Corrective actions
Beneficiary 1-CNRS	Nothing to report			
Beneficiary 2-CSIC	• ESR1: The secondments for ESR1 will occur later than planned, These shifts in schedule do not affect the rest of the activities: in February in Rennes (4 months: Feb- June 2019) and in Lausanne (4 Months: Feb- June 2020)). • ESR14: One month of secondment completed at the UCPH, from October 14th to November 13th, 2018. The secondment at UNIL that was planned for December 2018 was rescheduled for January 2019. This change in schedule does not affect the rest of the activities.			
Beneficiary 3-JUELICH	• Nothing to report for ESR12 • For ESR10: - Not initially planned tests were done at the Hermalle test site (Liege): Multiple crosshole GPR data were measured. The multiple cross-hole planes will be inverted using the FWI and an improved characterization is expected which will increase our understanding of the lateral and vertical changes of the time-lapse ERT measured heated water plume (Hermans et al., 2015). - One task is still a work in progress: A numerical study of time-lapse GPR full-waveform inversions to detect tracer plumes is currently being carried out. Detailed hydrogeological, and GPR electrical aquifer model properties were generated based on various past measurements, containing the spatial variability of the aquifer at decimeter scale; the scale GPR-FWI can resolve. Different parameters have been investigated to make sure that an optimum measurement setup will be chosen for the planned tracer tests. There was some delay for this tracer test due to a delayed allowance and partly based on the results of the modeling study (as indicated above). The delay will not impact the planning.			
Beneficiary 4-LEIPZIG	The status of the tasks of ESR2 is generally in line with the originally proposed schedule. A previously not indicated task included a technical visit to the University of Liege (ULG) for two weeks (March 2018), where the ESR focused on learning and improving inversion techniques for time-lapse Electrical Resistivity Tomography (ERT), with data acquired from tests at the ESR's field site. A small deviation from the original time line occurred in the time period for ESR2's first secondment at the University of Neuchatel (UNINE),			

	which was shifted by a few months, in order to facilitate participation of the ESR in a short course on the parameter optimization software PEST, which took place at the host university (UNINE) in September 2018. Those minor changes, however, did not negatively affect the course and progress of the overall project of ESR2.
Beneficiary 5-ULG	Nothing to report
Beneficiary 6-EKUT	Milestones set for the first phase concerned (1) the compilation of research and experimental plans, (2) the completion and reporting of first hydrogeophysical experiments, (3) and the completion of deliverable D5.1 "Validated algorithms for fully coupled 3D inversion for tomographic datasets". Ad (1): Research and experimental plans are compiled, however, it is still open how the fully-coupled inversion is addressed, two approaches are followed until now. This needs to be solved in the next 6 months. Ad (2): First hydrogeophysical experiments are completed at the Lauswiesen test site, the compilation of the experimental data is in progress, and is expected to be completed in the next 6 months – before the second experimental phase starts. Ad (3): The deliverable 5.1 is completed as required until Dec31st, 2018
Beneficiary 7-UCPH	Nothing to report
Beneficiary 8-UNIL	Nothing to report
Beneficiary 9-UNINE	Nothing to report
Beneficiary 10-Muquans	Given the high level of innovation associated to the development of the Absolute Quantum Gravimeter, the delivery of the instrument has been delayed by several months. Therefore, the experiment plan proposed for Anne-Karin Cooke was delayed. However, the theoretical analysis conducted at the beginning of the project revealed the interest to investigate in detail the potential of gravity gradient measurements for the characterization of subsurface water storage, as well as for the definition of an improved procedure for the comparison between absolute gravimeters. The research activities of AK Cooke for her first year were therefore reoriented to investigate this question in detail. She has thus conducted several experiments with existing relative gravimeters, consolidated with some theoretical developments, to quantitatively evaluate the interest of gravity gradiometers for hydrology.
Beneficiary 11-Itasca	Nothing to report

3.2 Use of resources

3.2.1 Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

If you had a need for a contribution from third party within the Enigma ITN project:

Specify in this section:
a) the identity of the third party;
b) the resources made available by the third party respectively against payment or free of charges
c) explanation of the circumstances which caused the need for using these resources for carrying out the work.

	Issues/deviations	Reasons	Consequences	Corrective actions
Beneficiary –CNRS	UMR Metis is concerned in the ESR5 supervision as it is a joined unit of CNRS. The co-supervision of ESR5 between CNRS researchers at Metis and CNRS researchers at University of Rennes 1 was indicated in the initial proposal but the concerned table disappeared due to template issues in the Grant Agreement.			An agreement is currently in preparation to clarify these elements (UMR Metis will be officially add as Third party to CNRS) and to precise again the elements of the problematic tables.
Beneficiary 2-CSIC	Nothing to report			
Beneficiary 3-JUELICH	Nothing to report			
Beneficiary 4-LEIPZIG	Nothing to report			
Beneficiary 5-ULG	In the Enigma project proposal, ESR15 activities were planned according to the permanent staff (Prof. F. NGUYEN) and postdoctoral researcher T. HERMANS: "*Dr. Thomas Hermans (15%) is a postdoctoral researcher, geophysicist, expert in multiple-point geostatistics and inverse modelling, he will support ESRs15 and 11.*"[3] based on their complementary in terms of expertise. The research topic of ESR15 activities are based on the collaboration of Prof. F. NGUYEN and T. HERMANS			University of Ghent is a new partner of Enigma ITN network (for the details, please refer to the Formal Notification sent by Coordinator in November 2018).

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[3] See part B2, page 85 of the Sealed proposal on the Participant Portal

	In October 2017, Thomas HERMANS obtained a permanent position as Assistant Professor at Ghent University. Then, he officially left the ENIGMA consortium as Ghent University was not an official partner, but the collaboration continued until now and Thomas HERMANS has been participating to many actions of the network (for the details, please refer to the Formal Notification sent by Coordinator in November 2018)	
Beneficiary 6-EKUT	Nothing to report	
Beneficiary 7-UCPH	Nothing to report	
Beneficiary 8-UNIL	Nothing to report	
Beneficiary 9-UNINE	Nothing to report	
Beneficiary 10-Muquans	Nothing to report	
Beneficiary 11-Itasca	Nothing to report	

Table of appendices

Annex 1: Minutes of the two Enigma ITN meetings organized between February 2018 and December 2018

Annex 2: Communication documents (flyers distributed before beginning of the project and before the Summer School)

Annex 3: Details of all dissemination and communication activities achieved by the students during the Reporting Period 1

Annex 1

ENIGMA *Innovative Training Network:* **European training Network for In situ imaGing of dynaMic processes in heterogeneous subsurfAce environments**

Minutes of the Enigma ITN Meeting n°3

Lausanne, 09 & 10 February, 2018

University of Lausanne, Géopolis building, Room 2121

Programme of the meeting

Friday 09/02

09h00 – 09h30	General presentation & Summary/Feedback about Workshop 3 by the ESRs	Niklas Linde ESR
09h30 – 10h30	**ESR scientific presentations** **WP2 :** Explore coupled dynamic processes in highly instrumented sites : ESR 1, 2, 3, 4 *Individual ESR presentation [1]:* 10 min/ESR *Work Package common discussion [2]:* 5 min group presentation by ESR 1, 2, 3, 4 followed by 15 min discussion	Chairman : Sander Huisman (FZJ)

Coffee break

11h0 -12h00	**ESR scientific presentations** **WP3 :** Enhance our capacity to monitor temporal changes in the spatial distribution of subsurface water content and fluxes : ESR 5, 6, 7, 8 *Individual ESR presentation[1] :* 10 min/ESR *Work Package common discussion[2]* : 5 min group presentation by ESR 5, 6, 7, 8 followed by 15 min discussion	Chairman : Majken Looms Zibar (UCPH)
12h00 – 13h00	**Supervisory Board meeting** - Mid-term review meeting to be decided (date, place: Barcelona 2019) - Dates for workshop 5 in Barcelona 2019	P.Davy & presentation about Barcelona by CSIC
13h00 – 14h00	**Lunch**	

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[1] *Individual ESR presentation*
- o Scientific objectives, first results, open questions, and planed actions (e.g. experiments, sites data archiving) : 4 to 8 slides [8']
- o Questions [2']

[2] *Work Package presentation by the ESR group corresponding to each WP :* 5 minutes presentation (4/5 slides) to:
- o Identify the common main questions of each WP
- o Discuss about possible joint experiments or actions
- o Propose a plan for a review article for each WP

14h00 -15h00	**ESR scientific presentations** **WP4 :** Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids : ESR 9, 10, 11, 12 *Individual ESR presentation[1] :* 10 min/ESR *Work Package common discussion[2] :* 5 min group presentation by ESR 9, 10, 11, 12 followed by 15 min discussion	Chairman : N. Linde (UNIL)

Coffee break

15h30 – 16h20	**ESR scientific presentations** **WP5 :** Design inverse modelling strategies for imaging dynamic processes in complex subsurface structures: ESR 13,14,15 *Personal presentation[1] :* 10 min/ESR *Work Package common discussion[2] :* 5 min group presentation by ESR 13,14,15 followed by 15 min discussion	Chairman : O. Cirpka (UT)
16h20-17h00	Discussions between supervisors and ESRs about secondments (reminder of rules and the ones planned)	Chairman : F. Nguyen & P. Davy
17h00- 18h00	**Experimental infrastructure Board** meeting: Experimental sites supervisors report questions / issues / opportunities raised from ESR presentations Database: - Synthesis of data archiving and disseminating strategy for each ESR - Plan to resolve remaining issues - Link between Enigma website & databases	Chairman: T. Le Borgne

19h30   *Social Event at Café du Grütli*

Saturday 10/02

09h00 – 09h30	Reporting aspects of Enigma ITN: - *Presentation of already registered delivrables & future ones (MS6…)* - *Planning for next scientific deliverables* - *Potential of doing scientific deliverables as review articles*	M-F.Gerard T.Le Borgne
09h30-10h00	Training & tutoring Committee (PCDP status & eventual questions)	F. Nguyen
Coffee break		
10h30 – 11h00	Organization of the upcoming Cargese summer school: - organization of practical works (geophysics on the beach, fibre optics, drone, modeling, lab…) - organization of advisory board meeting - involvement of ESRs - Summer School Organization of Barcelona Workshop (2019)	D. Jougnot C. Roques T. Le Borgne CSIC
11h00-12h00	Discussions between supervisors and ESRs about secondments / Informal discussion	

Lunch

List of Participants

Participant Enigma meeting - Lausanne	Concerned ESR (Beneficiary)				
Niklas LINDE	ESR9-UNIL Lausanne				
Olaf A. Cirpka	ESR13 - Uni Tübingen				
Philippe DAVY	Coordinator CNRS				
Marie-Françoise GERARD	Coordinator CNRS				ESR
Tanguy LE BORGNE	Coordinator CNRS		1	ESR 13	Veronika Rieckh
Damien Jougnot	Coordinator CNRS		2	ESR 02	Guilherme Nogueira
Sander HUISMAN	ESR12-FZ Jülich		3	ESR11	Richard Hoffmann
Alain DASSARGUES	ESR11-ULG Liège		4	ESR15	Jorge Lopez Alvis
Jan-Olof Selroos	SKB - partner of ESR4		5	ESR04	Justine Molron
Nico Trauth	ESR2-UFZ Leipzig		6	ESR07	Joel Tirado Conde
Olivier Bour	ESR6-CNRS Rennes		7	ESR08	Anne Karin Cooke
Caroline Darcel	ESR4- ITASCA		8	ESR05	Lara Blazevic
Majken Caroline Looms Zibar	ESR7- UCPH		9	ESR03	Alvaro Pardo Alvarez
Philip Brunner	ESR3 - UNINE		10	ESR12	Satoshi Izumoto
Marco Dentz	ESR1-CSIC		11	ESR14	Andrea Palacios
Jean Lautier-Gaud	ESR8-Muquans		12	ESR9	Alejandro Fernandez Visentini
Frederic NGuyen	ESR14-Uni Liège		13	ESR10	Peleg Haruzi
Annick Battais	CNRS coordinator (database)		14	ESR1	Kevin de Vriedt
Charlotte le Traon	CNRS coordinator (database)		15	ESR6	Behzad Pouladi

Friday 09/02

❖ General presentation & Summary/Feedback about Workshop 3

Introduction by Niklas Linde
Short self-introductions by all participants. Presentation of the meeting programme, social event & city opportunities by Niklas Linde.

❖ ESR and Work package scientific presentations

To prepare ESR presentations and discussions, the email in Annex 1 was sent to the network before the meeting. The ESRs were asked to work as a team of 3/4 people (corresponding to each WP, for instance ESR 1,2,3,4 for WP 2) to prepare the discussion for each work package. In particular, the objective was to think about the possible content and structure of a scientific review for each work package, which could be coordinated by each ESR group with the help of senior researchers from the network.

Reminder: reviewlet is a new suggestion from the Journal of Hydrology. The following explanation from one author or editor was provided by Tanguy le Borgne to the ESRs:

"

Mini reviews are focused in terms of topic and period of time, and are short in length.

It might be useful to contrast to the more common comprehensive type of review. For example, rather than "Review of Hydrogeophysics", a mini review should be something like "Advances in Near-Surface Hydrogeophysics 2000-2015". Or instead of "Parameter Estimation in Groundwater Modeling", it could be something like "Recent Advances in Computational Methods for Large-Scale Data Assimilation". Or instead of "Hydrologic

Observations", it could be something like "Recent Developments in Sensor Technologies for Near-Surface Hydrology".

In terms of length, the paper should not exceed 3000 words (not including references, abstract, and title and author blocks). References would be limited to no more than 80, to inspire selectivity. These requirements should encourage timeliness, focus, and tractability. Authors will undertake to write such reviews after invitation and consultation with the supervising editor. Reviews can be proposed by readers using a brief synopsis (e.g., one page) of the proposed scope.

A mini review should be reasonably complete but should also have a tutorial component. It should be much more than a listing of papers published on a topic in a certain period of time. It should give a sense of what are the motivations for the research, what are the real challenges, what factors drive progress, and what are future challenges. These papers should be accessible to new graduate students and should be useful to non-specialists. What we try to achieve: (1) If one wanted to quickly get a snapshot of a given field, this would the kind of article to pick up and read, and (2) If one wanted to introduce students / postdocs to a given area, one might hand them a handful of such reviews.

Some mini reviews may have a big tutorial component – there is a need for suggesting better ways to explain advanced concepts in research. They should be balanced but some mini reviews may also have a substantial opinion component, as long as the opinion and editorializing parts are clearly indicated as such.

"

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Summary of identified potential reviewlets

WP2: Tracer and geophysical techniques for river/GW interactions
Senior leaders: Jan Fleckenstein & Philippe Brunner

ESR Kevin de Vriendt, Guilherme Nogueira, Alvaro Pardo Alvarez+ additional involved ESR Joel Tirado Conde

Remark: Given the large number of reviews on river/GW interactions, the precise topic of the reviewlets should be focused on an aspect that was covered by recent reviews. In any case, this review will be very useful to the ENIGMA students.

WP3: Novel methods for soil moisture/storage and fluxes
Senior leaders: Majken Looms Zibar and Olivier Bour

ESR Lara Blazevic, Behzad Pouladi, Joel Tirado Conde, Anne-Karin Cooke

Remark: the topic should be more focused for a reviewlet. Question: do we want to include both storage and fluxes?

WP4: Process-based Imaging transport and reactivity
Senior leader: Niklas Linde

ESR Alejandro Fernandez Visentini, Peleg Haruzi, Richard Hoffmann, Satoshi Izumoto + additional involved ESR Kevin de Vriendt

Remark: this topic is quite clear for a reviewlet.

WP5: Joint inversion versus joint prediction
Senior leaders: Olaf A. Cirpka & Frederic Nguyen

ESR Veronika Rieckh, Andrea Palacios, Jorge Lopez Alvis + additional involved ESR Justine Molron

Remark: this topic is quite clear for a reviewlet.

Plan for starting the reviewlets:
- **Before Cargèse:** exchanges between ESRs and senior leaders to define a skeleton/plan
- **At Cargèse:** brainstorming and discussions on each reviewlet
- **After Cargèse:** writing the draft

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Details of discussions

1. **WP2 :** Explore coupled dynamic processes in highly instrumented sites : ESR 1, 2, 3, 4

Individual Presentations by Kevin de Vriendt[1], Guilherme Nogueira[2], Alvaro Pardo Alvarez[3], Justine Molron[4]

WP2 Common presentation chaired by Sander Huisman (link to on line WP2 presentation)

Sander Huisman: the division into WPs may be inappropriate; the subject of WP2 is the core of the whole ENIGMA

- Activities: there are difficulties to find common subjects/interests for the deliverables or for common reviews.
- Possible joint experiments : they have 4 ideas for common experiments
    - Conservative/reactive tracer tests to evaluate main groundwater flow paths and residence times/reaction rates (ESR 1, 2, 3 and 4)
    - Tracer tests combined with ERT/GPR (ESR 1, 2, 3 and 4)
    - Joint experimental campaigns using techniques developed in the different ESR projects (ESR 2 and 3)
    - Experimental benchmarks for models (ESR 1, 2, 3 and 4)

Sander Huisman feels that it is difficult to relate to this WP because it is really broad.
For instance for the deliverable D2.1: the subject is much broader than just WP2.
It is the same case for D2.2
For deliverable D2.3, the entire network is concerned.

Niklas Linde: good job on these presentations. The idea was to start talking together; eventually your links with other ESRs will be according to affinity between subjects. The organization of presentations in terms of work packages was to avoid the complexity to coordinate 15 ESRs/projects together. The idea today is to have some discussions and start to see how we could advance.

Olaf A. Cirpka: for Kevin de Vriendt, mixing of solutes, not sure whether the reactivity in the hyporheic zone is similar to that of freshwater/saltwater […] *Scientific discussion with Nico Trauth and Kevin de Vriendt*

Jan Olof Selroos: in workpackage WP2, a way to link between Justine Molron (ESR4, a subject that is not immediately related to the other subjects in WP2) & the others could be through tracer tests and density effects of water with different compositions.

Majken Looms Zibar: One possibility is to consider the WP2 title: "highly instrumented sites" and focus on highly instrumented sites -> to focus on what additional information and insights are offered by such sites.

It is a difficult task for these four ESRs only, but other ESRs can contribute. The 4 ESRs in WP2 are the ones in charge to gather and write down the common required deliverables and/or potential review.

2. WP3 : Enhance our capacity to monitor temporal changes in the spatial distribution of subsurface water content and fluxes : ESR 5, 6, 7, 8

Individual Presentations by Lara Blazevic[5], Behzad Pouladi[6], Joel Tirado Conde[7], Anne-Karin Cooke[8]

WP3: Common presentation chaired by Majken Looms Zibar (link to on line WP3 presentation)
Joel Tirado Conde: this WP is also very broad; how can we write a 6 page-reviewlet? Maybe focusing on soil moisture, this could possibly be a solution.

Possible joint experiments or actions:
- o Application of the different methodologies (seismic, gravity, temperature) to a common site to quantify (for example) soil moisture in order to see whether we obtain similar results with all of them.
- o Couple seismic, thermal imaging techniques and gravimetry to better represent/characterize the medium and groundwater flow

Jean Lautier Gaud: a suggestion: you can investigate the ability to collocate the changes/
To what extent can you adapt fiber optics / collocated measurements?
Or to use the components within gravimeters to do something with fiber optics

Majken Looms Zibar: for the review, you could see what has already been done, what is already available.

Olaf A. Cirpka: do we have to stick with the project plan? The WPs are very artificial.

Philippe Davy: this might be possible but we have to discuss together how to manage this.

Majken Looms Zibar: it would be a very artificial review so it have to be a way that you could identify and consider the relevant methods. It could be interesting to find a way to write something.

Niklas Linde: a reviewlet could be written in the later part of the project. This is just to keep in mind. First, write the reports/deliverables and then we will see if there are reviewlets that could come out of the reports. The reports are more specific things.

Tanguy Le Borgne: you should not stick to the WP, for interested individual PhDs, feel free to evolve. Most important: to have something which has a sense for the group. In WP3, it seems natural to work together, this is going in a good direction. In WP2, only

Justine was not really in the global subject. What site could be relevant for common experiments?

Lara Blazevic: 3 of the ESRs are in France, so … this would probably be in France for common experiments, probably in Larzac.
Tanguy Le Borgne: in Ploemeur, it could be interesting too.

3. **WP4 :** Create new methods for tracking the transport and reactivity of chemical species in subsurface fluids : ESR 9, 10, 11, 12

Individual Presentations by Alejandro Fernandez Visentini[9], Peleg Haruzi[10], Richard Hoffmann[11], Satoshi Izumoto[12]

WP4 Common presentation chaired by Niklas Linde (link to on line WP4 presentation)
This WP is relatively easy to handle, not too broad.
Some reviews exist, but there are still space for new reviews and comments.

Joint experiments: Joint/multiple tracer approach complemented by geophysical tools (WP4.2)

Tanguy Le Borgne: there is clearly space for an interesting review in this field.

The general feedback is that the group is working well together and that there is clear plan for common actions and review.

4. **WP5 :** Design inverse modelling strategies for imaging dynamic processes in complex subsurface structures: ESR 13,14,15

Individual Presentations by Veronika Rieckh[13], Andrea Palacios[14], Jorge Lopez Alvis[15]

WP5 Common presentation chaired by Olaf A. Cirpka (link to on line WP5 presentation)
For them, the WP is fine, there are commonalities as they all focus on inversion.

Possible joint experiments or actions:
  1.   "Prediction focused approach" (Bayesian Evidential Learning) in Argentona site.
  2.   Inversion of time lapse crosshole ERT (CHERT) data using Ensemble Kalman Filter for "natural" salt tracer tests in Argentona site.
  3.   ERT acquisition strategies (surface and CHERT).
  3.a.   ERT data filtering -because time-lapse data might be very sensitive on noise in the data
  4.   Comparison of data inversion, data assimilation and Bayesian Evidential Learning methods
  5.   Applying result to the Selke site (Guilherme, Leipzig)

The general feedback is that the group is working well together and that there is clear plan for common actions and review.

❖ Secondments

Marie-Françoise Gerard and Philippe Davy present the terms and conditions of secondments to the network. They remind what was proposed in the initial contract: this is what is supposed to happen. If there are absolute necessary changes, with scientific explanations, the ESRs and the supervisors should let the Coordinator know rapidly so that the Project Officer could be contacted to discuss about the changes.
Marie-Françoise Gerard will wait for emails from the ESRs with secondments details of all ESRs before March 20th. The Project Officer would be contacted once all the information of the different secondments for all ESRs to discuss about the potential necessary modifications.

❖ Experimental Infrastructure Committee (EIC) meeting, chaired by Tanguy Le Borgne

To prepare these EIC discussions, the email in Annex 2 was sent to the network before the meeting. The ESRs were asked to fill in a shared document "Enigma data: strategies, database, formats _ January 2018" in order to develop a strategy to save and store all the data produced in ENIGMA, and also to plan secondments and field experiments.

Summary of main ENIGMA joint experiments

The purpose of the discussion was to identify possible joint experiments where the colocation of the different instruments and methods developed within ENIGMA would be interesting. This will bring an added-value of the network beyond a collection of 15 PHD students working in parallel. A few experiments were already identified (see below) but there are clearly more opportunities. Marie-Françoise will gather information of on-going and planned experiments to update regularly a common calendar of ENIGMA experiments/field activities and secondments on the website.

Krauthausen natural gradient tracer experiment (Jülich)
Leaders: Peleg Haruzi and Jan Van der Kruk
Participants: ULG Liege + Guilherme Nogueira + other interested?

Emme site pumping experiment (Neuchâtel)
Leaders: Alvaro Pardo Alvarez and Philip Brunner
Participants: Joel Tirado Conde

Lauswiesen site forced gradient tracer experiment (Leipzig)
Leaders: Veronika Rieckh and Carsten Leven
Participants: Peleg Haruzi

SKB tracer test experiment
Leaders: Justine Molron, Niklas Linde, Philippe Davy
Participants: Lara Blazevic, Behzad Pouladi, Tanguy Le Borgne, Olivier Bour

Argentona pumping test experiment (CSIC Barcelona)
Leaders: Andrea Palacios, Jesus Carrera
Participants: Lara Blazevic, Kevin de Vriendt, Maria Pool, Marco Dentz

> **Others**
> Information on other experiments will be gathered and updated on the website.

Details of discussions on data archiving

The discussion about the choice of database and storage/dissemination strategy was done following Table 1 & Table 2. Each ESR should have chosen a database before the Cargese summer school.

ESR	Sites	Models	Data types	Foreseen Database	Format
ESR11 - ULG Richard	• Hermalle sous Argenteau (+Colonster), • Hyderabad • Test site at Mons?	HydroGeoSphere Pest	• Chemistry samples + multiparameter probe data: O2, CO2, pH ...	• H+ database	• H+ format
			• hydraulic data + pumping test data (drawdown)	• H+ database	• H+ format
			• Tracer test: fluoscein concentrations + Temperature (+DTS)	• H+ database	• H+ format
			- Geophysics: GPR	• Repository in H+database	• segy + pdf with explanations
ESR3-UNINE	Emme site	- HydroGeoSphere (HGS) - OpenFOAM	• Tracer test • UAV data • Hydraulic data	• HydroShare database	• To be defined
ESR7-UCPH Joel	•HOBE sites (UCPH) •TERENO sites (UFZ)	Hydrogeosphere	• UAV data • Hydraulic data • DTS data • Temperature (profile) data	HOBE database	• H+ format

| ESR	Sites	Models	Data types	Foreseen Database	Format
ESR12-FZJ Satoshi	• Ploemeur site • SIP measurement system • Imaging setup (camera etc.)		• SIP signal • Image data • Hydraulic parameters	• H+ database	• H+ format
ESR15-ULG Jorge	• Hermalle sous Argenteau • Llobregat-Argentona	-pyGIMLi -mGstat	• ERT (surface and borehole) • GPR (borehole) • Tracer test	• H+ database	• H+ format
ESR14-CSIC Andrea	• Argentona site		• Time lapse ERT (crosshole) • Heat tracer data (fiber optics) • Time series of Head data, conductivity, temperature, salinity (borehole monitoring)	• H+ database (in discussion)	• H+ format

ESR	Sites	Models	Data types	Foreseen Database	Format
ESR2-UFZ Guilherme	• TERENO Selke (UFZ) • HOBE sites (UCPH)	MIN3P / (HGS)	• Time series of Q,WL,T,EC,DO • Tracer test data (salt, reactive compounds: DO, Raz/Rru) • ERT • Hydrogeological parameters (aquifer props.)	To be defined	To be defined
ESR8-µQuans Anne-Karin	Larzac (H+)	Larzac (H+)	?	? => Probably H+ database	?
ESR5-CNRS Lara	• Ploemeur • Orgeval • HRL SKB	• SWIP • PFC3D, 3DEC	- • Seismic data • Core data	• H+ database • Irstea Oracle • Aspo HRL database	• H+ format • segy

Table 1: Data strategies- 1/2

ESR	Sites	Models	Data types	Foreseen Database	Format
ESR 1- CSIC Kevin	Argentona site	• SUTRA • TRANSIN • COMSOL	• Tracer Test, Pumping Test geophysical data	H+ database	H+ format
ESR6- CNRS Behzad	• Ploemeur • HRL SKB	• MATLAB • COMSOL	DTS, DSS	H+ database	H+ format
ESR9- UNIL Alejandro	Possibly, Argentona site	• MATLAB • COMSOL	Tracer tests at laboratory scale. Electrical conductivity.	H+ Database	H+ format

ESR	Sites	Models	Data types	Foreseen Database	Format
ESR10- FZJ Peleg	Krauthausen	TRACE and PARTRACE codes (written in FZJ); gprMax	Tracer test (saline), GPR	TERENO data portal	
ESR13-UT Veronika	Lauswiesen	e4d-pflotran (USGS) DUNE modelling code (https://www.dune-project.org/news/) - high performance PDE solver	• Tracer tests (heat, salt) • ERT • GPR	CAMPOS Database	- To be defined
ESR 4 – Itasca Justine	Äspö		• GPR • hyraulic data • geological data • Tracer test	• SKB database • H+ database ? (to discuss)	. rad / rd3 / rd7 - excel

Table 2 : Data strategies- 2/2

- For ESR11: All formats are ready in the H+ database. For GPR (Ground Penetrating Radar), the format is being finalized (it may be available for the summer).
- For ESR3: Alvaro will check if the HydroShare database can handle tracer tests data/formats
- For ESR7: UAV (drone) data are maps. HOBE is quite flexible so it should be fine for this data storage. Joel will verify this.
- For ESR2: Tereno database is considered.
- For ESR8: it will be the H+ database
- For ESR5: SKB and H+, data should be stored and the majority should be public. For SKB, normally you can ask for the data but it is not completely guaranteed that access will be granted (even if it is most likely). The best would be to also have the Enigma data on the H+ database.
- For ESR12: SIP data, mostly in the lab but possibly also on the Ploemeur site
- For ESR14: in discussion for the H+ database. Andrea suggested installing messages when the data are downloaded to see who is interested and using the data. The Argentona site is in preparation on the H+ database.

Lara Blazevic: asks the questions about legislation, is it alright legally to send a message when the data are downloaded?
Niklas Linde: there should be a warning message for the users before uploading/downloading.

- ESR1: probably H+ database
- ESR6: Ploemeur & SKB: H+ formats
- ESR9: H+ database
- ESR10: Peleg will check with the TERENO data portal
- ESR13: CAMPOS database is under construction, this would be used to store the data.

- ▪ ESR4: SKB data, we should see/discuss with Annick Battais about what is possible.

Discussions to setup a common calendar so that everybody is informed about on-going experiments and the opportunities to bring other instruments. Marie-Françoise Gerard will ask on a regular basis to have the dates of the experimental campaigns.

Olaf A. Cirpka: an advice: avoid the news section on the website: not good if there are no recent news!!
Question about ERT data: should we store also the raw data in the database -> yes
Frederic Nguyen: it would be in a zip data file.

End 09/02/2018

Saturday 10/02

❖ Reporting aspects of Enigma ITN, <u>presentation</u> by Marie-Françoise Gerard.

We have agreed on the ESRs and senior researchers in charge for each deliverable (see details Annex 3). They will be in charge of collecting the deliverable sections. For this, they will be supported by the senior supervisor of the concerned workpackage.

❖ TTC (Training & tutoring committee), presentation by Frederic Nguyen

Majken Looms Zibar: can we have some details on training needs assessment plans?
Frederic Nguyen: this would be a compilation.

Niklas Linde & Majken Looms Zibar: we need to discuss about the final conference in Copenhagen: what is intended? If it will be a bigger workshop, how is it seen…
Tanguy Le Borgne: the original idea was to open it to a larger group. Do a meeting that would include Tereno, HOBE and H+ & other people (Spring 2020, before end of April).
Majken: 200 people or less?
Olaf A. Cirpka: 100 people is enough, it would be more manageable. It could be joined with something else, more realistic.
Tanguy Le Borgne: H+ has annual meetings, Tereno too so it could be done together.
Sander Huisman: H+ and other people affiliated from Germany would be enough.
Majken Looms Zibar: we will see what the possibilities are.
Niklas Linde: finally, not do it too big.
Olaf A. Cirpka: what is the money available?
Marie-Françoise Gerard: <u>it will depend on the other events before</u>. But there would be about 30 k€.

Olaf A. Cirpka: integrated water research: style like Gordon conference. Not 15 minutes talk but invitation of interesting people; only 1 hour keynote presentations and posters. Tanguy Le Borgne: Gordon conference in Italy or Switzerland in 2020 but more general subject.

❖ Organization of the upcoming Cargese summer school, chaired by Damien Jougnot

65 places for students (including 15 ESRs),

❖ Secondments – Informal discussion

End 10/02/2018

ANNEXES

Annex 1: Email about Workpackages
Annex 2: Email about Data storage strategies
Annex 3: Deliverables management

Annex 1: Email about Workpackages

Dear Enigma ESR-PhDs,

The next Enigma meeting in Lausanne will place special emphasis on
scientific discussions concerning individual ESR projects and common
actions to be developed in the network.
In order to structure these discussions we have chosen to organize them
following the four scientific work packages of ENIGMA. Each ESR project
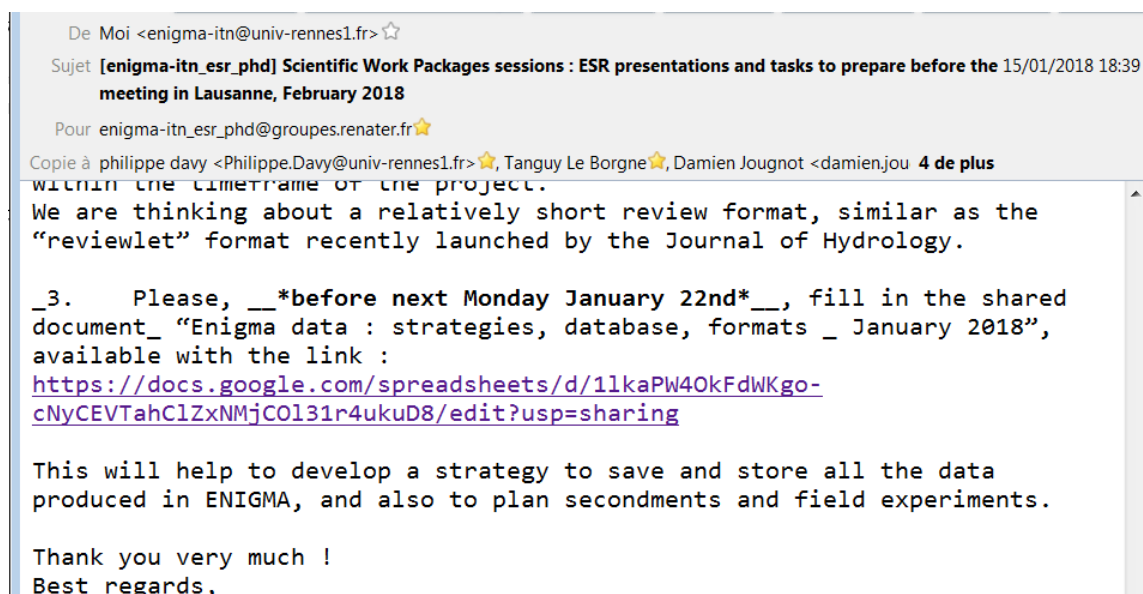is associated to one main work package (see attached table).

Therefore, in addition to your individual presentation, we would like to
ask you to work as a team of 3/4 persons (corresponding to each WP, for
instance ESR 1,2,3,4 for WP 2) to prepare the discussion for each work
package.
In particular, the objective will be to think about the possible content
and structure of a scientific review for each of the work package, which
will be coordinated by each ESR group with the help of senior
researchers from the network.

Therefore, for the next meeting, three presentations/tasks are expected
from you:

_1.   Individual ESR presentation: 10 minutes presentation (4 to 8
slides) summarizing :_
    o   Scientific objectives of your project
    o   First results that you have obtained
    o   Open questions (for which you may ask the advice of people from
the network)
    o   Planned actions (e.g. secondments, experiments on ENIGMA sites,
data archiving…)

_2.   Group presentation: for each WorkPackage, please prepare a 5
minutes presentation_ (4/5 slides) within the group corresponding to
each WP (see table) to:
    o   Identify the common main questions of each WP
    o   Discuss about possible joint experiments or actions
    o   Propose a plan for a review article for each WP

You can of course also contact the WP leader, who will be chairing the
discussion, to ask for advice about this common presentation.
The advantage of the review paper is that i) it will help to complete
your initial literature review ii) it may form a basis for the
deliverables iii) it could potentially be a highly cited paper.
It is important however to think before about i) what would be the
content and structure of the review paper (i.e. what are the most recent
innovations in this field),
ii) how this review would be positioned compared to other recent reviews
on similar topics (i.e. is there scope for a review in this particular
field ? what are the existing reviews?) and
iii) how to organize collectively the writing of such review papers
within the timeframe of the project.
We are thinking about a relatively short review format, similar as the
"reviewlet" format recently launched by the Journal of Hydrology.

Annex 2: Email about Data storage strategies

De Moi <enigma-itn@univ-rennes1.fr>

Sujet **[enigma-itn_esr_phd] Scientific Work Packages sessions : ESR presentations and tasks to prepare before the** 15/01/2018 18:39
meeting in Lausanne, February 2018

Pour enigma-itn_esr_phd@groupes.renater.fr

Copie à philippe davy <Philippe.Davy@univ-rennes1.fr>, Tanguy Le Borgne, Damien Jougnot <damien.jou **4 de plus**

```
within the timeframe of the project.
We are thinking about a relatively short review format, similar as the
"reviewlet" format recently launched by the Journal of Hydrology.

_3.    Please, __*before next Monday January 22nd*__, fill in the shared
document_ "Enigma data : strategies, database, formats _ January 2018",
available with the link :
https://docs.google.com/spreadsheets/d/1lkaPW4OkFdWKgo-
cNyCEVTahClZxNMjCOl31r4ukuD8/edit?usp=sharing

This will help to develop a strategy to save and store all the data
produced in ENIGMA, and also to plan secondments and field experiments.

Thank you very much !
Best regards,
```

Annex 3: Deliverables management

WP2 : Explore coupled dynamic processes in highly instrumented sites – **Leader : Jülich**

Del n°	Due Date
D2.1 : In situ datasets on space and time patterns of fluxes and reactivity in mixing interfaces	Month 48: December 2020
D2.2 : In situ datasets on flow distributions and transport patterns in fractured media	Month 48: December 2020
D2.3 : Report on the added value of in situ experimentation for understanding and quantifying coupled flow, transport and reaction processes in critical areas of the subsurface	Month 48: December 2020

Lead-Contribution for this Workpackage:		**Senior manager**
D2.1	**Main person in charge: KEVIN DE VRIENDT[1]** Other contributors: Guilherme Nogueira[2], Alvaro Pardo Alvarez[3]	**Sander Huisman**
D2.2	**Main person in charge: JUSTINE MOLRON4** Other contributors: Lara Blazevic[5]	**Caroline Darcel**
D2.3	**Main person in charge: GUILHERME NOGUEIRA[2]** Other contributors: all WP2 ESRs Kevin[1], Guilherme[2], Alvaro[3], Justine[4]	**Jesus Carrera/Marco Dentz**

WP3: Quantify temporal changes in subsurface water content and fluxes distributions – **Leader UCPH**

Del n°	Due Date
D3.1 : Validated prototype of portable absolute gravimeter for large scale water content distribution	Month 36 : December 2019
D3.2 : Field test of novel techniques for quantifying water content spatial distributions and temporal fluctuations	**Month 24: December 2018**
D3.3 : Report: Critical assessment of emerging techniques for in situ monitoring of water content and fluxes	**Month 24: December 2018**

Lead-Contribution for this Workpackage:		**Senior manager**
D3.1	**Main person in charge: ANNE-KARIN COOKE[8]**	**Bruno Desruelle**
D3.2	**Main person in charge: LARA BLAZEVIC5** Other contributors: Behzad Pouladi[6], Joel Tirado Conde[7]	**Philip Brunner**
D3.3	**Main person in charge: JOEL TIRADO CONDE7** Other contributors: all WP3 ESRs Lara[5], Behzad[6], Joel[7], AnneKarin[8]	**Majken Looms Zibar**

WP4	Leader UNIL
Create new methods for tracking the transport and reactivity of chemical species in subsurface	

Del n°	Due Date
D4.1 : Laboratory facility: Geophysical millifluidic lab for testing geophysical monitoring of transport and reactions	Month 36 : December 2019
D4.2: In situ datasets that couple tracer experiments and geophysical monitoring available	Month 48 : December 2020
D4.3 : Report on process-based geophysical methodologies to monitor subsurface Processes	Month 36 : December 2019

Lead-Contribution for this Workpackage:		Senior manager
D4.1	**Main person in charge: ALEJANDRO FERNANDEZ VISENTINI[9]** Other contributors: Satoshi Izumoto[12]	**Laurent Longuevergne**
D4.2	**Main person in charge: RICHARD HOFFMANN[11]** Other contributors: Peleg Haruzi[10] , Veronika Rieckh[13] Andrea Palacios[14] and Justine Molron[4]	**Sander Huisman**
D4.3	**Main person in charge: PELEG HARUZI[10]** Other contributors: all WP4 ESRs Alejandro[9], Peleg[10], Richard[11], Satoshi[12],	**Niklas Linde**

WP5	Leader EKUT
Design inverse modelling strategies for dynamic processes in complex subsurface structures	

Del n°	Due Date
D5.1: Validated algorithms for fully coupled 3-D inversion	**Month 24: December 2018**
D5.2: Report on joint inversion procedures for multiple and disparate datasets (soft and hard data) with realistic subsurface structure reconstruction methods	**Month 24: December 2018**

Lead-Contribution for this Workpackage:		Senior manager
D5.1	**Main person in charge: VERONIKA RIEKCH[13]** Other contributors: Jorge Lopez Alvis[15]	**Olaf A. Cirpka**
D5.2	**Main person in charge: ANDREA PALACIOS[14]** Other contributors: all WP5 ESRs Veronika Rieckh[13], Jorge Lopez Alvis[15]	**Frederic Nguyen**

End of the Enigma meeting n°3

ENIGMA *Innovative Training Network:* **European training Network for In situ imaGing of dynaMic processes in heterogeneous subsurfAce environments**

Minutes of the Enigma ITN Meeting n°4

Cargèse, 30 June 2018

IESC, Cargèse, Corsica

Photo 1: Enigma ITN network: ESR-PhD students, Beneficiaries representatives, Partner organizations representatives, Advisory Board Committee, Coordination team

The 4th Enigma meeting took place in Cargèse on June 30th 2018. The Advisory Board was present to interact with the network (Photo 1 & Photo 7)

Programme of the meeting

Saturday 30/06

15h00 - 16h00	POSTER session *(1h)* During the week, the Advisory Board will have opportunities to discuss with all ENIGMA PhD students at their posters. Each Advisory Board member will be invited to review 3 PhD-posters during this particular poster session. There will also be a written feedback in a report provided by the Advisory Board at the end of the Summer School.	Chairman : P.Davy & T.L.Borgne	Posters location
16h00-16h15	*Coffee break*		
16h15 – 17h30	**Advisory Board meeting part I** Presentation of ongoing and planned common actions/ experiments/ reviews - Discussion (1h20) Each WP (~ 4 PhD students) will present their ongoing common experiments, research or potential papers and how they deal with their data.	Chairman : P.Davy & T.L.Borgne	Lecture room
17h30 – 17h50	Discussion and Feedback about the WP presentations with the Advisory Board *(20 min)*		
17h50 – 18h00	*break*		

18H00–18H30	**Advisory Board meeting part II** General presentation of the network Enigma network, objectives, Training & Tutoring Committee… Short presentation of represented partners *(15 min)*	P. Davy, T. Le Borgne & F. Nguyen	Lecture room
18h30-19h00	**Experimental infrastructure Board meeting**: - Summary of experimental plans of PhDs students & opportunities for joined experiments - Data storage plans & dissemination Exchanges & feedback with the Advisory Board	Chairman: T. Le Borgne	Lecture room
19h00 – 19h30	**Supervisory Board meeting** - Mid-term review meeting: Barcelona 2019, presentation of purpose, expected elements - Secondments terms/summary - Milestones supposed to be achieved (MS4; state of the art => presentations & posters to send to M-F.Gerard) - Next deliverables	P.Davy & presentation about Barcelona by CSIC & M-F.Gerard	Lecture room

Social Event : 20h15 – Le Continental Cargèse

List of Participants

Participant Enigma meeting - Cargèse	Concerned ESR (Beneficiary)		
Philippe DAVY	Coordinator CNRS/ESR4		
Tanguy LE BORGNE	Coordinator CNRS		
Damien JOUGNOT	Coordinator CNRS		
Marie-Françoise GERARD	Coordinator CNRS		
John SELKER	Partner/ESR6-CNRS Oregon Univ	ESR 13	Veronika Rieckh
Frederic NGUYEN	ESR15-Liège	ESR 02	Guilherme Nogueira
Niklas LINDE	ESR9-UNIL Lausanne	ESR11	Richard Hoffmann
Alain DASSARGUES	ESR11-ULG Liège	ESR15	Jorge Lopez Alvis
Sander HUISMAN	ESR12-FZ Jülich	ESR04	Justine Molron
Kamini SINGHA	Advisory Board	ESR07	Joel Tirado Conde
Olivier BOUR	ESR6-CNRS Rennes	ESR08	Anne Karin Cooke
Guillaume de Schepper	Aquale	ESR05	Lara Blazevic
Olaf A. CIRPKA	ESR13 - Uni Tübingen	ESR03	Alvaro Pardo Alvarez
Ty FERRE	Advisory Board	ESR12	Satoshi Izumoto
Beth PARKER	Advisory Board	ESR14	Andrea Palacios
Andrew BINLEY	Advisory Board	ESR9	Alejandro Fernandez Visentini
Marco DENTZ	ESR1-CSIC	ESR10	Peleg Haruzi
Clement ROQUES	Co organisator Summer School in Cargese	ESR1	Kevin de Vriendt
Yves MEHEUST	Coordinator CNRS	ESR6	Behzad Pouladi
Jef CAERS	Partner – Stanford University		
Jesus CARRERA	CSIC-ESR14		

Bruno Desruelle, head of Muquans, Peter Engesgaard, supervisor of ESR7 and Francesco Ciocca, representative of Silixa attended the meeting via RenaterVisio conference.

Saturday 30/06

❖ Advisory Board meeting : Poster session

During the week, the Advisory Board composed of Beth Parker (Photo 2), Andrew Binley (Photo 3), Kamini Singha (Photo 5), Ty Ferre (Photo 4) and Bridget Scanlon had opportunities to discuss with all ENIGMA PhD students at their posters. Each Advisory Board member was invited to review 3 PhD-posters during this particular poster session. There was also a written feedback in a report provided by the Advisory Board at the end of the Summer School. The reviews were personally forwarded to each ESR.

Photo 2: Beth Parker, Enigma Advisory Board member discussing with ESR10 Peleg Haruzi

Photo 3 : Andrew Binley, Enigma Advisory Board member discussing with ESR1 Kevin de Vriendt

Photo 5 : Kamini Singha, Enigma Advisory Board member discussing with ESR9 Alejandro Fernandez
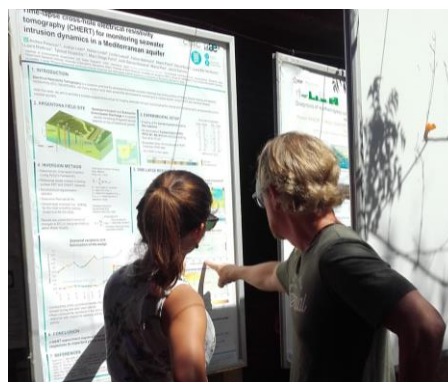
Photo 4: discussion between Ty Ferre (Enigma Advisory Board member) and ESR14 Andrea Palacios

❖ Presentation of ongoing and planned common actions/ experiments/ reviews – Discussion

WP2 presentation by ESRs: Tracer and geophysical techniques for river/GW interactions

Senior leaders: Jan Fleckenstein & Philippe Brunner
ESR Kevin de Vriendt, Guilherme Nogueira, Alvaro Pardo Alvarez+ additional involved ESR Joel Tirado Conde

The WP2 ESR-Students (Photo 6) are thinking of a Surface Water-Groundwater interaction reviewlet.

There are already a lot of reviews, but there is still a possibility to focus on Mixing and reactions between GW-SW-seaW over multiple scales

J. Selker: perhaps you need more focus on temporal (and spatial) scales to design monitoring programs.

J. Carrera: Do not think people did not do that, but look for weak spots in the existing studies

J. Selker: I was just suggesting a way of looking at existing reviews

A. Binley: you should look about what you have to look at, and go more in a precise detail.

K. Singha: Think of it like a "Way to go". Ask yourself the question: why now? Why this is important?

O. Cirpka: Maybe a review is already too ambitious? Maybe you should focus on what you are doing to make it more helpful.

T. Le Borgne: Aim to do a 300 words format, this is what is required in Journal of Hydrology

J. Fleckenstein: You should consider to do something more focused.

Photo 6: presentation of Workpackage 2 ongoing works and ideas for reviewlet by the ESR-PhD students

WP3 presentation by ESRs: Quantify temporal changes in subsurface water content and fluxes distribution

Senior leaders: Majken Looms Zibar and Olivier Bour

ESR Lara Blazevic, Behzad Pouladi, Joel Tirado Conde, Anne-Karin Cooke

For a reviewlet, the structure proposed would be about: quantify storage and study fluxes. They present a review of each method.

J.Carrera: you should add electrical methods and you don't need to follow the deadline!
Ph.Davy: we would need a report for the EU. What is required is the deliverable, the reviewlets are added-value for the network and an opportunity to use the network.
T.Ferré: You should use the deadline for motivation
T.Le Borgne: You may propose a plan for a joint experiment. For instance, look for a place where to do an experiment (e.g. choose a site).
K.Singha: maybe some numerical test? Add NMR?
A.Binley: come to UK! Look for alternative approaches, like GPR? Make comparison between methods. Look for a general view and not a specific study on a test site.
N.Linde: try to make something out of that reviewlet.

WP4 presentation by ESRs: Process-based Imaging transport and reactivity

Senior leader: Niklas Linde

ESR Alejandro Fernandez Visentini, Peleg Haruzi, Richard Hoffmann, Satoshi Izumoto + additional involved ESR Kevin de Vriendt

They present several options for a reviewlet:
Option 1: dimensionality approach
Option 2: following key topics of each ESRs
Option 3: following a practice stream
They proposed a complete workflow for the reviewlet.

A.Binley: the general workflow is great, BUT which kind of geophysical properties can help for reactivity? A possible root for the reviewlet would be to identify the experiments possible at the field scale.
T.Ferré: it is probably too optimistic. You should focus on your tool and push it. You are missing context, there is a lack of reading habits and expertise.
A.Binley: I disagree with T.Ferré
T.Le Borgne: the senior researchers are here to help the student gaining time.

WP5 presentation by ESRs: Joint inversion versus joint prediction
Senior leaders: Olaf A. Cirpka & Frederic Nguyen
ESR Veronika Rieckh, Andrea Palacios, Jorge Lopez Alvis + additional involved ESR Justine Molron

Their proposition for a reviewlet on this subject is to do it in a tutorial style.

T.Ferré: The tutorial format is a very smart idea.
Ph.Davy: Sometimes it is better to decompose processes in 2. You all want to reduce uncertainty in predictions, but don't trust models. The estimation of the variability behind the model is a way to better grasp the uncertainty.
O.Cirpka: Is the target structural? Or prediction for a specific process? But you don't need to understand everything to predict (e.g. machine learning). You have to emphasize on why you want to reduce your uncertainty.
J.Carrera: The risk assessment is different from prediction.
O.Cirpka: Don't aim at getting a lot of citations
B.Parker: Simply aim for good research, you'll be cited in due time.

Photo 7: Meeting - lecture room Cargèse

❖ General presentation of the network

ENIGMA ITN short oral presentation by P. Davy.

❖ ENIGMA Training and Tutoring Committee (TTC) presentation by F.Nguyen

The presentation is online on the Enigma website, on the 4th meeting webpage: link

❖ ENIGMA Experimental Infrastructure Board (EIC) meeting presentation by T.Le Borgne

This presentation shows the different available sites and databases and the discussions about data archiving. It is online on the Enigma website, on the 4th meeting webpage: link

K.Singha: how do you plan to deal with data between the sites and the several databases? And what about the geophysical formats?
T.Le Borgne: that is part of the objectives of the ITN. How is it in the US?
K.Singha: there is a system in place (CUAHSI: https://www.cuahsi.org/), but it is still a struggle…
J.Caers: CUAHSI is the greatest contribution of hydrology to environmental studies.
CUAHSI data link: https://www.hydroshare.org/
T.Le Borgne: in general, for instance, in the H+ database, it is organized by data type (e.g. water level)
K.Singha: CUAHSI has outstanding metadata, you could base your work on it http://his.cuahsi.org/mastercvreg/cv11.aspx--)

Objectives: joint experiments between the ESRs (planned experiments)

K.Singha: you could use more the social media applications for the experiments (for instance twitter)
A.Palacio: we (as Enigma group) are already on Linkedin and Researchgate

❖ Supervisory board meeting presentation M-F.Gerard

The presentation is online on the Enigma website, on the 4th meeting webpage: link

There is a suggestion to move the final conference from April 2020 to December 2019 (to be as close from the end as possible but to still have all the PhD students present)

J.Carrera: At the midterm, all representatives will be here and also the EU representatives, to help and to be constructive.

There is a reminder that WP1 is ethics and the requirements.
And that there is a need for the secondments dates at the end of the summer school to establish the new calendar and for the ongoing amendment.
Then the previous and next deliverables and milestones are presented.

J.Selker: Do a 3min video in front of the poster during the summer school, it is good to train to present their research and important.
J.Carrera: During the mid-term meeting in Barcelona, let's take the opportunity to go to Argentona!
A.Binley: Please ask yourself what you want for us (the Advisory Board). ESR-Students have to contact the advisory board when needed!

Then there was a social event in the village (Photo 8)

Photo 8: Social event after Enigma meeting n°4.

❖ Advisory Board final meeting

During the last week of the summer school, there was an informal meeting/a discussion with the Advisory Board and all the ESR Students (Photo 9) to exchange about the summer school and about the network.

The Advisory Board conclusions were positive, they advised the ESR-students to dare to contact them for any questions or visits or potential collaboration.

They highlighted the unique status of the Enigma ITN network in the environmental research field and the excellence of the involved scientists.

Photo 9: Discussion with the Advisory Board - here, Beth Parker, Bridget Scanlon and Kamini Singha discuss the network results and ongoing works

The Enigma Advisory Board sent after this meeting a review of each poster and discussion with the ESRs. The reviews were personally forwarded to each ESR.

End 30/07/2018

End of Minutes of the Enigma meeting n°4

End of Annex 1

Annex 2

MARIE CURIE ACTIONS

ITN Enigma

ENIGMA *Innovative Training Network: 15 PhD positions*

European training Network for in situ imaGing of dynaMic processes in heterogeneous subsurfAce environments

ENIGMA is an Innovative Training Network (ITN) funded by the European Commission. The ENIGMA ITN aims at training a new generation of young researchers **in the development of innovative methods for imaging process dynamics in subsurface hydrosystems,** in order to enhance understanding and predictive modelling capacities and to transfer these innovations to the economic sector.

The 15 young future PhD students will contribute to develop the spatial representation of subsurface heterogeneity, fluxes, chemical reactions and microbial activity, through the **integration of data** and approaches from **geophysics, hydrology, soil physics, and biochemistry**.

The ENIGMA network gathers 21 partners (14 academic and 7 industrial) from 8 European countries.

Each of the **15** future PhD students will conduct the research work in 2 or 3 institutions, in collaboration with industrial partners. ENIGMA will start in January 2017.

Website: https://enigma-itn.eu/

We are now recruiting students with a Master degree for three-year PhD positions (starting before July 2017). Applicants should apply through the website with a motivation letter for up to 3 PhD topics from the list below (see website for further details), a CV with relevant documentation, and names of at least two referees.
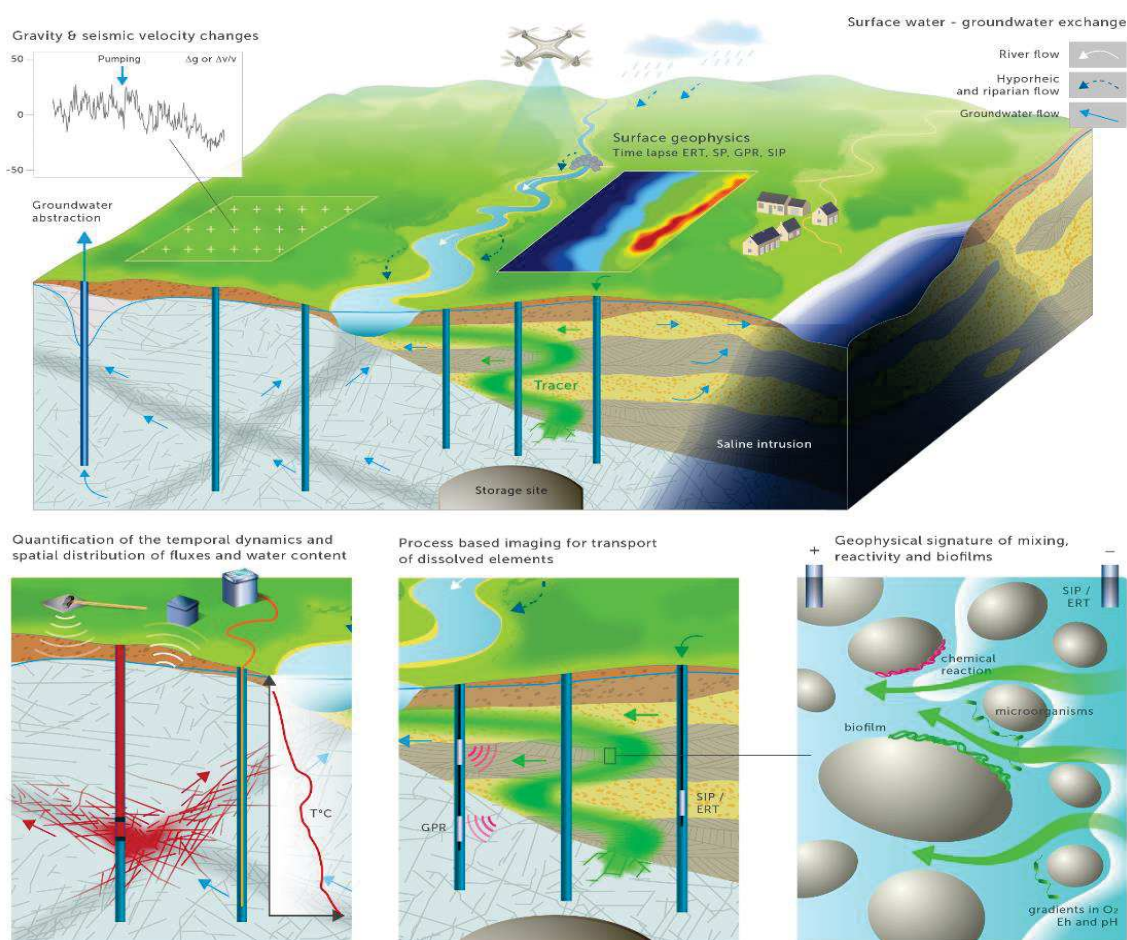
PhD POSITIONS AVAILABLE:

ESR1-PhD: Mixing and chemical reaction hotspots in saline-freshwater mixing zones
Supervisor: Marco Dentz, Jesus Carrera, **CSIC Barcelona** (CNRS Rennes, UNIL Lausanne, ACA Barcelona)[1]

ESR2-PhD: Imaging flow dynamics and reactivity in the stream-aquifer transition zone
Supervisor: Jan Fleckenstein, **UFZ Leipzig** (UCPH Copenhagen, UNINE Neuchâtel)[1]

ESR3-PhD: Closing the observational gap between the hyporheic and meander scale
Supervisor: Philip Brunner, **UNINE Neuchâtel** (UFZ Leipzig, GEOTH Heiligenstadt)[1]

ESR4-PhD: Flow and transport in fracture networks: reducing uncertainty of DFN models by conditioning to geology and geophysical data
Supervisor: Caroline Darcel, **ITASCA,** Philippe Davy, **CNRS Rennes,** (UNIL Lausanne, SKB Sweden)[1]

ESR5-PhD: Monitoring spatio-temporal water redistribution in the subsurface with seismic methods
Supervisor: Laurent Longuevergne, **CNRS Rennes,** Ludovic Bodet, **UPMC Paris** (UNIL Lausanne, SKB Sweden)[1]

ESR6-PhD: Active Fiber-Optic DTS methods to monitor subsurface flow dynamics
Supervisor: Olivier Bour, **CNRS Rennes** (CSIC Barcelona, OSU Oregon, SILIXA)[1]

ESR7-PhD: Multi-scale thermal imaging of groundwater upwelling in stream valleys
Supervisor: Peter Engesgaard, **UCPH Copenhagen** (UNINE Neuchâtel, UFZ Leipzig)[1]

ESR8-PhD: Monitoring water storage changes with a new portable absolute quantum gravimeter
Supervisor: Bruno Desruelle, **µQuanS,** Cédric Champollion, **UM Montpellier** (UCPH Copenhagen)[1]

ESR9-PhD: Geophysical signatures of spreading and mixing
Supervisor: Niklas Linde, **UNIL Lausanne** (CNRS Rennes, CSIC Barcelona)[1]

ESR10-PhD: High resolution imaging of transport processes with GPR full-waveform inversion
Supervisor: Jan van der Kruk, **FZ Jülich** (CNRS Rennes, UNIL Lausanne)[1]

ESR11-PhD: Joint heat and solute tracer test inversion for imaging preferential pathways
Supervisor: Alain Dassargues, **ULG Liège** (BRGM Orléans, FZ Jülich)[1]

ESR12-PhD: Spectral induced polarization monitoring to quantify biochemical reactions
Supervisor: Sander Huisman, **FZ Jülich** (CNRS Rennes)[1]

ESR13-PhD: Fully coupled hydrogeophysical inversion of 3D tracer tomography
Supervisor: Olaf A. Cirpka, **UT Tübingen** (ULG Liège)[1]

ESR14-PhD: Geologically constrained joint inversion of hydraulic, tracer and ERT data for process visualization
Supervisor: Jesus Carrera, **CSIC Barcelona** (UCPH Copenhagen, ACA Barcelona)[1]

ESR15-PhD: Integration of dynamical hydrogeophysical data in a multiple-point geostatistical framework.
Supervisor: Frédéric Nguyen, **ULG Liège** (CSIC Barcelona, AQUA Montpellier)[1]

[1] Candidates will devote time to learn methods and/or do field work at co-supervising centers, in parenthesis.

ENIGMA Innovative Training Network: 08 PhD positions

European training **N**etwork for **in** situ ima**G**ing of dyna**M**ic processes in heterogeneous subsurf**A**ce environments

ENIGMA is an Innovative Training Network (ITN) funded by the European Commission. The ENIGMA ITN aims at training a new generation of young researchers **in the development of innovative methods for imaging process dynamics in subsurface hydrosystems,** in order to enhance understanding and predictive modelling capacities and to transfer these innovations to the economic sector.

The 15 young future PhD students will contribute to develop the spatial representation of subsurface heterogeneity, fluxes, chemical reactions and microbial activity, through the **integration of data** and approaches from **geophysics, hydrology, soil physics, and biochemistry**.

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Each of the **15** future PhD students will conduct the research work in 2 or 3 institutions, in collaboration with industrial partners. ENIGMA started in January 2017.

Website: https://enigma-itn.eu/

We are now recruiting students with a Master degree for three-year PhD positions (starting preferably before July 2017). Applicants should apply through the website with a motivation letter for up to 3 PhD topics from the list below (see website for further details), a CV with relevant documentation, and names of at least two referees.
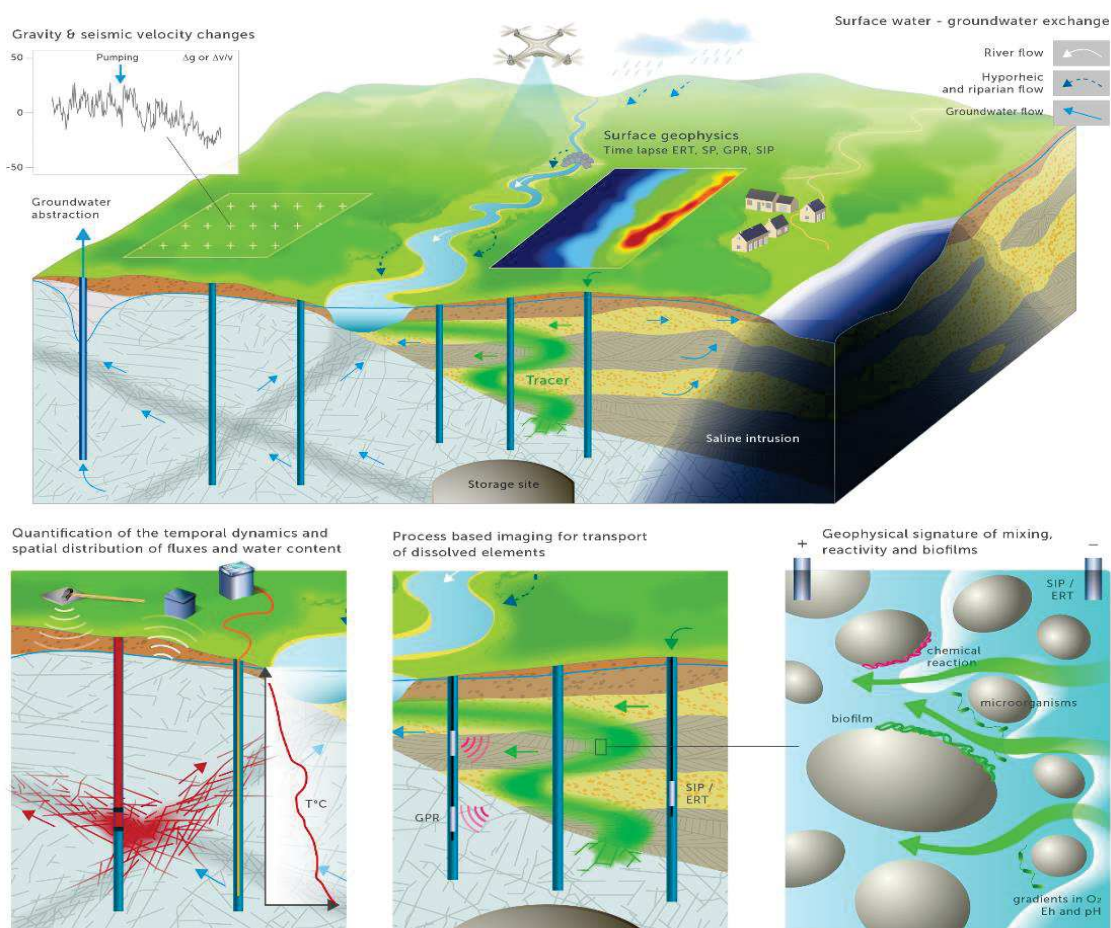
PhD POSITIONS:

ESR01-PhD: Mixing and chemical reaction hotspots in saline-freshwater mixing zones
Supervisor: Marco Dentz, Jesus Carrera, **CSIC Barcelona** (CNRS Rennes, UNIL Lausanne, ACA Barcelona)[1]

ESR02-PhD: Imaging flow dynamics and reactivity in the stream-aquifer transition zone
        Position filled

ESR03-PhD: Closing the observational gap between the hyporheic and meander scale
Supervisor: Philip Brunner, **UNINE Neuchâtel** (UFZ Leipzig, GEOTH Heiligenstadt)[1]

ESR04-PhD: Flow and transport in fracture networks: reducing uncertainty of DFN models by conditioning to geology and geophysical data
Supervisor: Caroline Darcel, **ITASCA,** Philippe Davy, **CNRS Rennes,** (UNIL Lausanne, SKB Sweden)[1]

ESR05-PhD: Monitoring spatio-temporal water redistribution in the subsurface with seismic methods
Supervisor: Laurent Longuevergne, **CNRS Rennes,** Ludovic Bodet, **UPMC Paris** (UNIL Lausanne, SKB Sweden)[1]

ESR06-PhD: Active Fiber-Optic DTS methods to monitor subsurface flow dynamics
Supervisor: Olivier Bour, **CNRS Rennes** (CSIC Barcelona, OSU Oregon, SILIXA)[1]

ESR07-PhD: Multi-scale thermal imaging of groundwater upwelling in stream valleys
        Position filled

ESR08-PhD: Monitoring water storage changes with a new portable absolute quantum gravimeter
Supervisor: Bruno Desruelle, **µQuanS,** Cédric Champollion, **UM Montpellier** (UCPH Copenhagen)[1]

ESR09-PhD: Geophysical signatures of spreading and mixing
        Position filled

ESR10-PhD: High resolution imaging of transport processes with GPR full-waveform inversion
Supervisor: Jan van der Kruk, **FZ Jülich** (CNRS Rennes, UNIL Lausanne)[1]

ESR11-PhD: Joint heat and solute tracer test inversion for imaging preferential pathways
        Position filled

ESR12-PhD: Spectral induced polarization monitoring to quantify biochemical reactions
        Position filled

ESR13-PhD: Fully coupled hydrogeophysical inversion of 3D tracer tomography
        Position filled

ESR14-PhD: Geologically constrained joint inversion of hydraulic, tracer and ERT data for process visualization
Supervisor: Jesus Carrera, **CSIC Barcelona** (UCPH Copenhagen, ACA Barcelona)[1]

ESR15-PhD: Integration of dynamical hydrogeophysical data in a multiple-point geostatistical framework
        Position filled

[1] Candidates will devote time to learn methods and/or do field work at co-supervising centers, in parenthesis.

4th Cargèse Summer School on *Flow and Transport in Porous and Fractured Media, Development, Protection, Management and Sequestration of Subsurface Fluids*

Summer School
June 25th to July 7th 2018
Corsica, France

Website: https://cargese2018.sciencesconf.org/

Registration will open on January 15, 2018

Organized in the framework of

ENIGMA *Innovative Training Network*

European training Network for in situ imaGing of dynaMic processes in heterogeneous subsurfAce environments

Feet in the sun head in the shade, let science blossom

End of Annex 2

Annex 3

Annex 3: Details of all dissemination and communication activities occurred during the Reporting Period 1

Concerned ESRs	Dissemination and communication activities
ESR01 – De Vriendt Kevin	- Saltwater intrusion meeting **conference** (Gdansk, Poland) 2018 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** : Mixing and calcite dissolution in heterogeneous coastal aquifers | A numerical 2D study
ESR02 - Nogueira Guilherme	4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** "Imaging flow dynamics and resulting reactivity in the transition zone between streams and riparian aquifers »
ESR03 - Pardo Álvarez Álvaro	**Conference** CMWR in Saint Malo, France 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** Closing the conceptual gap between the hyporheic zone and the river corridor
ESR04- Molron Justine	**Conference** CMWR in Saint Malo, France **Poster** for the 4th Cargèse Summer School: Molron, J; Linde, N.; Baron, L.; Darcel, C. ; Davy, P. ; Selroos, J-O. (2018). Reducing the uncertainty of discrete fracture network models by ground penetrating radar imagery: case study at the Äspö Hard Rock Laboratory, Sweden.
ESR05- Blazevic Lara	4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** with the title Monitoring spatio-temporal water redistribution in the subsurface with seismic methods **Oral presentation** at doctoral school days at MINES ParisTech: 05/04/2018 Paris: Journées des Doctorants - École Doctorale Géosciences, Ressources Naturelles et Environnement - AGU 100th Fall Meeting, 2018. **Poster presentation** "Finding appropriate rocks physics models to interpret seismic data in hydrogeophysics applications"
ESR06 - Pouladi Behzad	4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** with the title Temperature as a powerful tool in understanding the subsurface process and properties

ESR07 - Tirado Conde Joel	• 33rd Nordic Geological Winter Meeting 2018. Copenhagen, January 10-12 2018. **Poster presentation** "Temperature profiles to measure groundwater discharge to Ringkøbing Fjord". • Computational Methods in Water Resources XXII. Saint-Malo, June 3-7 2018. **Oral presentation** Benchmarking the use of heat as a tracer by the use of integrated surface and subsurface hydrologic models • 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** "Heat as a tracer to study groundwater upwelling: fiel data and benchmarking integrated hydrological modelling".

ESR08 - Cooke Anne-Karin	• **Presence and oral Presentation** : 8-13/04/2018, Vienna, Austria: General Assembly of the European Geoscience Union 2018 (EGU) Abstract:https://meetingorganizer.copernicus.org/EGU2018/EGU2018-14372.pdf
	• **Poster presentations** at two doctoral school days:
	  - 22/03/2018 Montpellier: Journée de Doctorants: Institut Montpelliérain de l'Eau et de L'Environnement (IM2E) (http://www.im2e.org/)
	  - 18/05/2018 Montpellier: Journée des doctorants Géosciences Montpellier
	• Several introduction courses at doctoral school GAIA (Umontpellier) and a day seminar on ethics in science (also by GAIA) (Formation à l'éthique de la recherche et à l'intégrité scientifique)
	• 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** On the potential of vertical gravity gradient monitoring for hydrological signal detection.

ESR09 - Fernandez Visentini Alejandro	• 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** "Millifluidic tracer experiments to investigate the signature of saline diffusion on effective electrical conductivity"
ESR10 - Haruzi Peleg	• Oral presentation at the 2018 SEG Annual Meeting in Anaheim, CA :Time-Lapse Ground Penetrating Radar Full-Waveform Inversion to detect tracer plumes, A Numerical Study • Board member of the "RWTH Aachen SEG Student Chapter". More information on : https://rwthseg.wixsite.com/rwth-seg/board • Poster presented during the 4th Cargèse Summer School :Testing the potential of GPR-FWI to detect tracer plumes in time-lapse monitoring

ESR11- Richard Hoffmann	• **Oral presentation + Conference Paper** (2018): Prior uncertainty investigation of density-viscosity dependent joint heat and solute in alluvial sediments. *Computational Methods in Water Ressources XXII – CMWR 2018*, Saint Malo (France). • **Oral presentation** (2018): Fractured aquifer heterogeneity characterization for advanced transport modelling based on multiple single fracture tracer tests. *45th IAH Congress – Groundwater and Life: Science and Technology into Action*, Daejeon (South-Korea). • **Oral Presentation + Conference Paper** (2018): The double porosity of the chalk and its influence on solute and heat transport. 6th International Geologica Belgica Meeting 2018 – Geology Serving Society, Leuven (Belgium). • **Poster (Purpose: Discussion with Advisory Board)** (2018): Multi scale transport modelling in heterogenous porous and fractured media. *4th Cargèse Summer School: Flow and transport in porous and fractured media*, Cargèse (Corsica, France).
ESR12- Izumoto Satoshi	• **Poster presentation** at 5th International Workshop on Induced Polarization. Rutgers University, New York (2018) Spectral induced polarization response of calcite precipitation. • **Poster presentation** at American Geophysical Union Fall Meeting. Washington, D.C. (2018) Spectral induced polarization of calcite precipitation in a porous media. • 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** "Effects of solution composition on the spectral induced polarization signals of calcite precipitation »
ESR13 - Rieckh Veronika	• **Poster presentation** at the RTG Hydrosystems Modelling Conference – April 2018, Tübingen • 4th Cargèse Summer School. Cargèse, 25 June – 7 July 2018. **Poster presentation** Fully-coupled Salt Tracer Test Tomography with Time-lapse Electrical Resistivity Tomography
ESR14 - Palacios Andrea	• June 2018: **Oral presentation** at the 25th Salt Water Intrusion Meeting (SWIM), titled "Time-lapse cross-hole electrical resistivity tomography (CHERT) for monitoring seawater intrusion dynamics in a Mediterranean aquifer". • July 2018: **Poster presentation** during the 4th Cargèse Summer School "Time-lapse cross-hole electrical resistivity tomography (CHERT) for monitoring seawater intrusion dynamics in a Mediterranean aquifer" • December 2018: **Oral presentation** at the American Geophysical Union (AGU) 2018 Fall Meeting, Washington DC, USA

ESR15- Lopez Alvis Jorge	• June 2018: **Oral presentation** at the 2018 Computational Methods in Water Resources (CMWR) conference, titled "Updating prior geologic uncertainty with GPR traveltime tomographic data". • July 2018: **Poster** presented during the 4th Cargèse Summer School, titled "Updating uncertainty in hierarchical subsurface model using geophysical data: synthetic case for crossborehole-hole GPR". • November 2018: **Geology Research seminar** in University of Ghent, titled "Using geophysical data to update uncertainty in structural parameters of subsurface models".

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End of Annex 3

End Of Deliverable D7.8-D32