ALEYIN

地下机器人之旅
(An underneath Robotic Journey)
喀斯特勘探机器人系统
(Robotic system for Karst Exploration)

A FLAGSHIP PROJECT OF NUMEV

莱昂内尔 拉皮埃尔
(Lionel Lapierre)

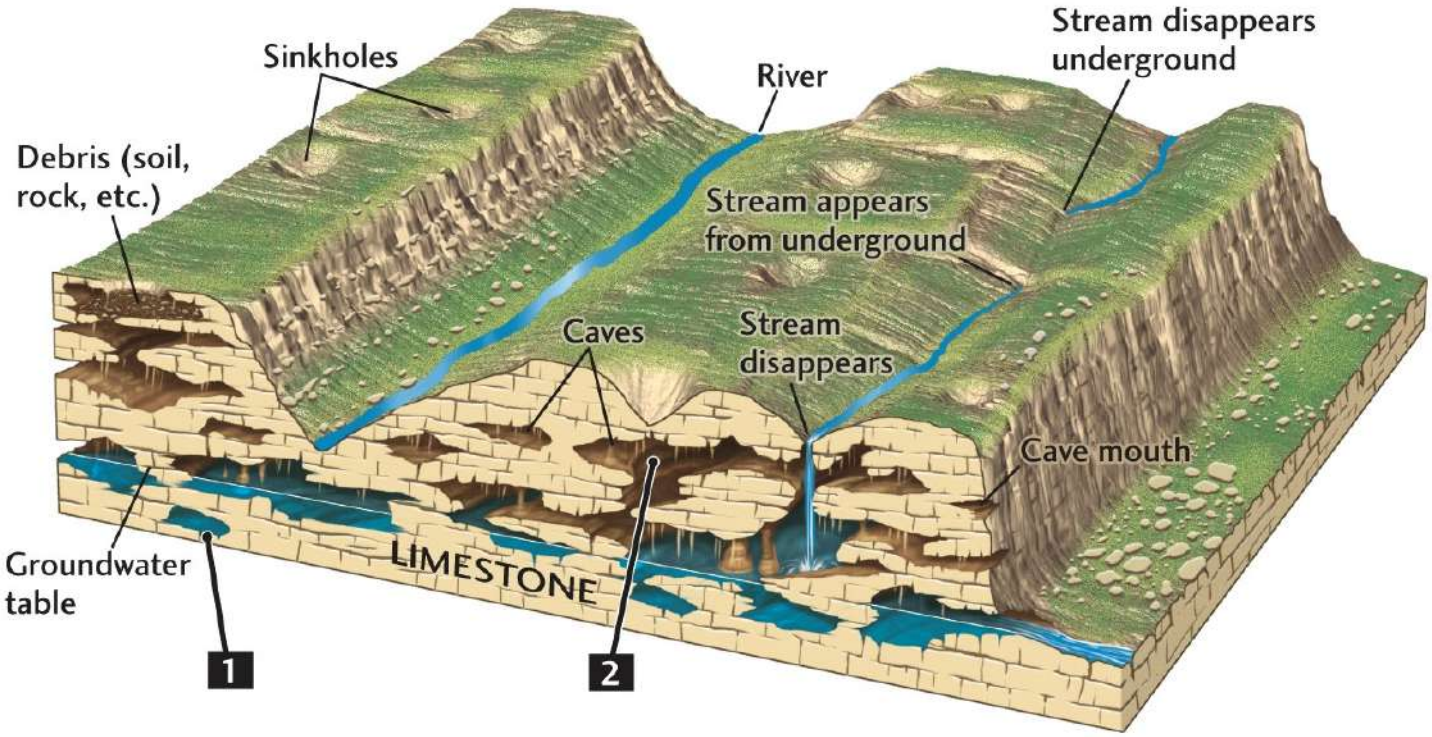
USYS'18, HUST, Wuhan, China, 3/12/2018

Outline

- What is Karst ?
- Groundwater stakes
  - Prospection, Protection and Management of Water Resource
  - Prediction and Assessment of Hydrogeological Risk
- History of Karst exploration with robots
- The Aleyin Initiative
- First experiments
- Future
- Seeking for international collaborations

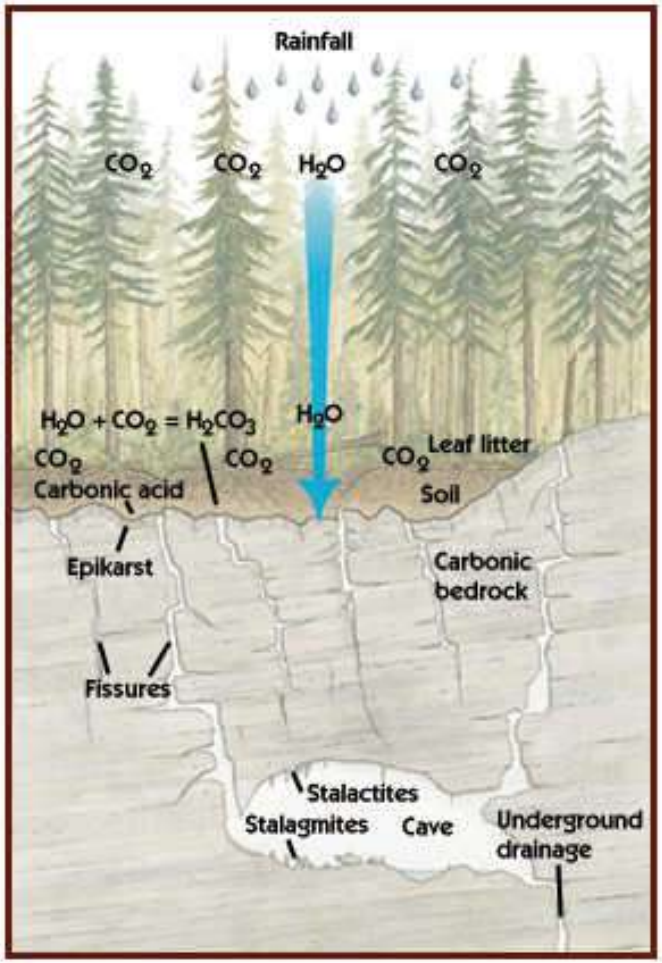
KARST : DEFINITION

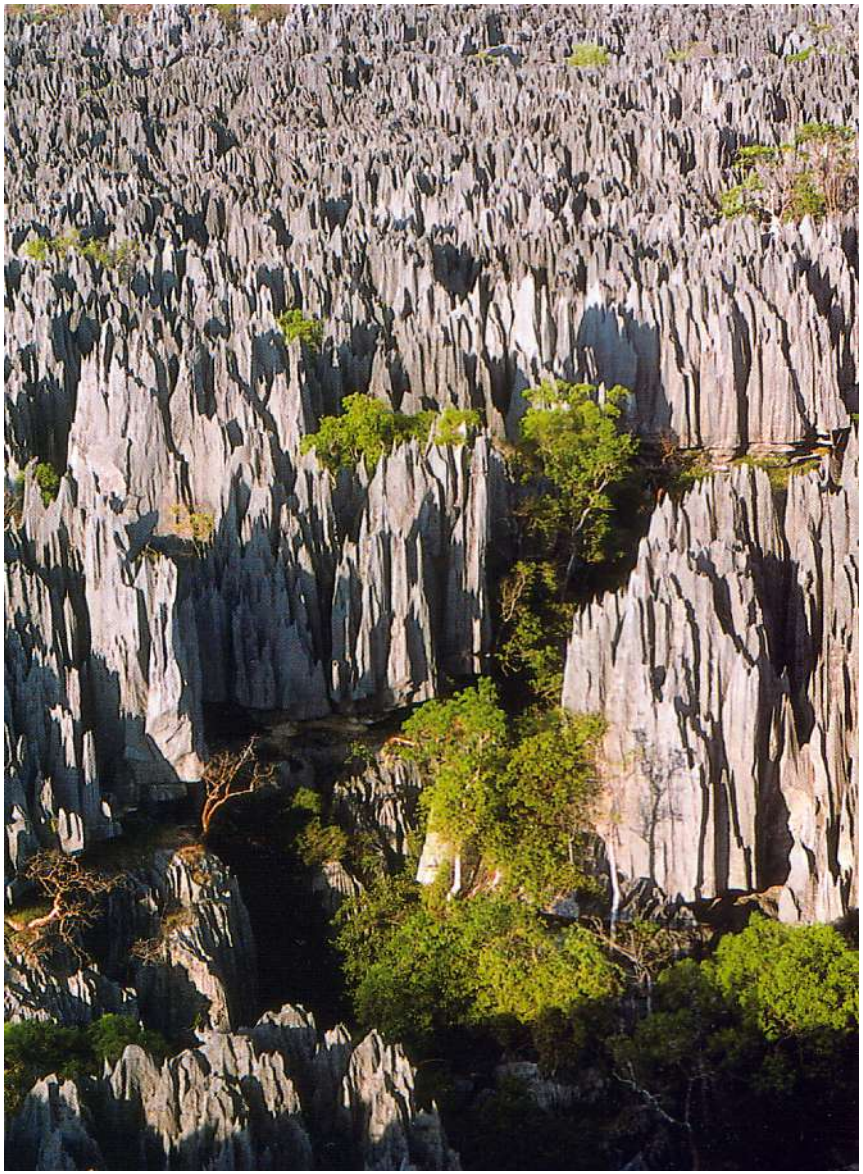
- A topography formed from the dissolution of soluble rocks such as limestone, dolomite, and gypsum,



- Characterized by **underground drainage hydrosystems** with sinkholes and caves.

KARST : DEFINITION



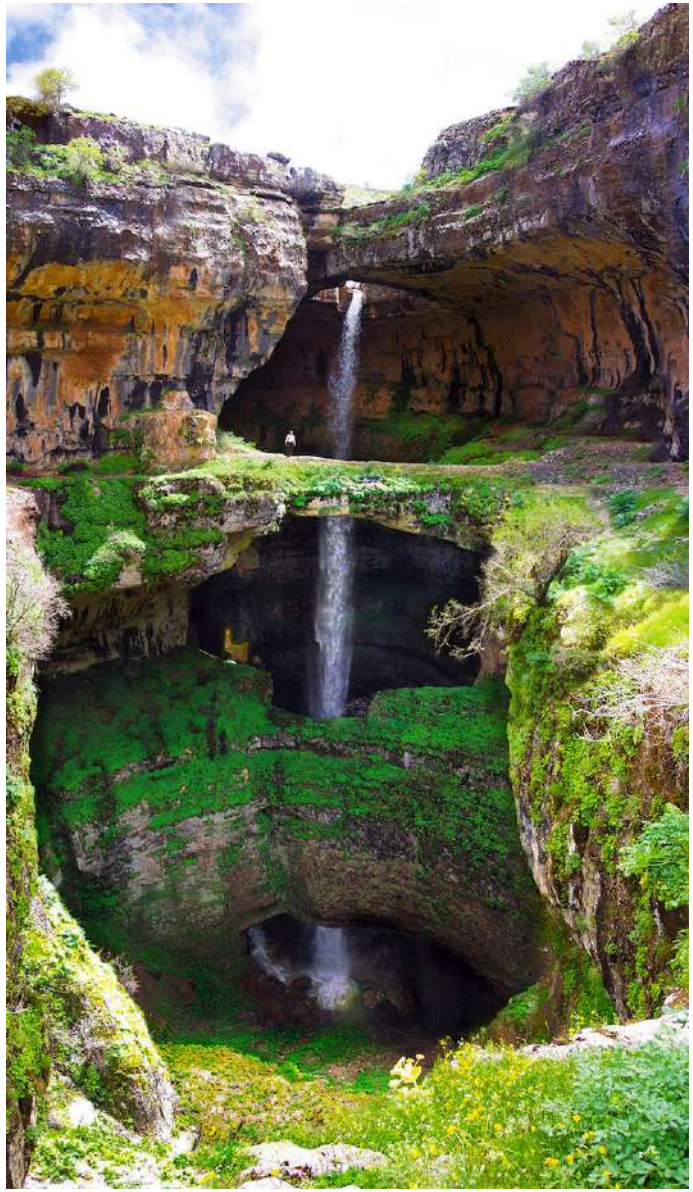


Tsingy de Bemaraha, Madagascar

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

$$CaCO_3 + CO_2 + H_2O \leftrightarrow Ca^+ + 2\,HCO_3^-$$

KARST : SURFACE STIGMATA



Balaa, Tannourine, Lebanon

Stone Forest, Shilin Yi, Yunnan, China

KARST : UNDERGROUND CONTINUATION

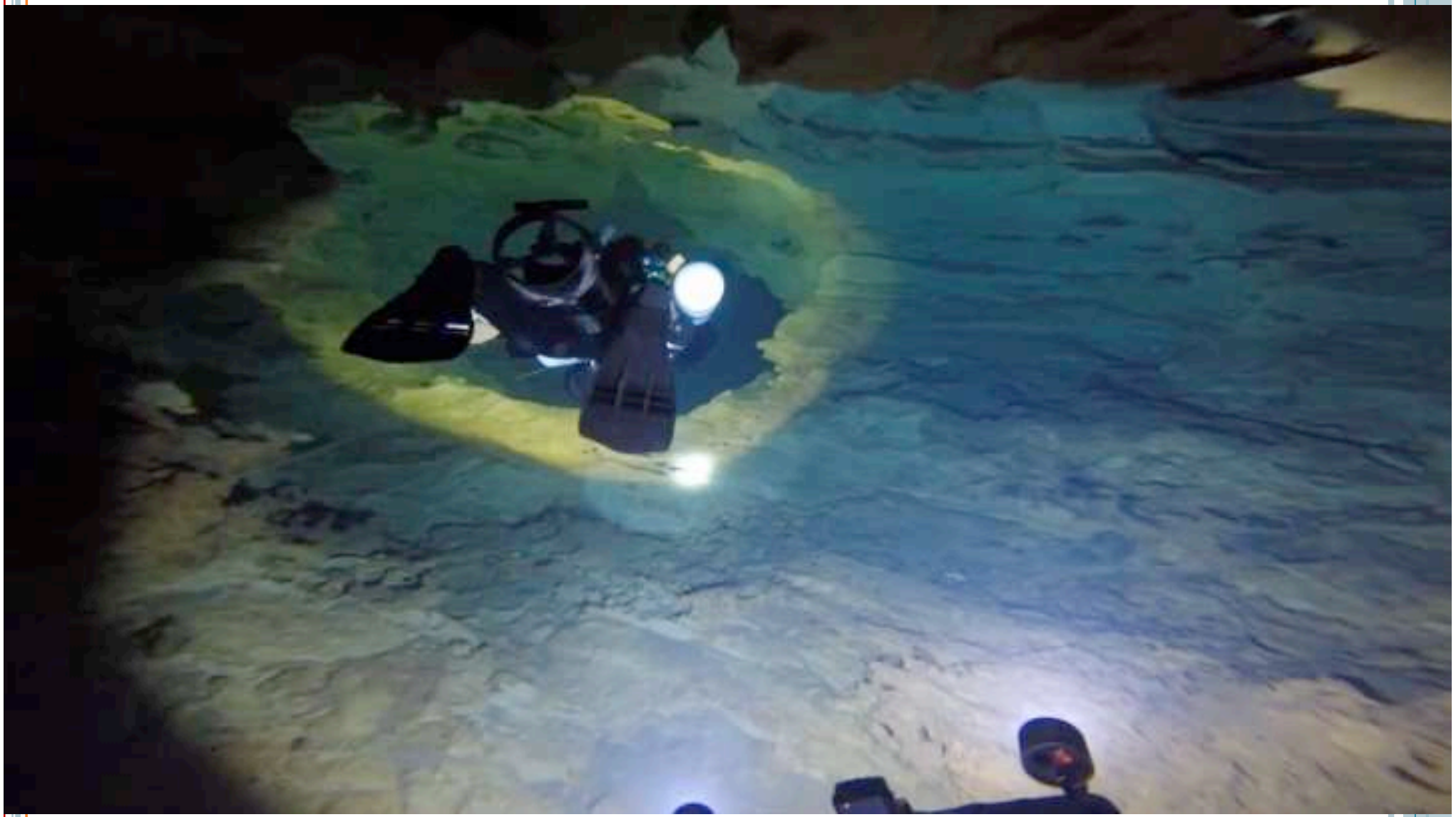
Ruby Falls ,Chattanooga, Tennessee, USA

Cueva de los Cristales, Naica,, Mexico

Furong Cave, Wulong District, Chongqing, China

KARST : GROUNDWATER RESERVOIR

KARST : GROUNDWATER RESERVOIR



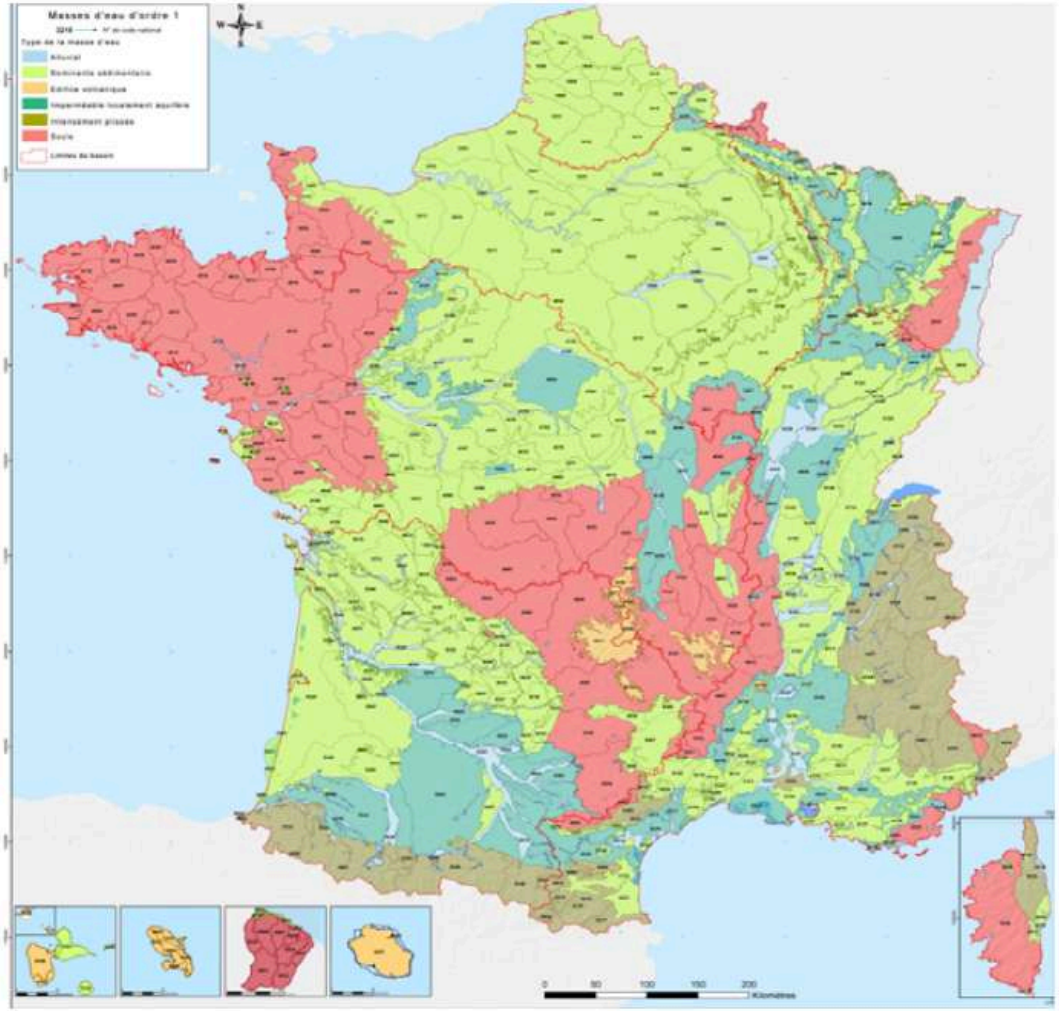
Pedro Balordi and Guenter Essig, Gourneyras, France, July 2015

KARST : MONUMENTAL HYDROSYSTEMS

Fontaine de Vaucluse,
Spring of the Sorgue,

Largest karstic resurgence
in Europe

KARST : GROUNDWATER MANAGEMENT, A NATIONAL ISSUE



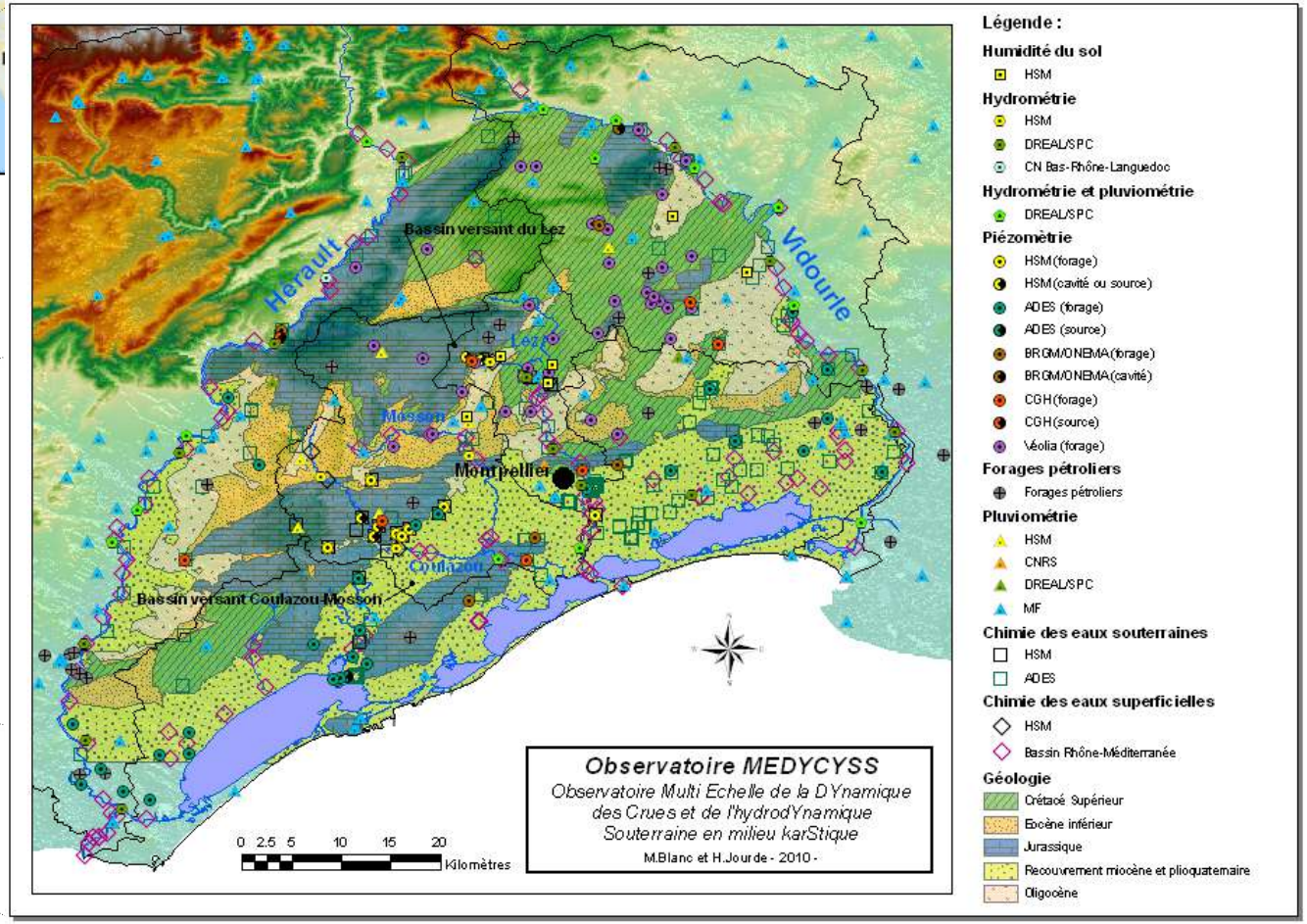
+ 50% of Drinking Water Supply

Service National d'Observation
du KARST,
SNO INSU/CNRS
OSU OREME (UM)
Coordinator H. Jourde

Carte hydrogéologique des formations carbonatées karstifiables (EASAC report)

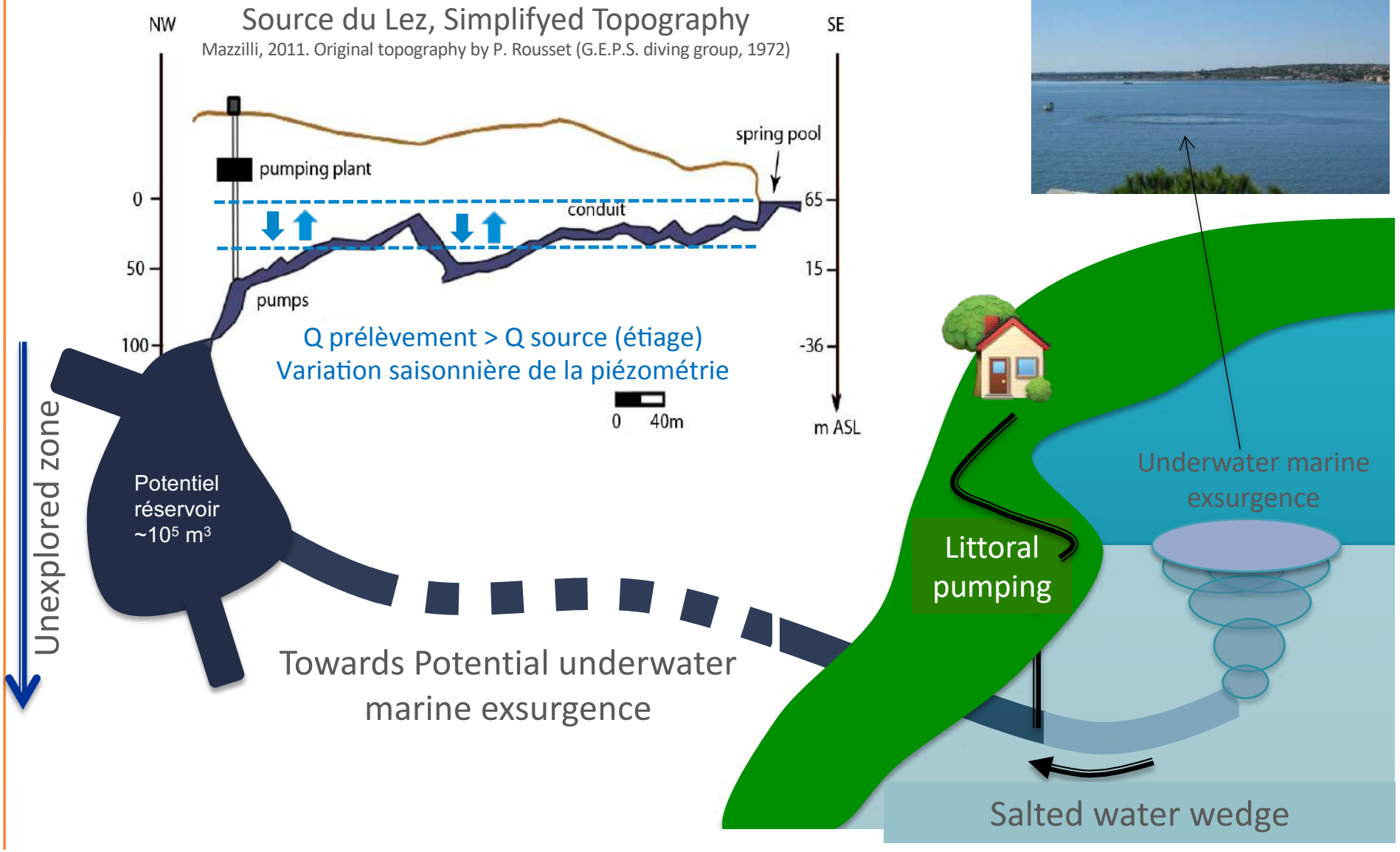
MONTPELLIER'S CATCHMENT BASIN : A SEMINAL CASE STUDY

MEDYCYSS KARST OBSERVATORY



Sources du Lez : a Seminal Case Study

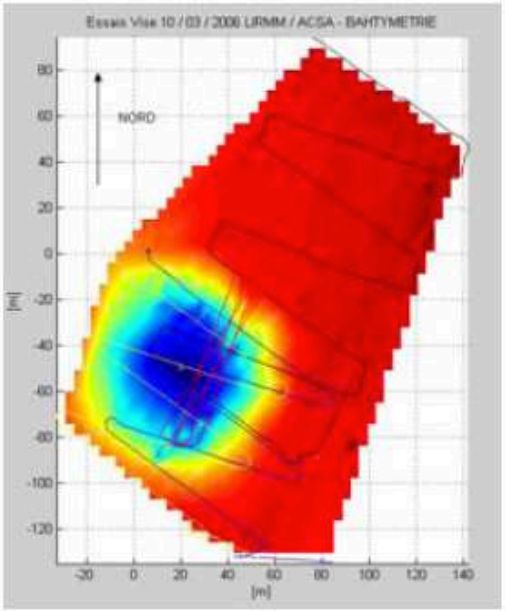
- Active Management of Water Ressource

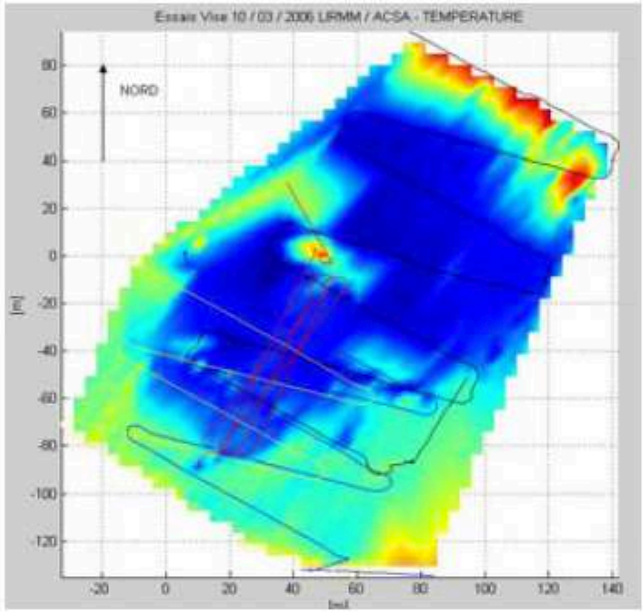


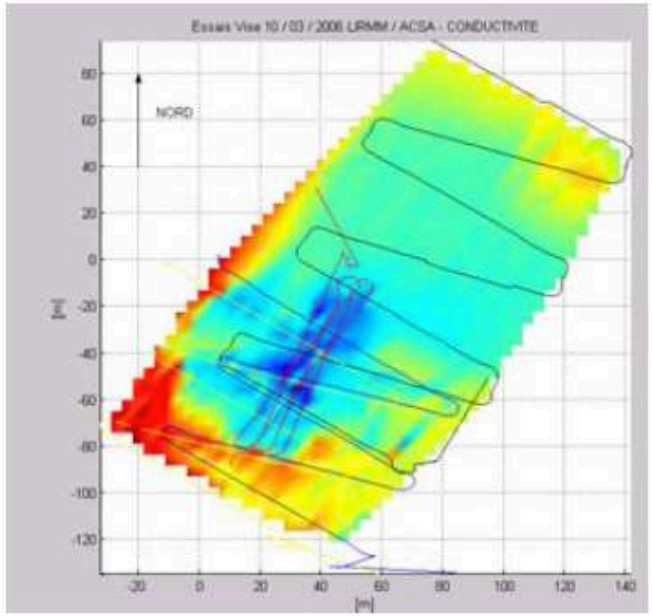
Sources du Lez : a Seminal Case Study

- Fresh water plume detection : Case of Source de la Vise

Taipan II

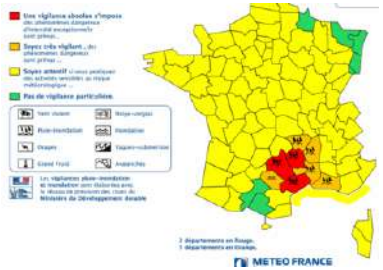


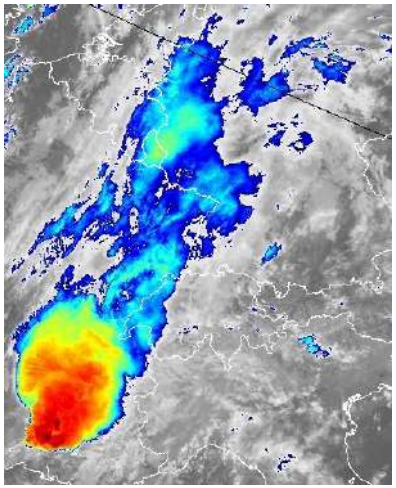




Montpellier's Catchment Basin : a Seminal Case Study

- Hydrogeological Risk Assessment





Floods of Coulazou River, December 2002

Floods of Lez River
6 Septembre 2005, Prades le Lez

HYDROGEOLOGICAL RISK : SKINHOLES

Harbin, Heilongjiang province, China.

Guatemala City, Guatemala

Orlando, Florida, USA

Dead-Sea shore, Israel

The Stakes

- Prospection / Preservation/ Management of Water Resource
  - Pumping and drilling regulation and guidance
  - Management of supply redundancy in case of massive contamination

- Hydrological Risk Assessement
  - Forecasting and Decision Aids
  - Skinholes detection
  - Karst as flood control dam: regulation and strategic positioning of pumping stations -> Active management of the resource

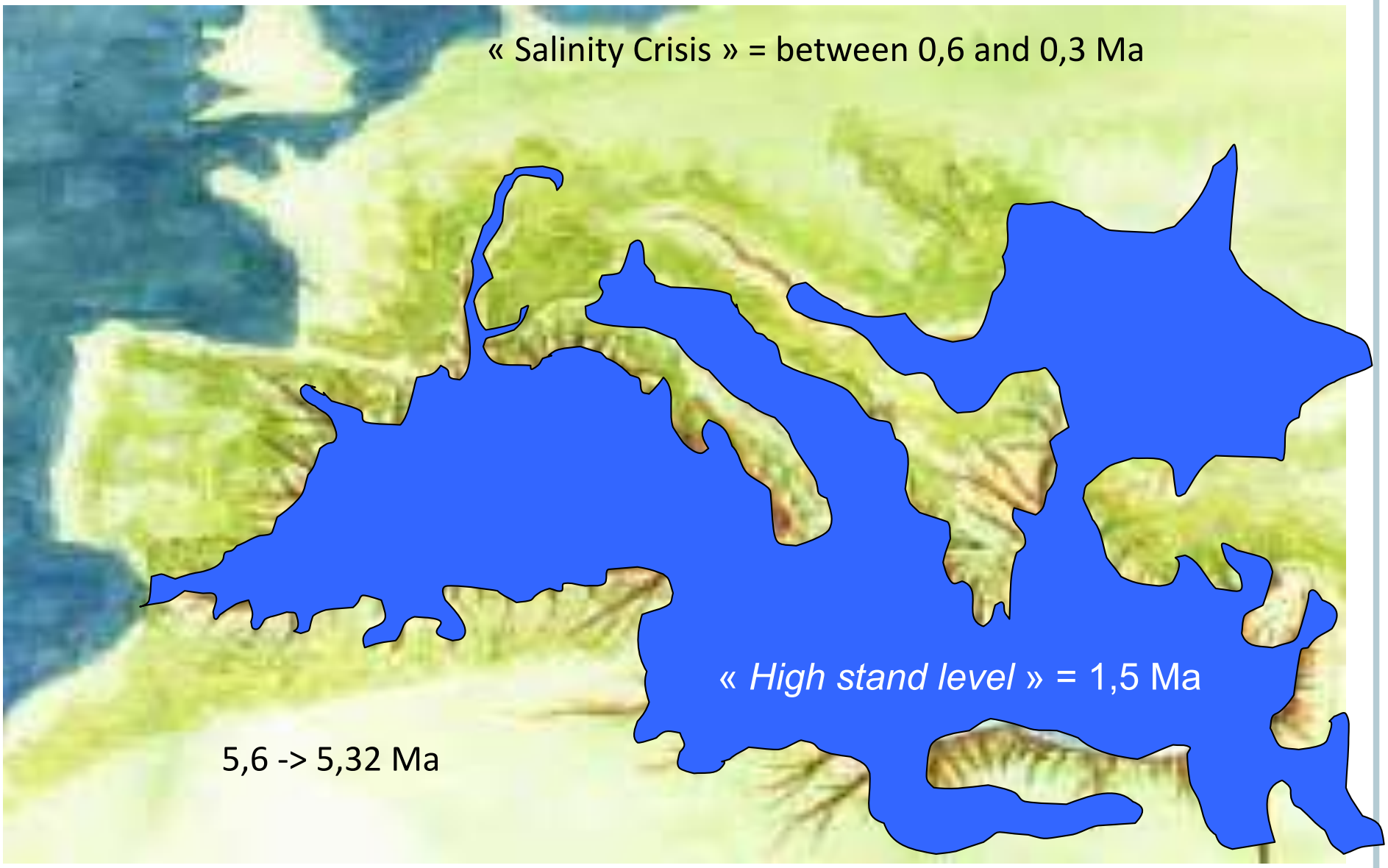
Closure of the Gilbraltar Strait

Messinian events : 2 salinity crisis

1/ 5.95 - 5.6 Ma 100 m

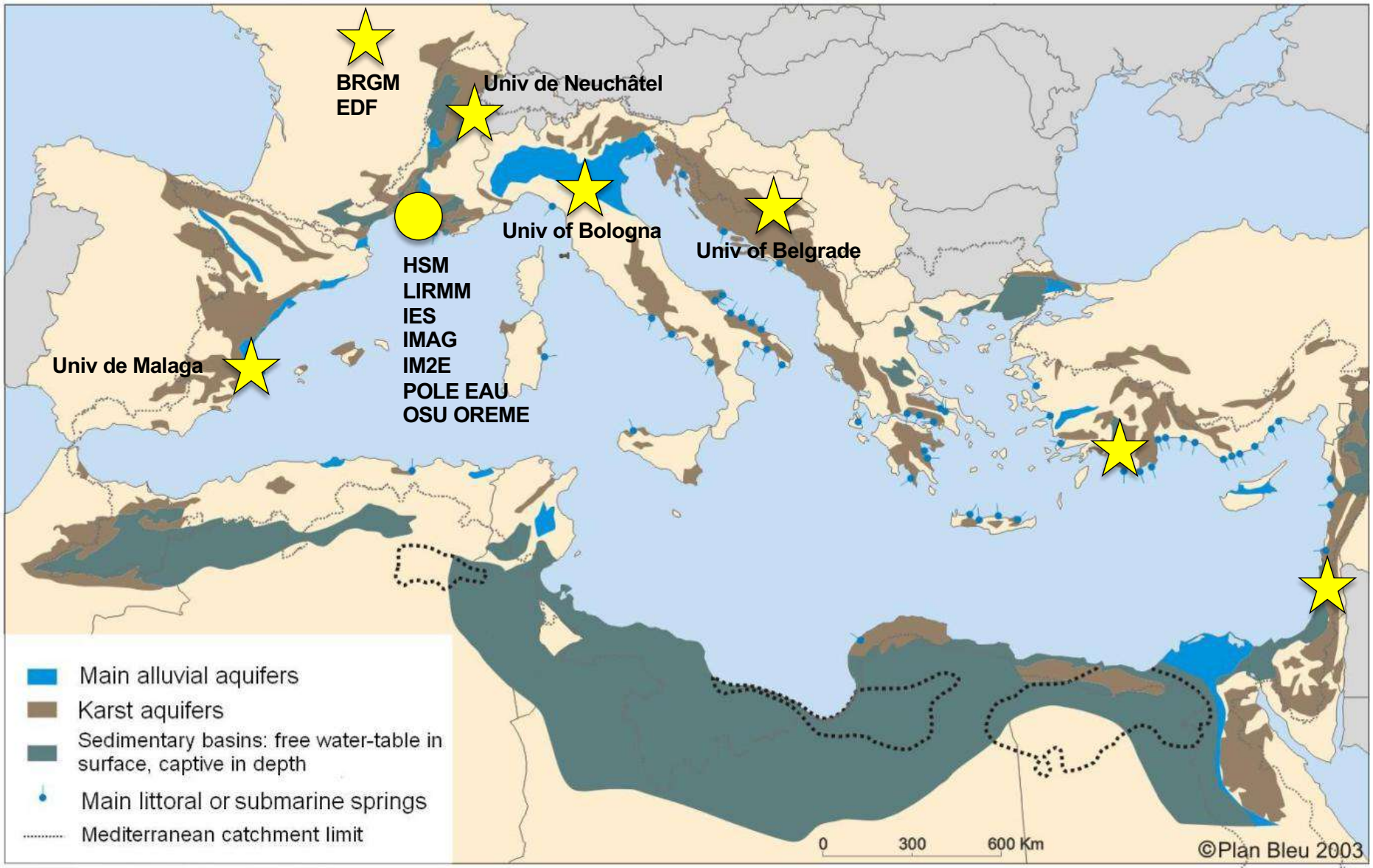
2/ 5.6 - 5.32 Ma 1500 m

Mediterranean Karsts During Messinian Salinity Crisis

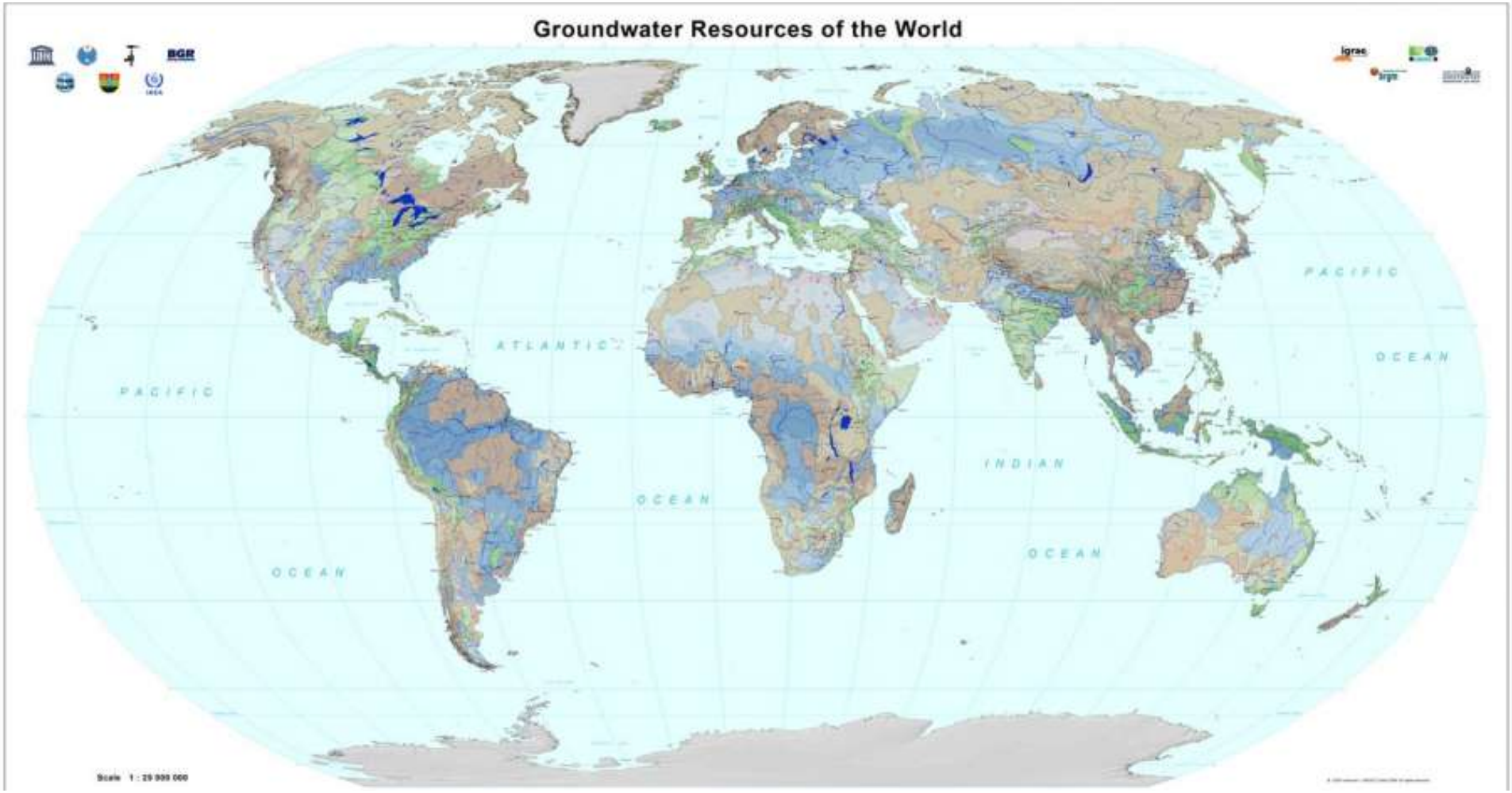


Deep Karstification

MEDITERRANEAN KARSTS

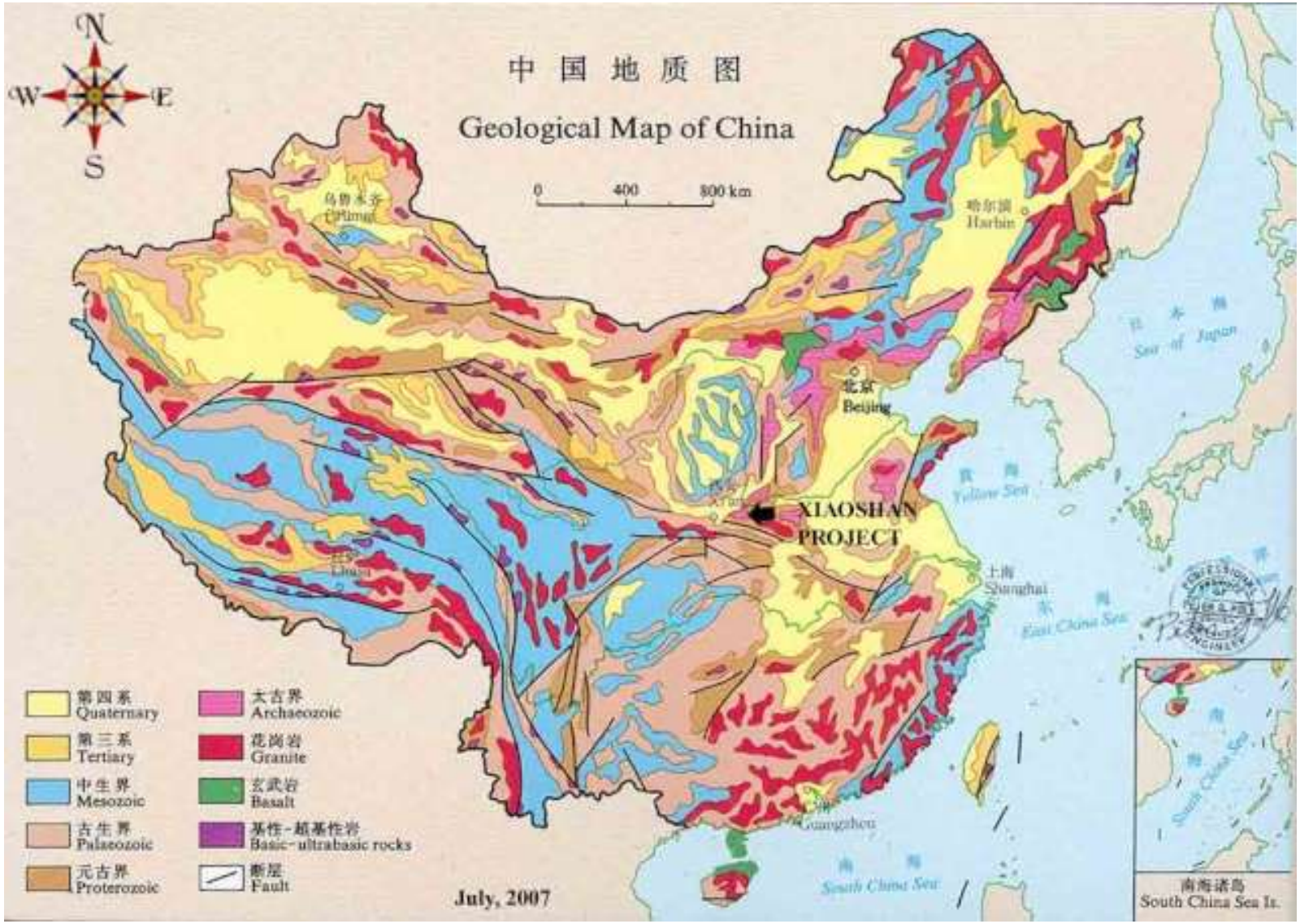


WOLRD KARSTIC REGIONS

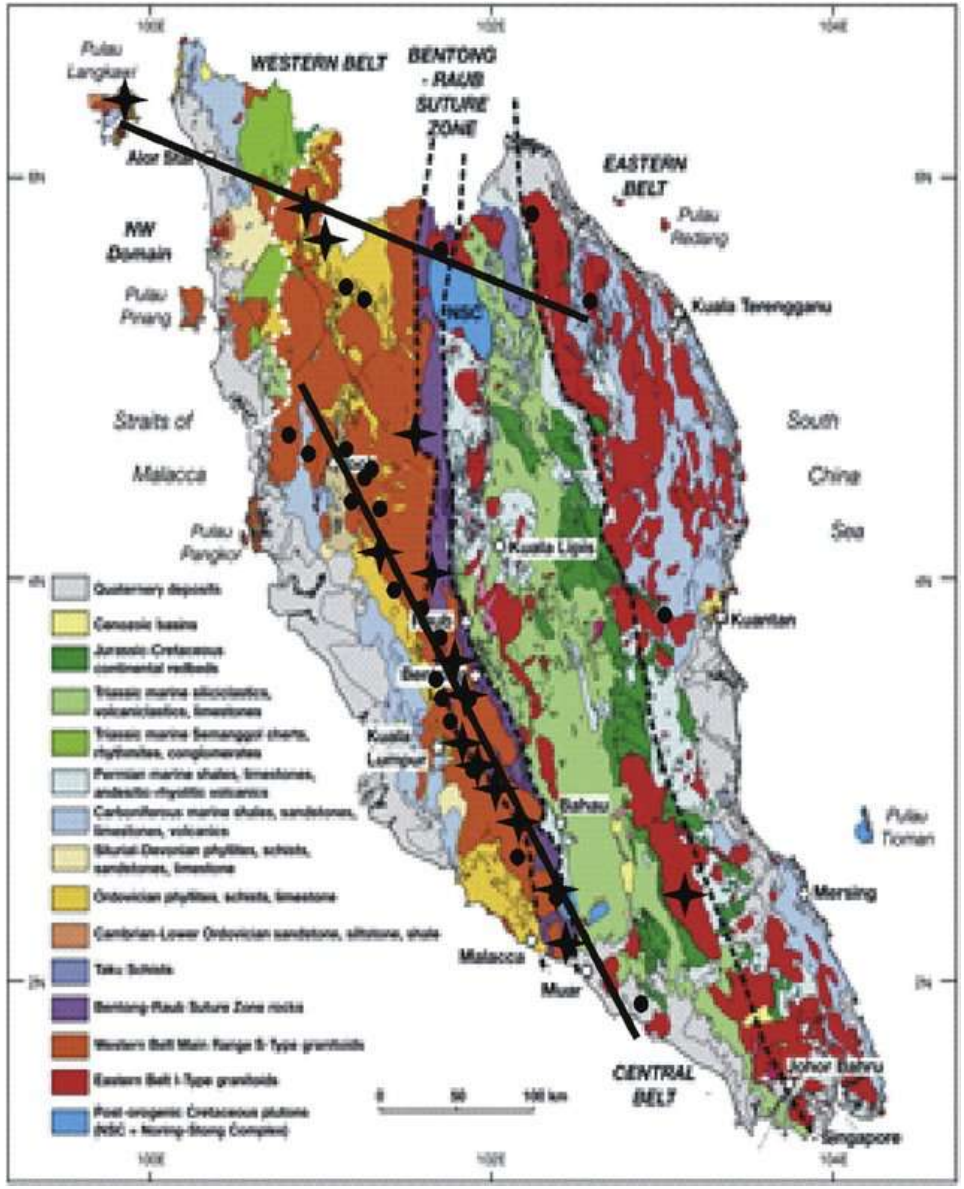


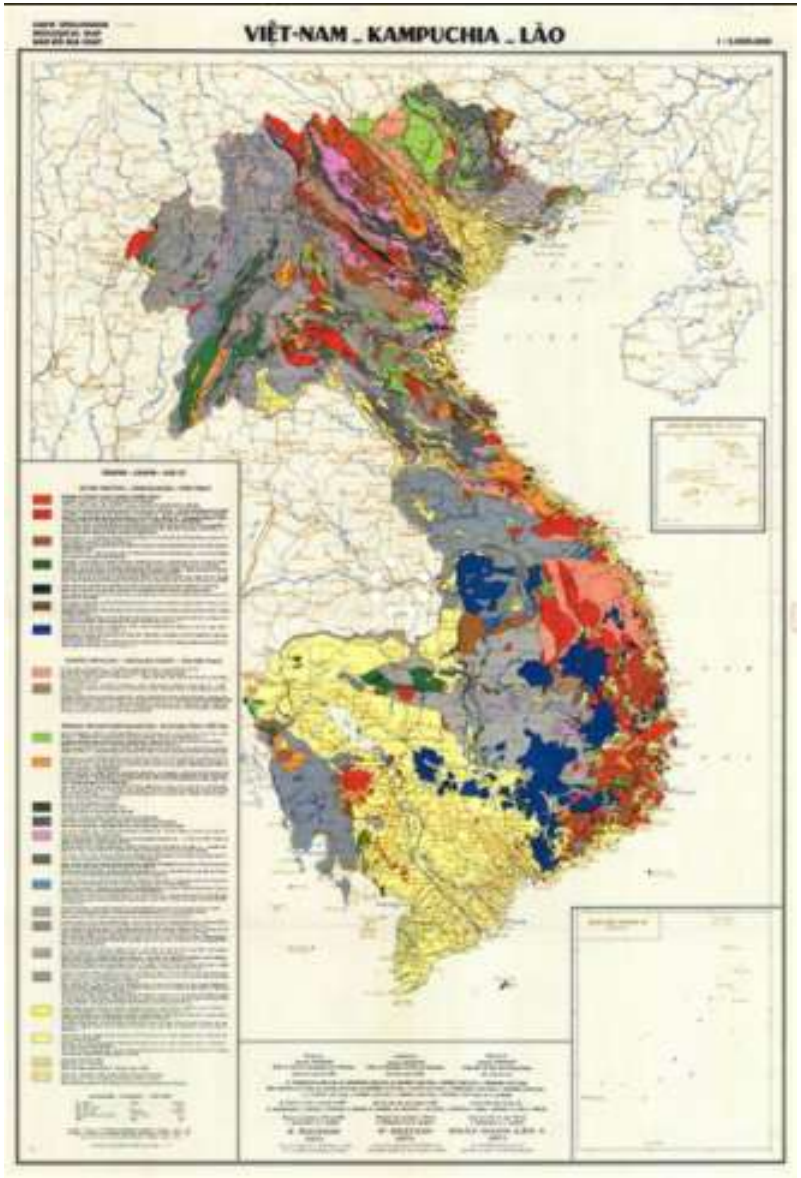
IAH : International Association of Hydrogeology, société savante.

Chinese Karstic Regions

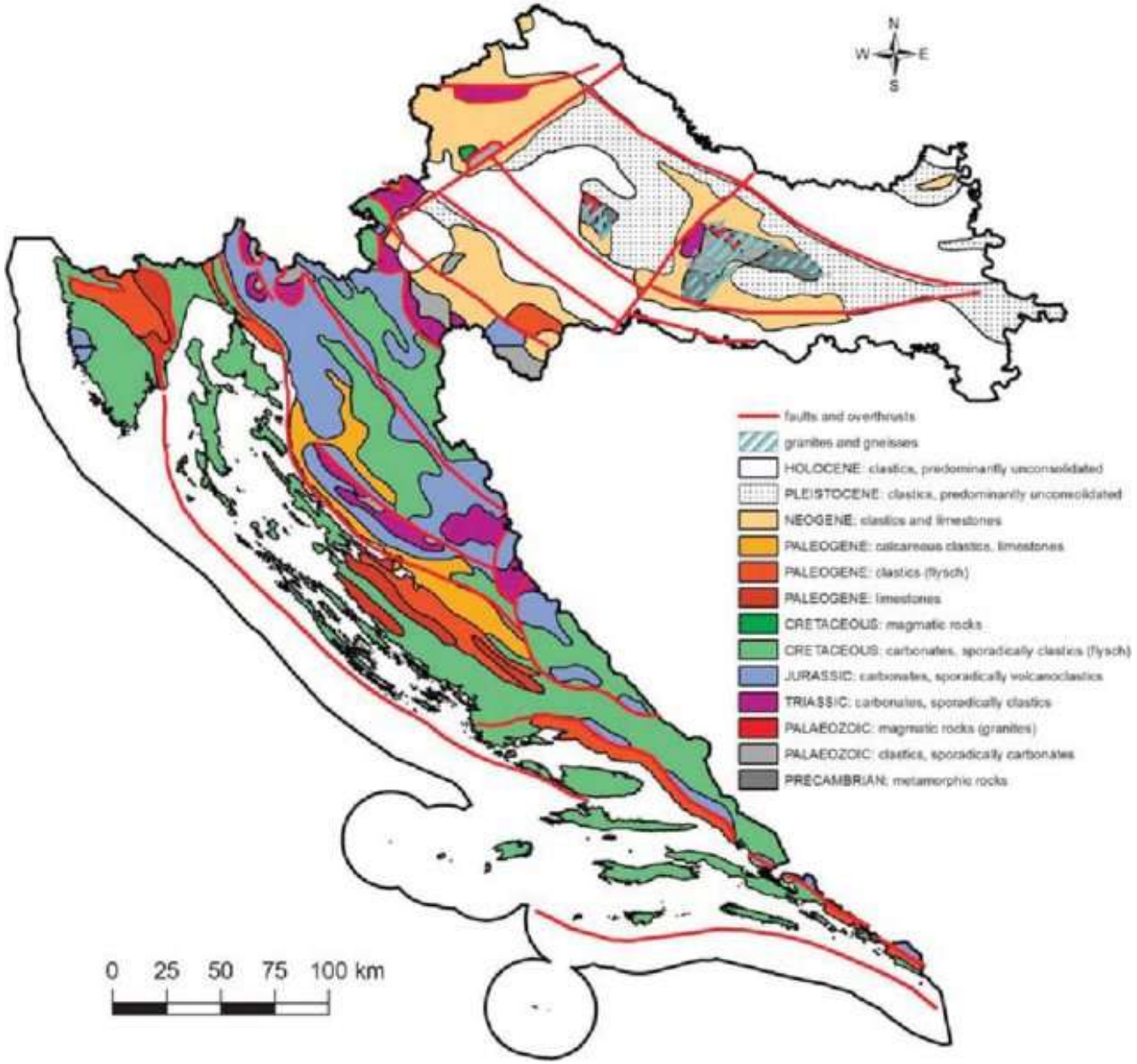


Malaysian & Vietnamese Karstic Regions

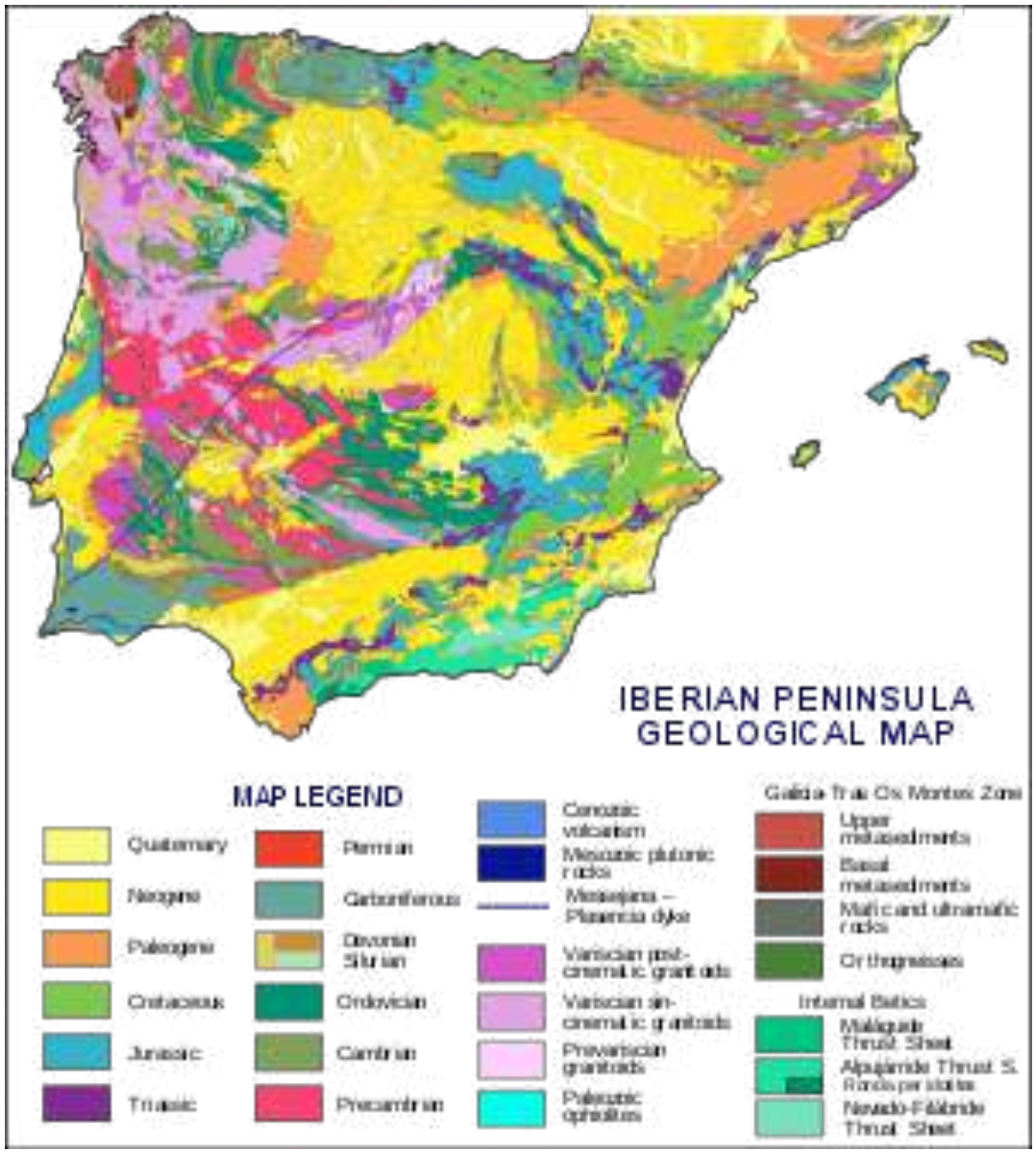




Croatian Karstic Regions



Portuguese and Spannish Karstic Regions



Explore Flooded Karst : Characterization of the Karst Dynamic

Network cartography beyond physiological limitations.

Seasonal measurements and Reproducible protocols.

Environment Instrumentation, specific marker drop.

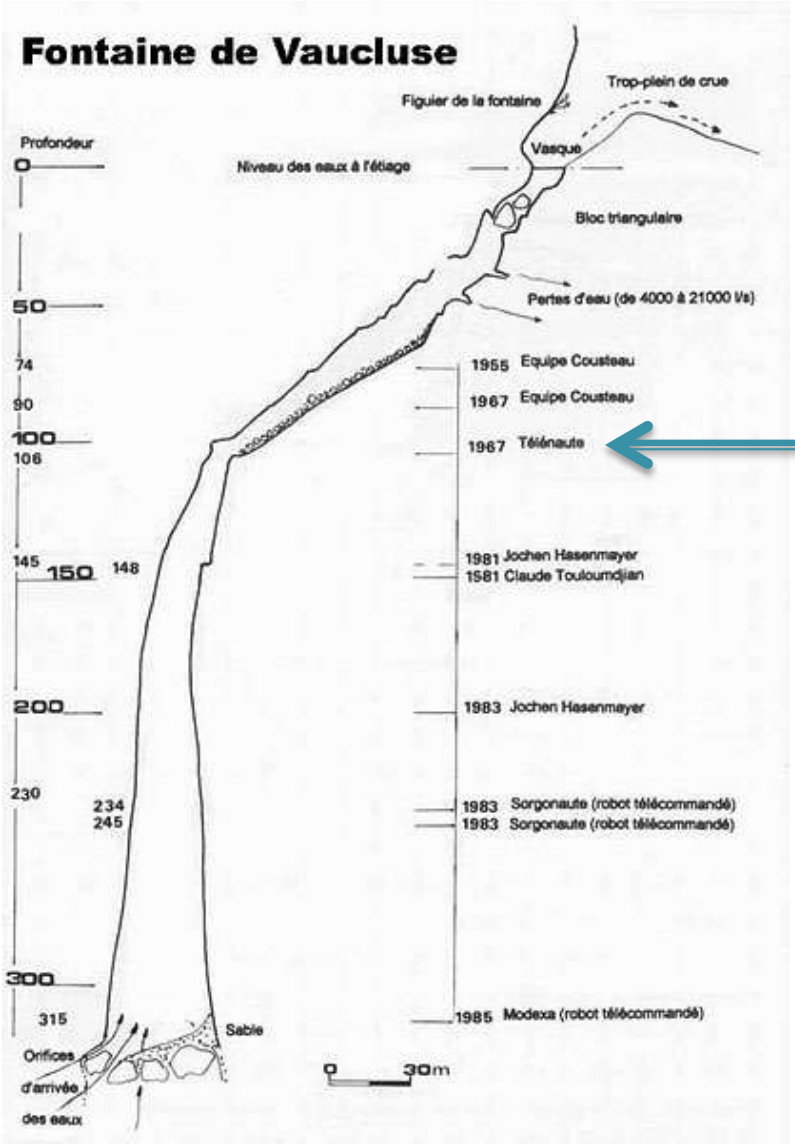
Geomorphology of the flooded zone (volumes) : new sensors, new models.

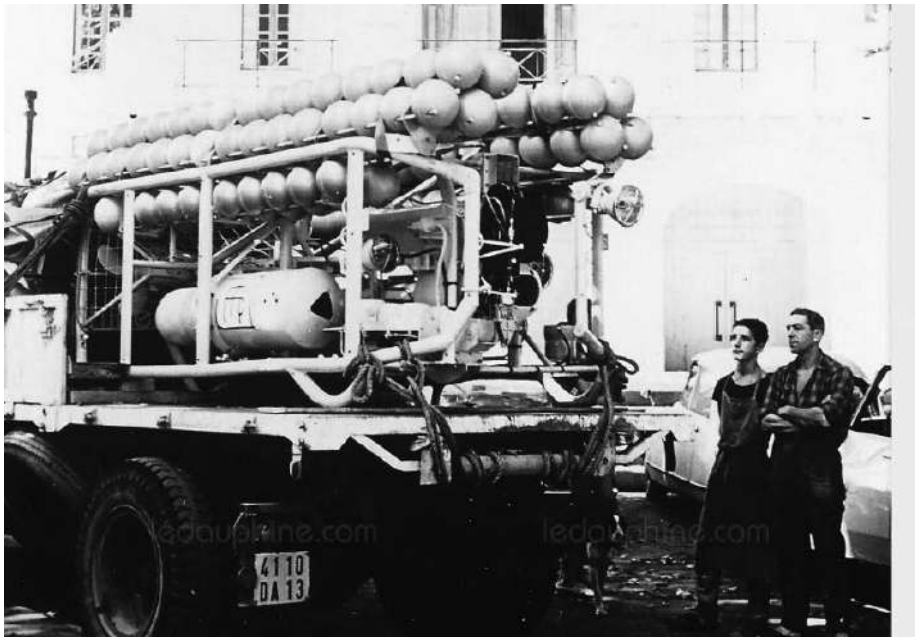
N-D geomorphological models

Karst Dynamics

A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

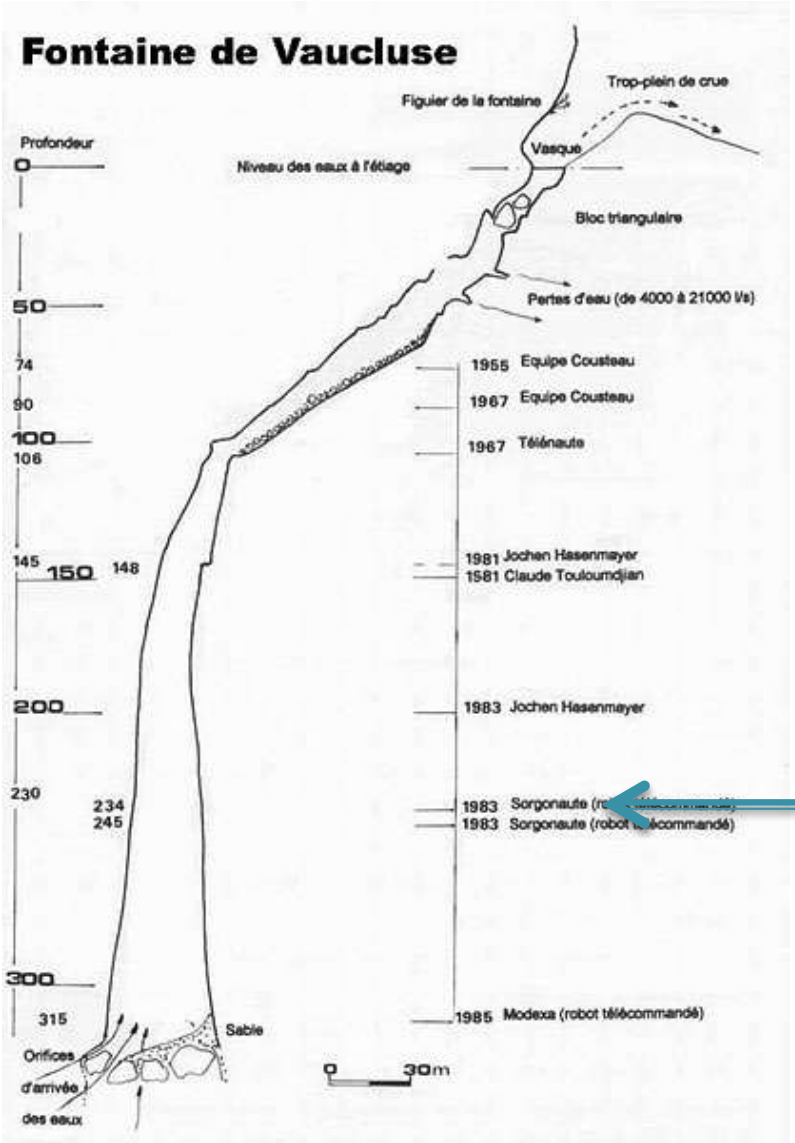




1967, Télénaute (Cdt Cousteau)
106m

A Rapid History of Karst Exploration With Robot

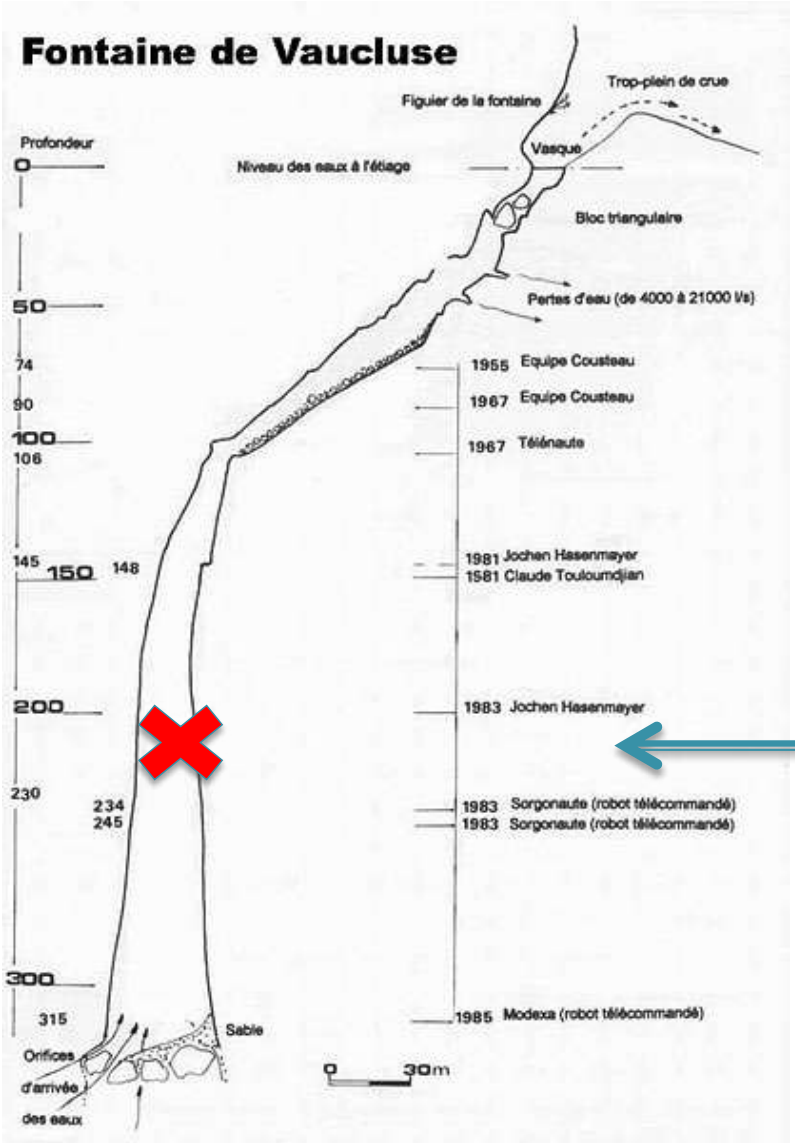
- Fontaine de Vaucluse : A magnificent Robotic Failure



1983, Sorgaunote (Renault)
243m
(stopped by cable length)

A Rapid History of Karst Exploration With Robot

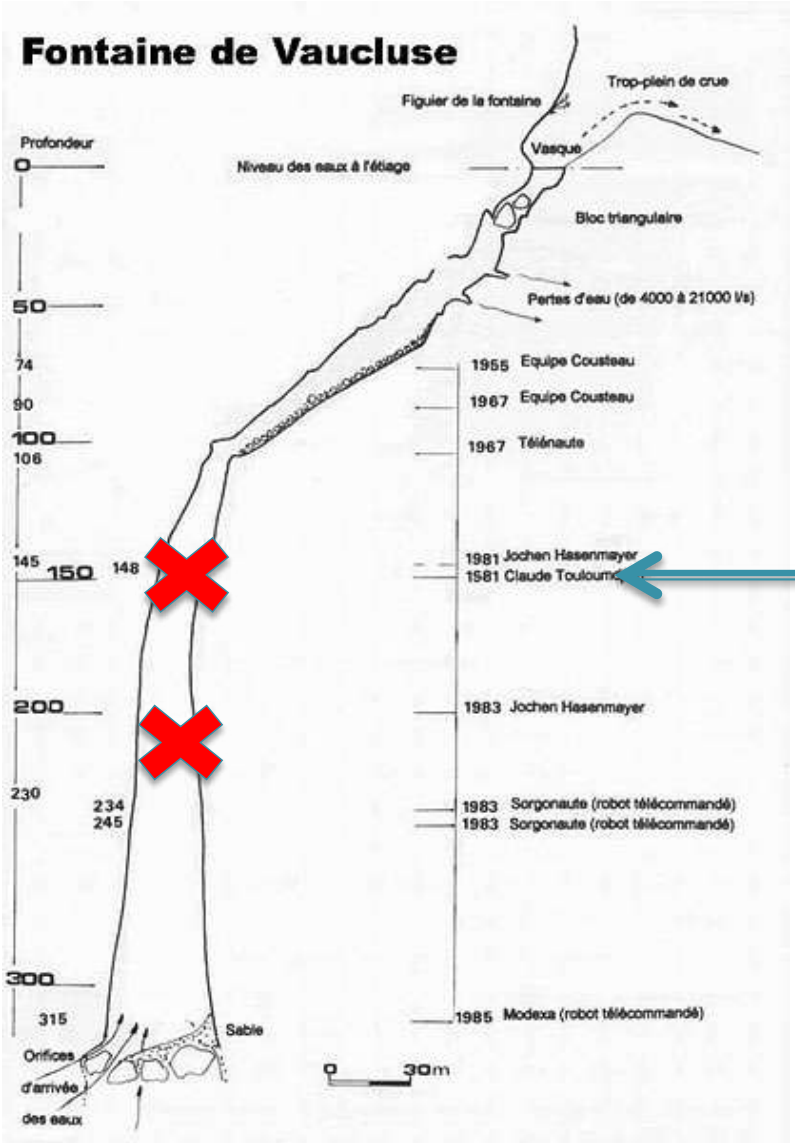
- Fontaine de Vaucluse : A magnificent Robotic Failure



1984, Sorgaunote II (Renault)
Lost at 233m
(Trapped in a remaining lifeline)

A Rapid History of Karst Exploration With Robot

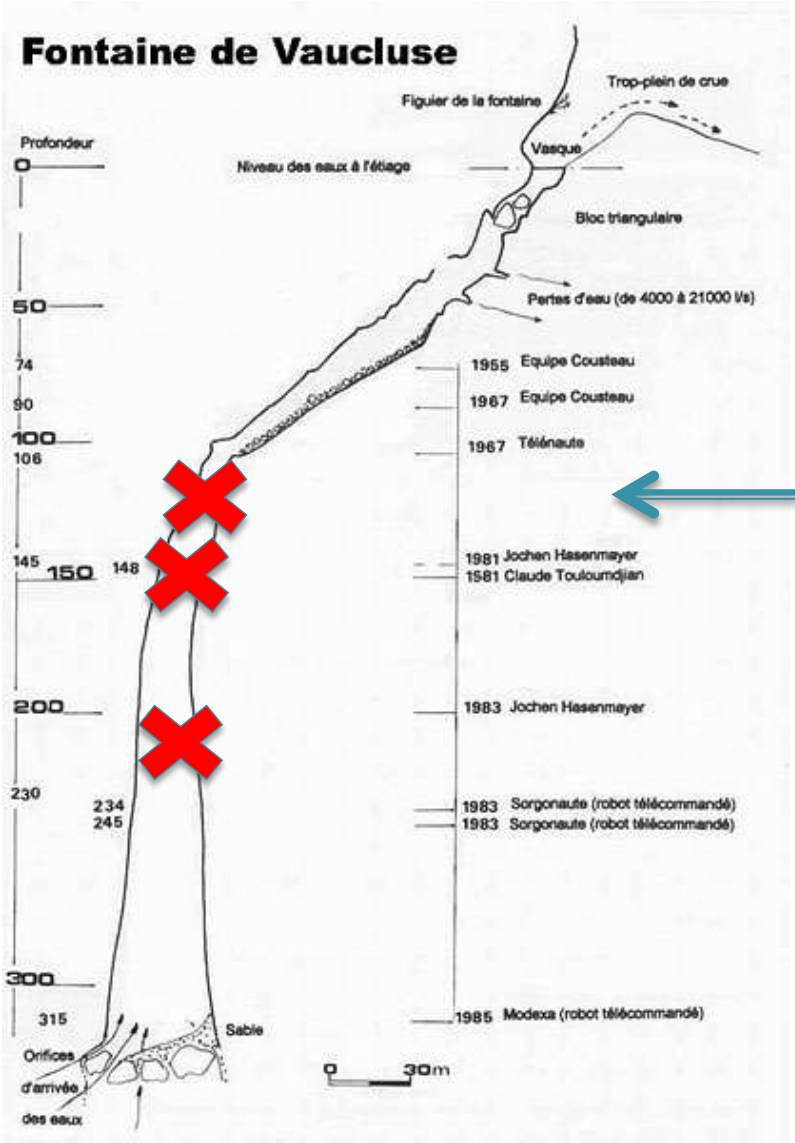
- Fontaine de Vaucluse : A magnificent Robotic Failure



1986, Sorgaunote III (Renault)
Lost at 150m
(Trapped in the cable of Sorgonaute II)

A Rapid History of Karst Exploration With Robot

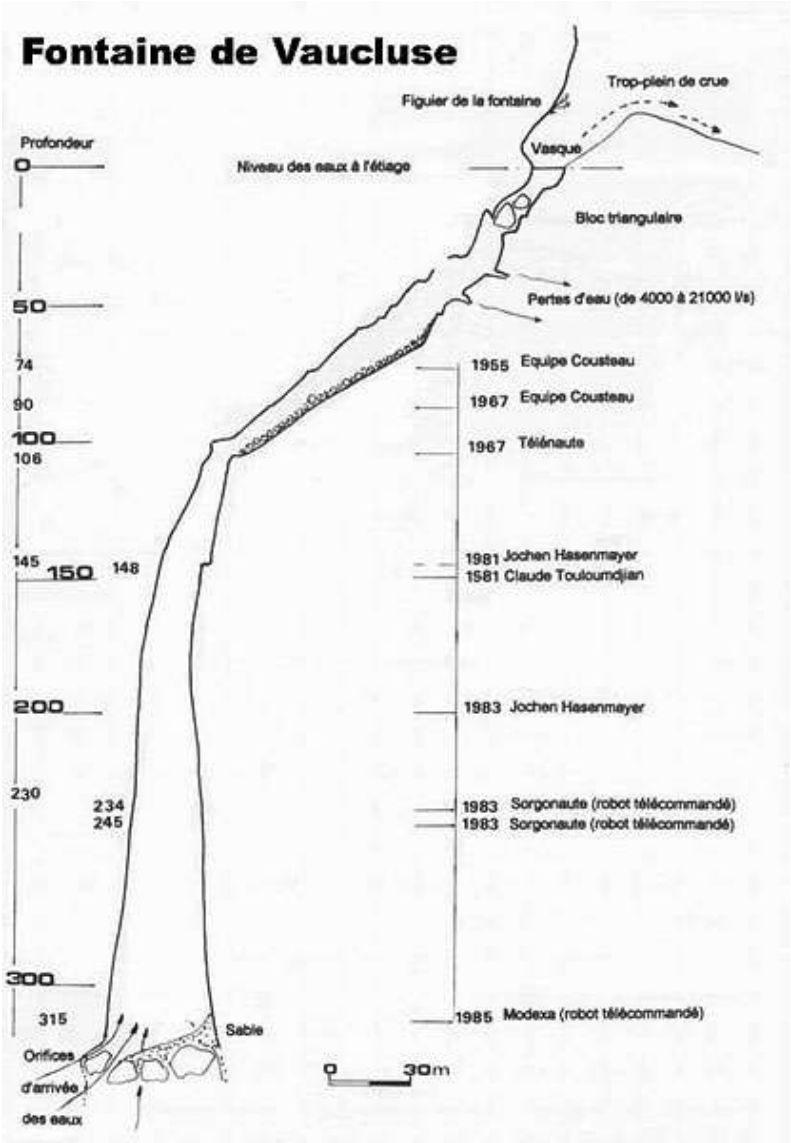
- Fontaine de Vaucluse : A magnificent Robotic Failure



1983, Sorgaunote IV (Renault)
Failure
(Unable to recover SI and SII)

A Rapid History of Karst Exploration With Robot

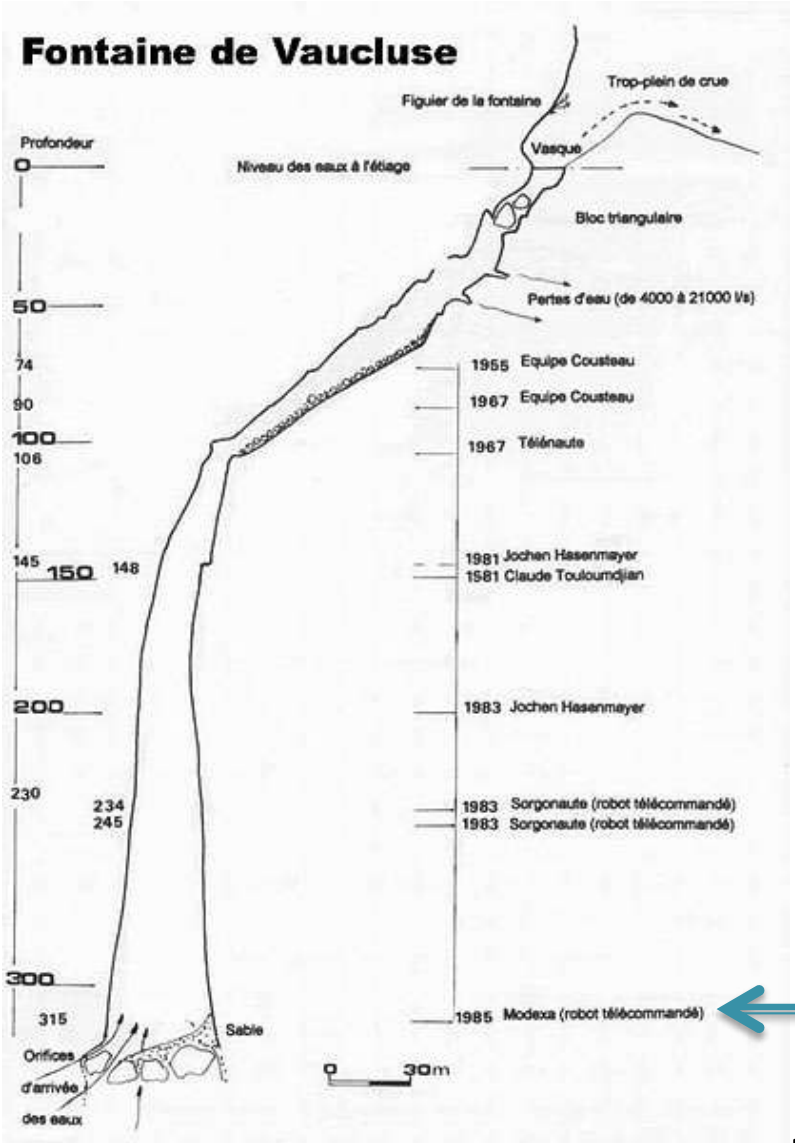
- Fontaine de Vaucluse : A magnificent Robotic Failure

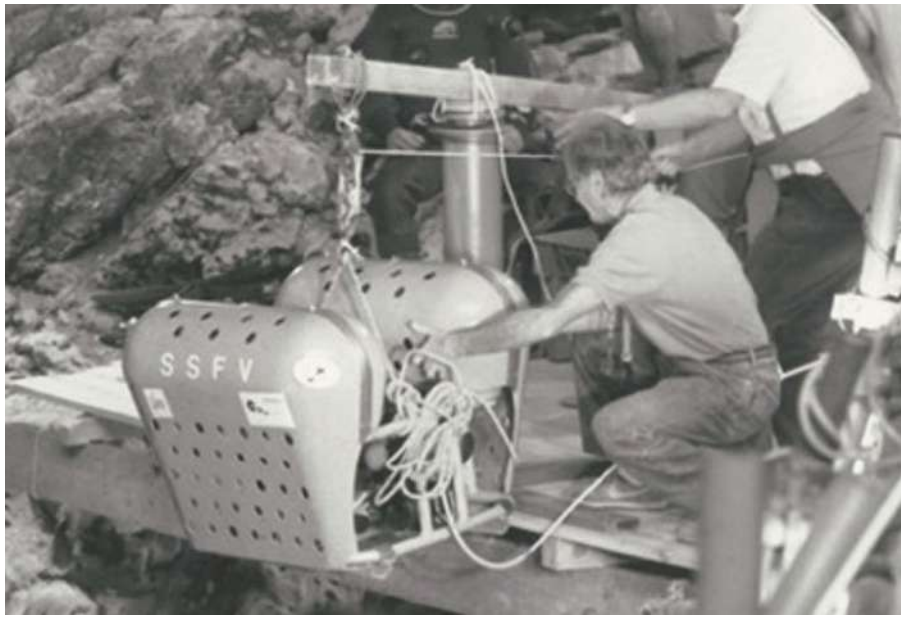


1984, The chasm was cleared by divers

A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure



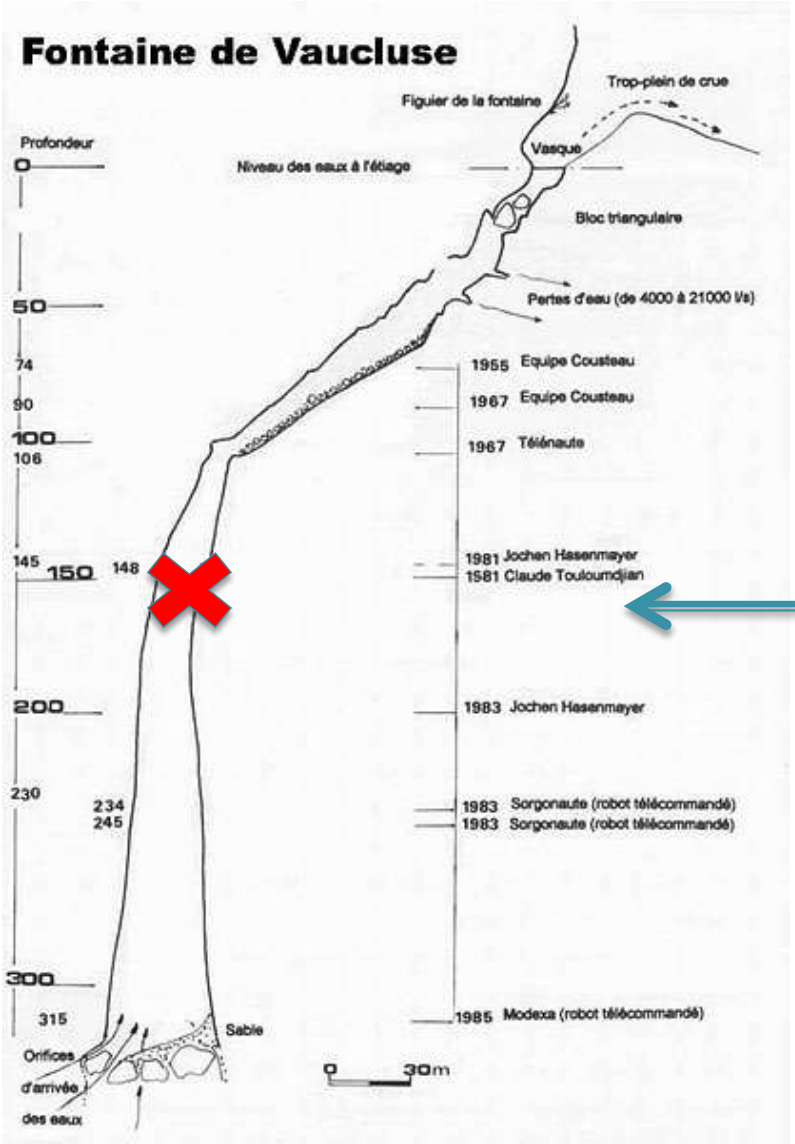


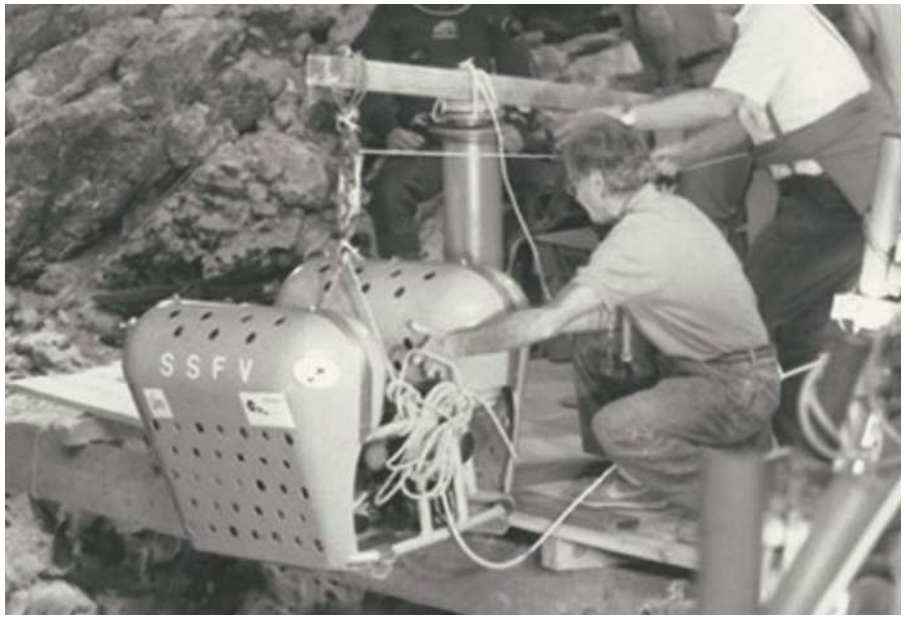
1989, Spélénaute (S.S.F.V.)
Touch-down : 315m

1985, Modexa (M.I.C), Touch-down : 315m

A Rapid History of Karst Exploration With Robot

- Fontaine de Vaucluse : A magnificent Robotic Failure

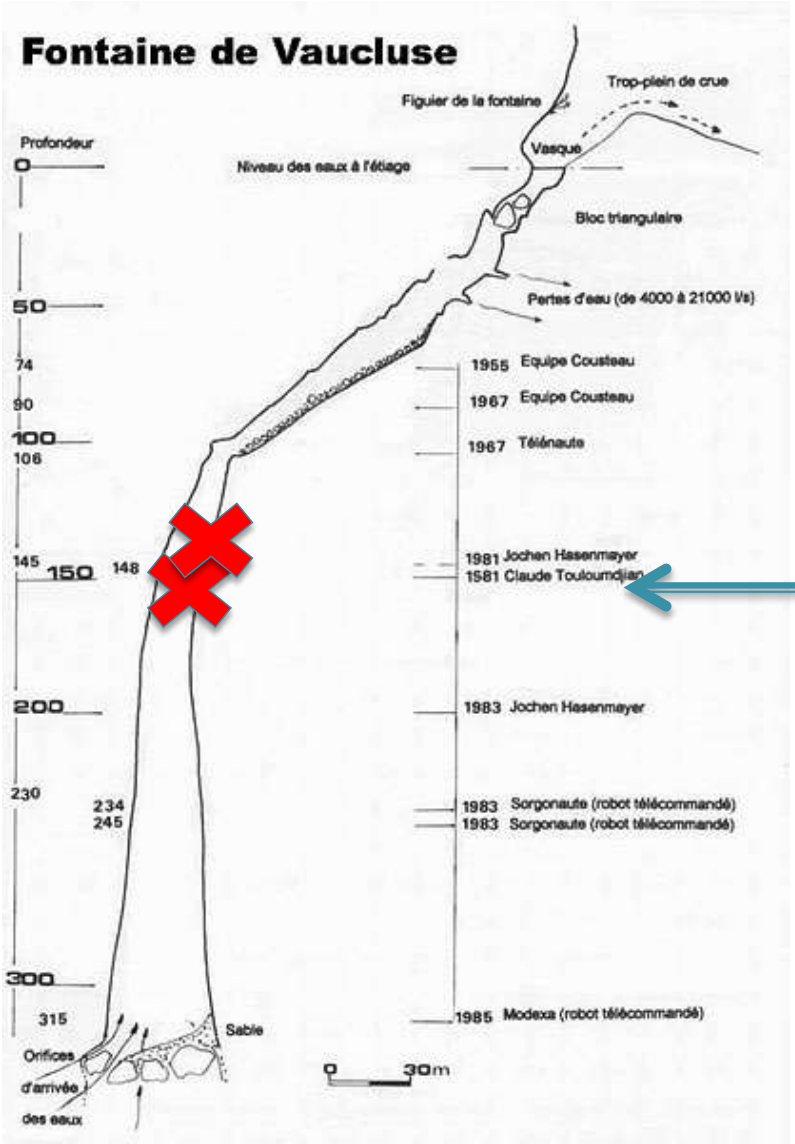




1996, Spélénaute III (S.S.F.V.)
Lost at 164m
(Trapped in a remaining lifeline)

A Rapid History of Karst Exploration With Robot

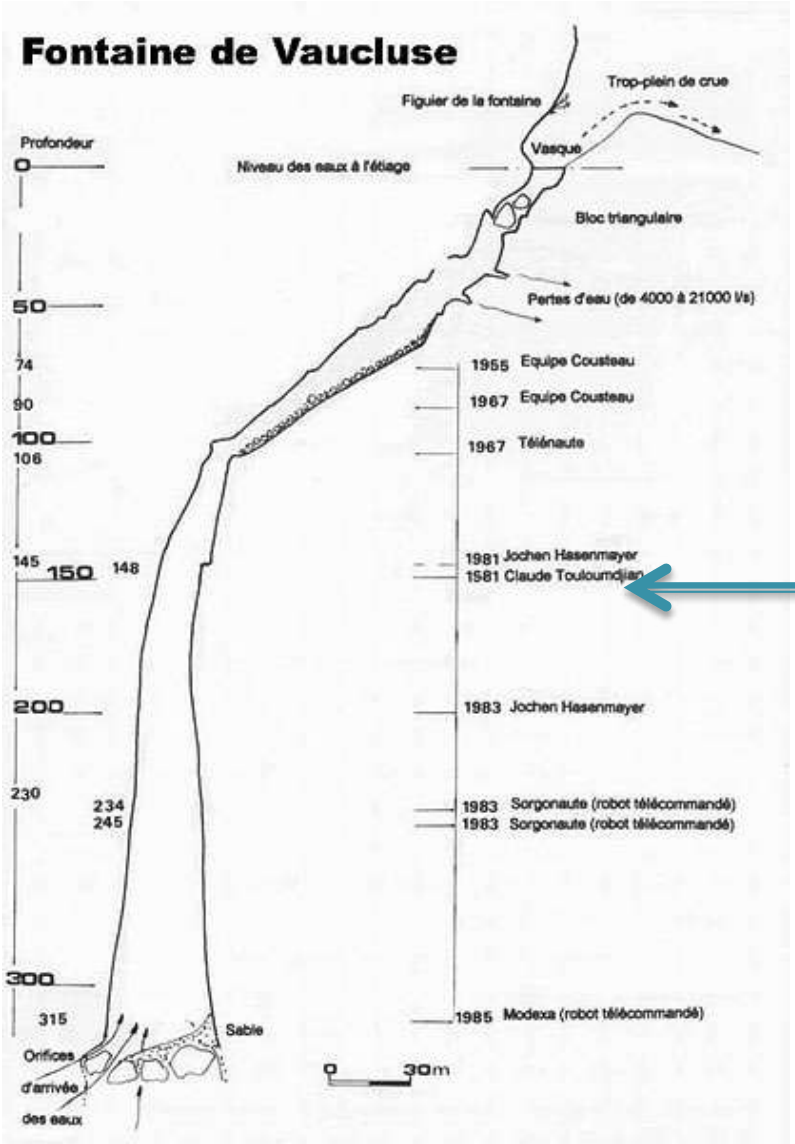
- Fontaine de Vaucluse : A magnificent Robotic Failure



1996, ROV COMEX
Lost at 164m
(Trapped in the cable of Spélénaute III)

A Rapid History of Karst Exploration With Robot

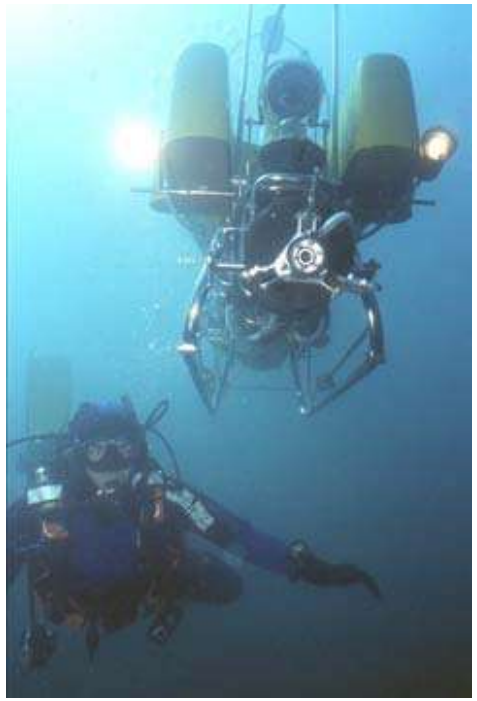
- Fontaine de Vaucluse : A magnificent Robotic Failure



1996, Chasm cleared by divers

A Rapid History of Karst Exploration With Robot

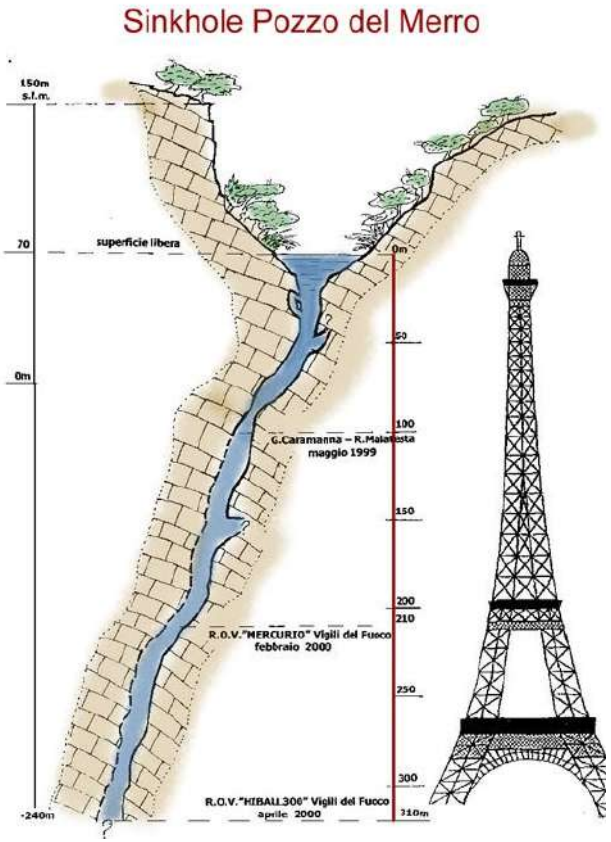
- Exploration of the Pozzo Del Merro (Italy)



2000, Mercury, 210m

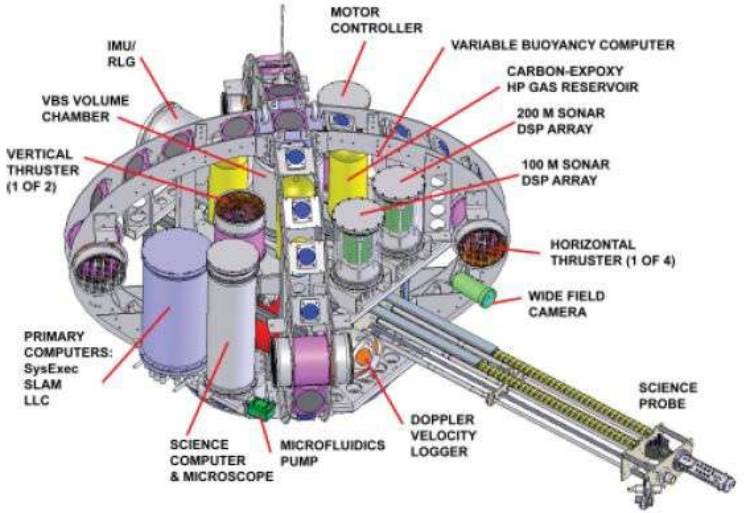
2001, Hyball, 310m

2002, Prometheus, 392m

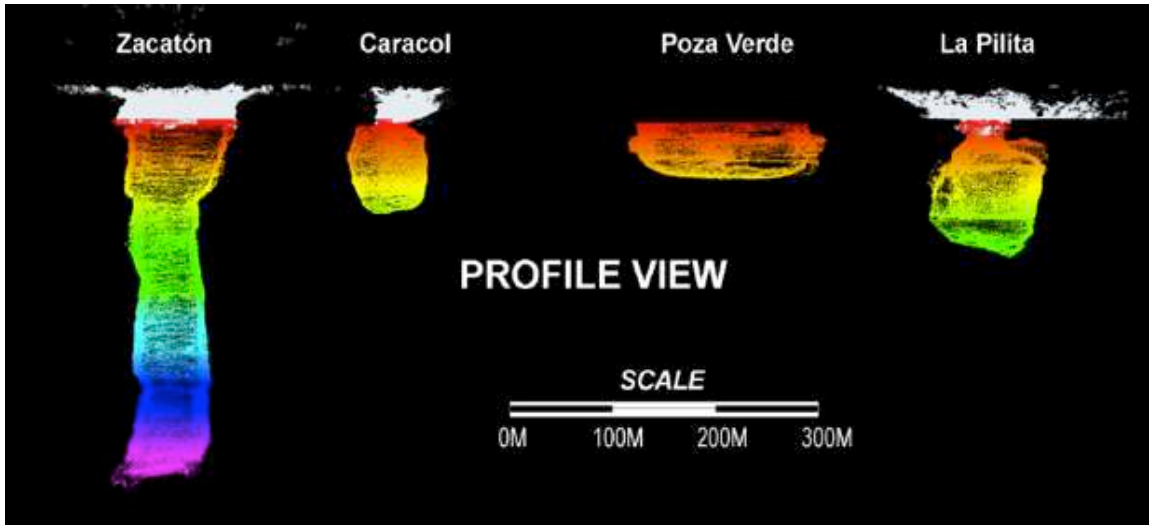


A Rapid History of Karst Exploration With Robot

- DepthX (DEep Phreatic THermal eXplorer)

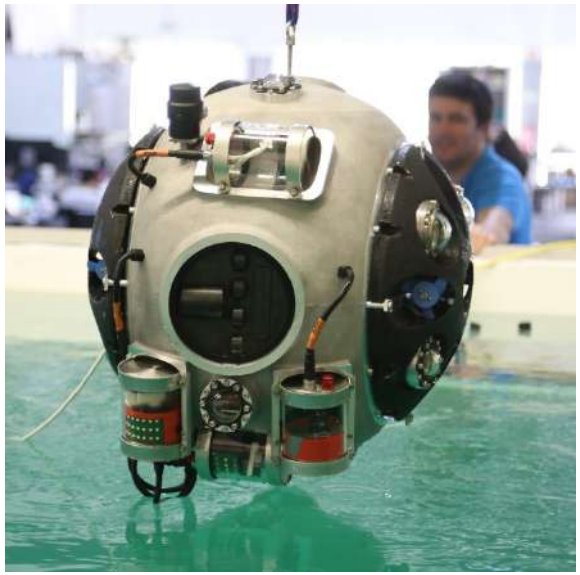


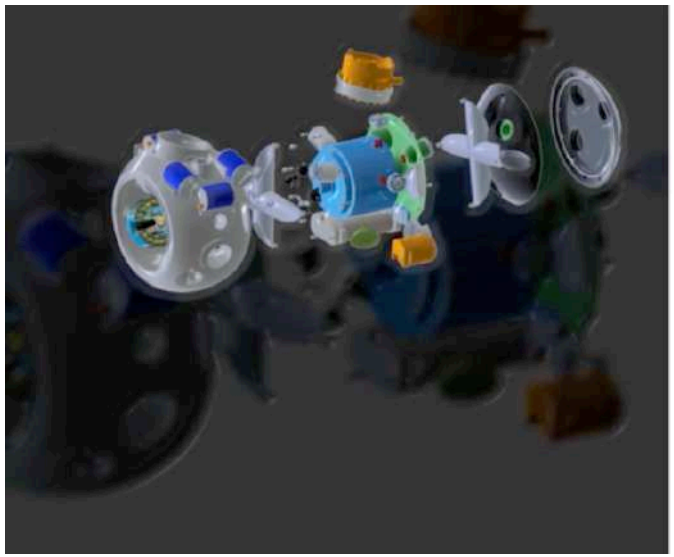
AUV for
Cenote (flooded skinholes)
exploration



A Rapid History of Karst Exploration With Robot

- Unexmin (UX-1 : AUV explorer for flooded mines)





EGYETEM

GeoZS Geološki zavod Slovenije

POLITÉCNICA

LPRC LA PALMA RESEARCH CENTRE

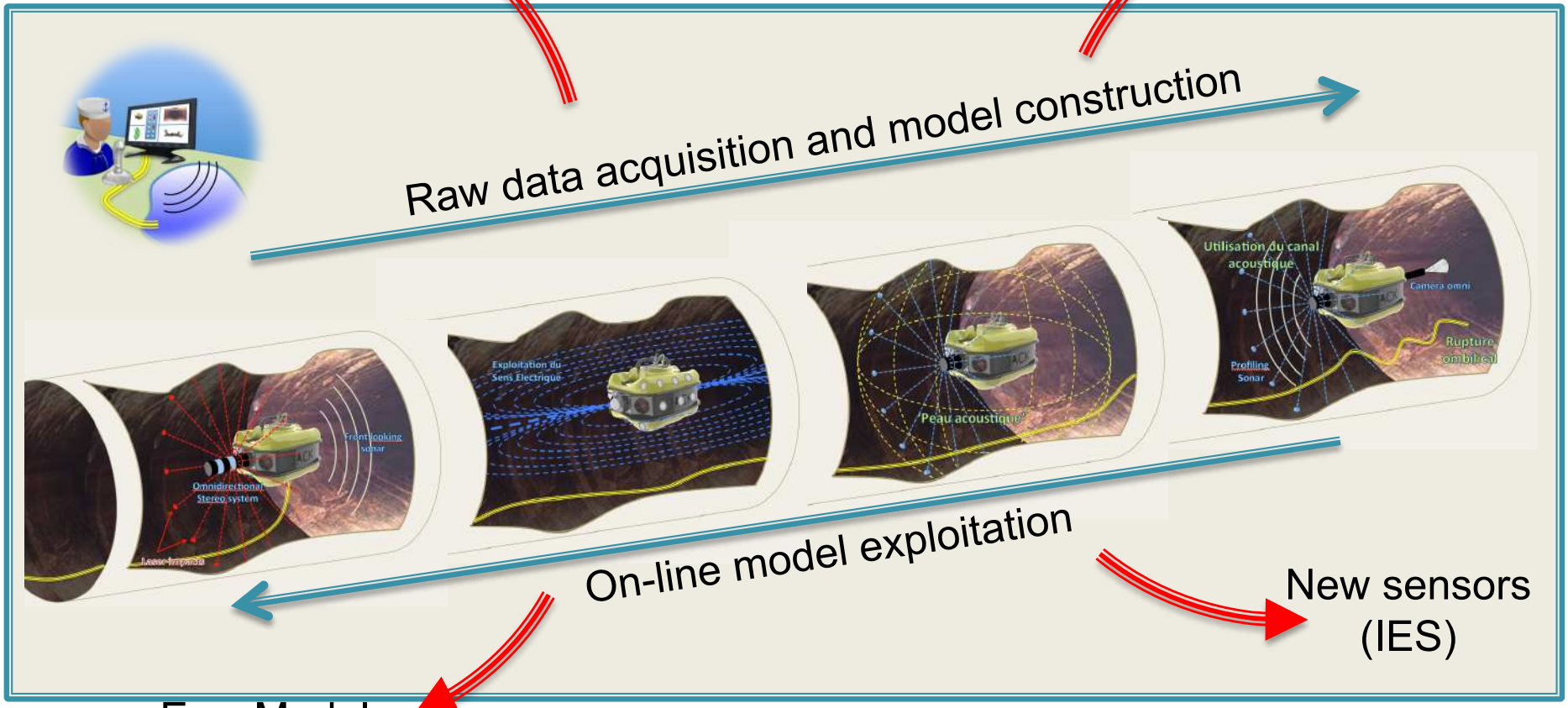
INESCTEC

- Water sampler
- Conductivity and pH measuring units
- Sub-bottom profiler
- Magnetic field measuring unit
- UV and SLS imaging units
- Multispectral camera
- Acoustic cameras
- Laser scanners
- Thrusters
- SONARs
- Pendulum and buoyancy control system
- Rechargeable batteries
- Protective pressure hull

The Aleyin Initiative

Vector
(LIRMM)

Environnement
(HSM)



New sensors
(IES)

Env. Models
(IMAG)

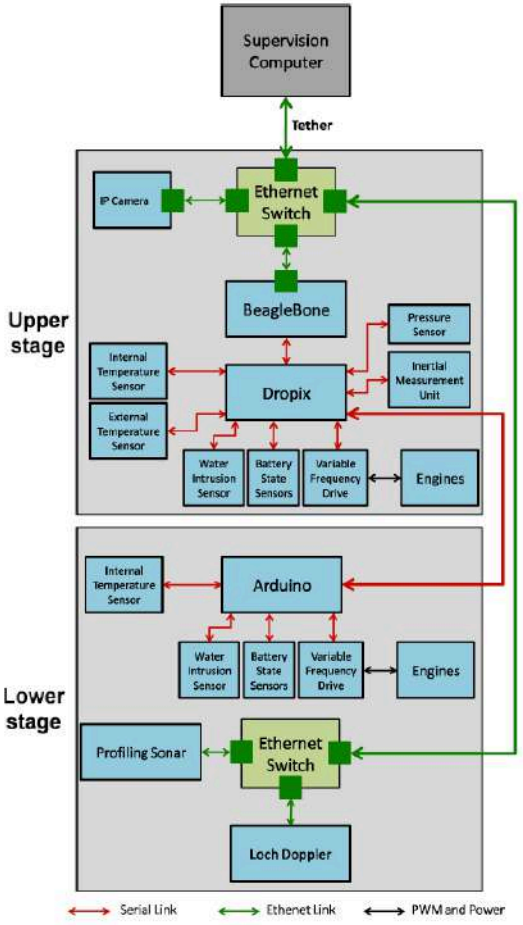
LIRMM HSM ies l'institut d'électronique IMAG INSTITUT MONTPELLIERAIN ALEXANDER GROTHENDIECK UNIVERSITE MONTPELLIER

The RKE Initiative : The Challenges

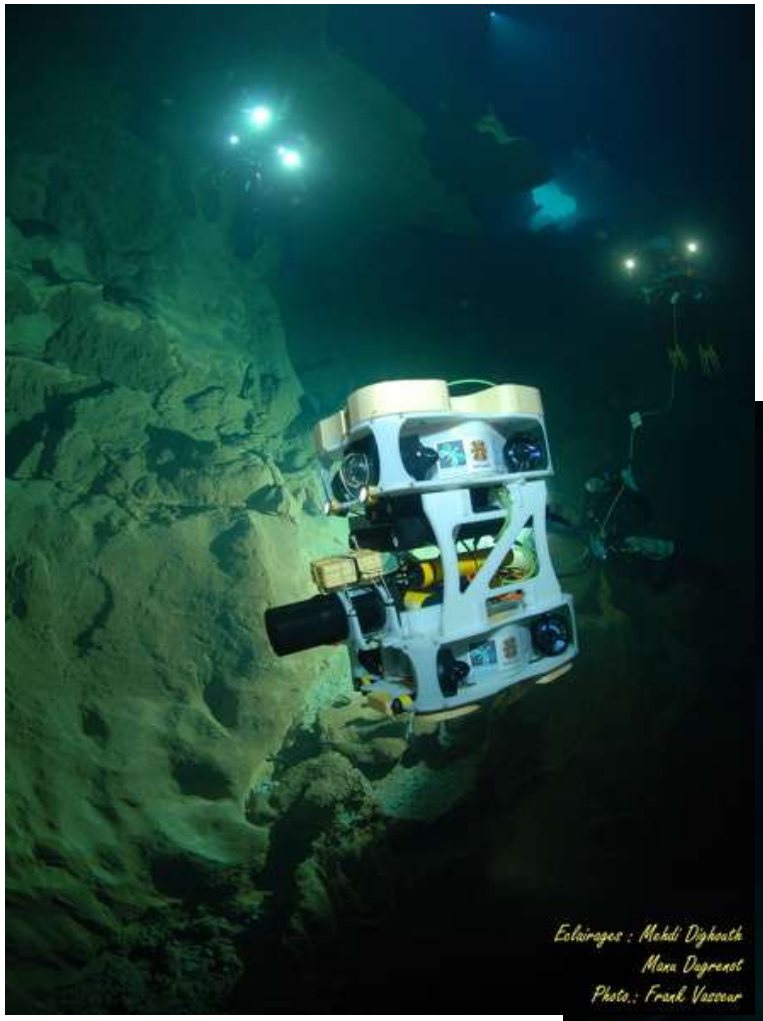
- New Sensors Development
  - Acoustic Skin
  - Active Umbilical
  - Fast Profiling Sonar
- Navigation
  - n-D SLAM
  - Vacancy Evidence Grids
- Guidance
  - Autonomous Centring
  - Autonomous Targeting
  - Env. Models inclusion
- Control
  - Robustness
  - Co-control
  - Open-loop stability
- Actuation
  - Reactive redundant A.S.
- Software Architecture
  - Management of sensors recruitment (acc. jamming)
  - Adaptive Autonomy
  - Dependability
  - Guarantees of Performances
- Models
  - Multi-modality & Scalability
  - Uncertainty Consideration
- Technology
  - Active Truncanner, NRJ opt.
- Economic
  - Evangelization of a Blue Ocean

The Aleyin Initiative : Ulysse

- 2x6 thrusters
- IMU
- Camera
- Acoustic Camera
- Profiling Sonar
- DVL



SYSTEMS

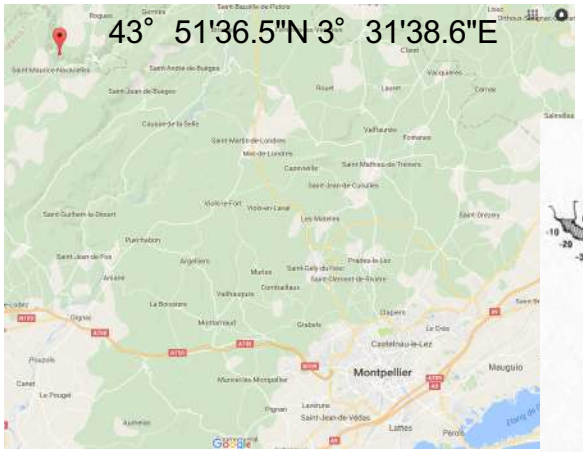


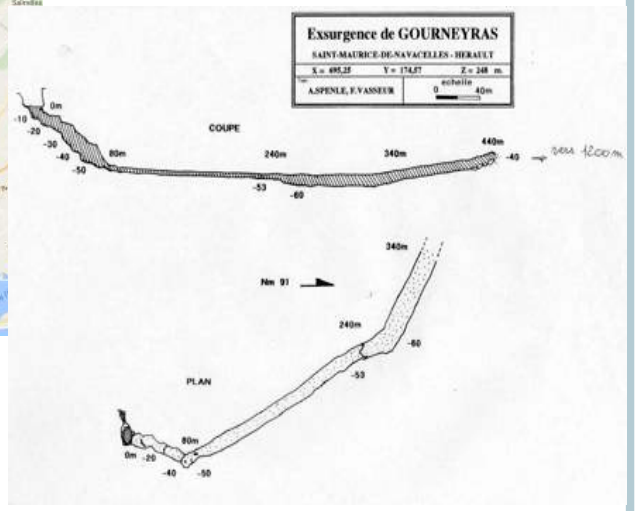
Ulysse

NavScoot

Fisrt Terrain Results

- Gourneyras, 11-14/07/2016





- Gourneyras, 23/01/2017.

Exploration and cartography of the entry chasm (robot)

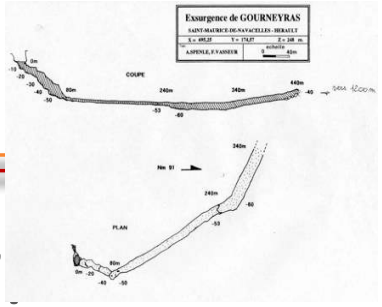
Extended network cartography (NavScoot)

Validations : co-control, new electronic and software architectures.

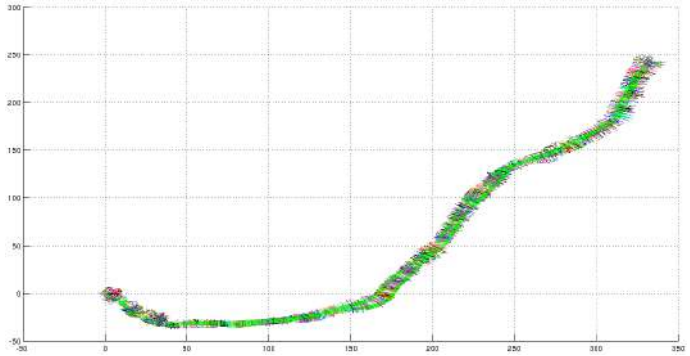
Fisrt Terrain Results

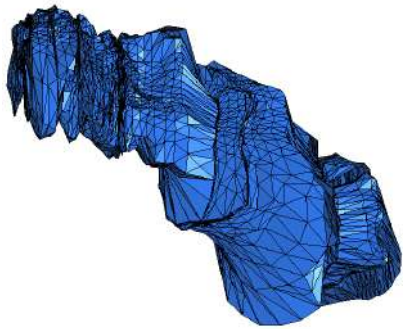
- Gourneyras, 11-14/07/2016 and 23/01/2017.

Fisrt Terrain Results

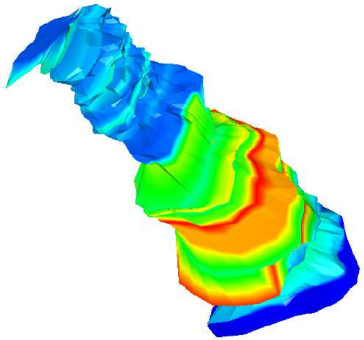


- Gourneyras, 11-14/07/2016 and 23/01/2017

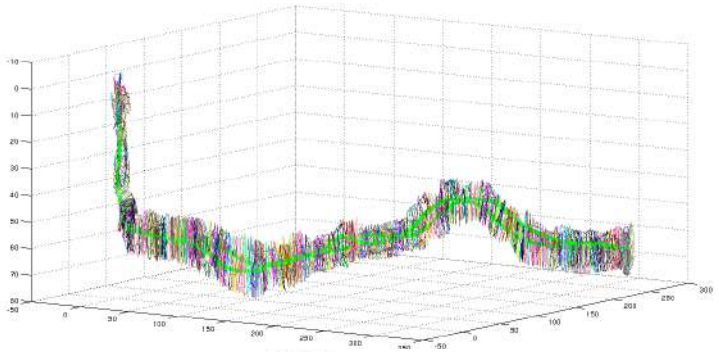


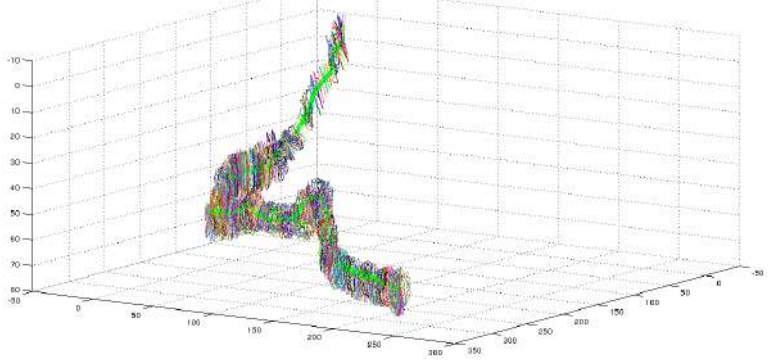


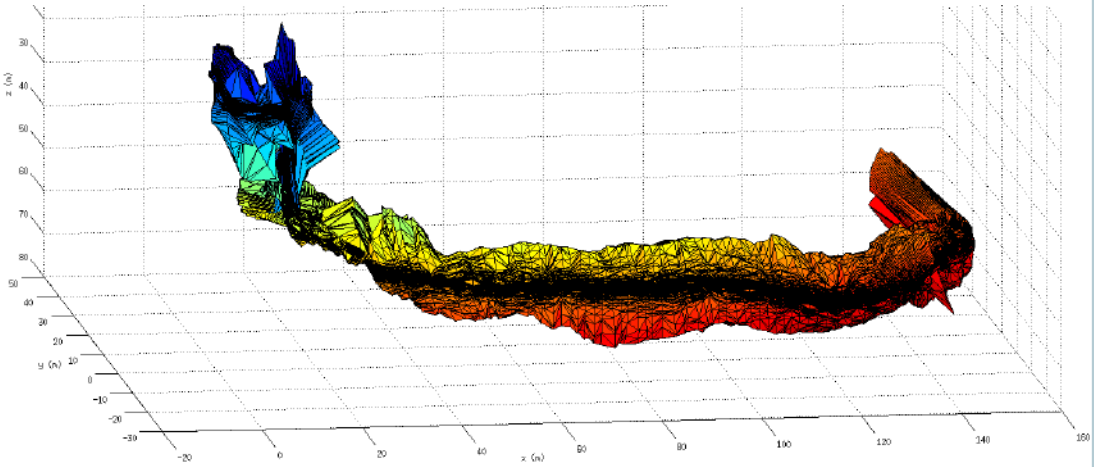
Volume (1187 m^3)



Uncertainty map

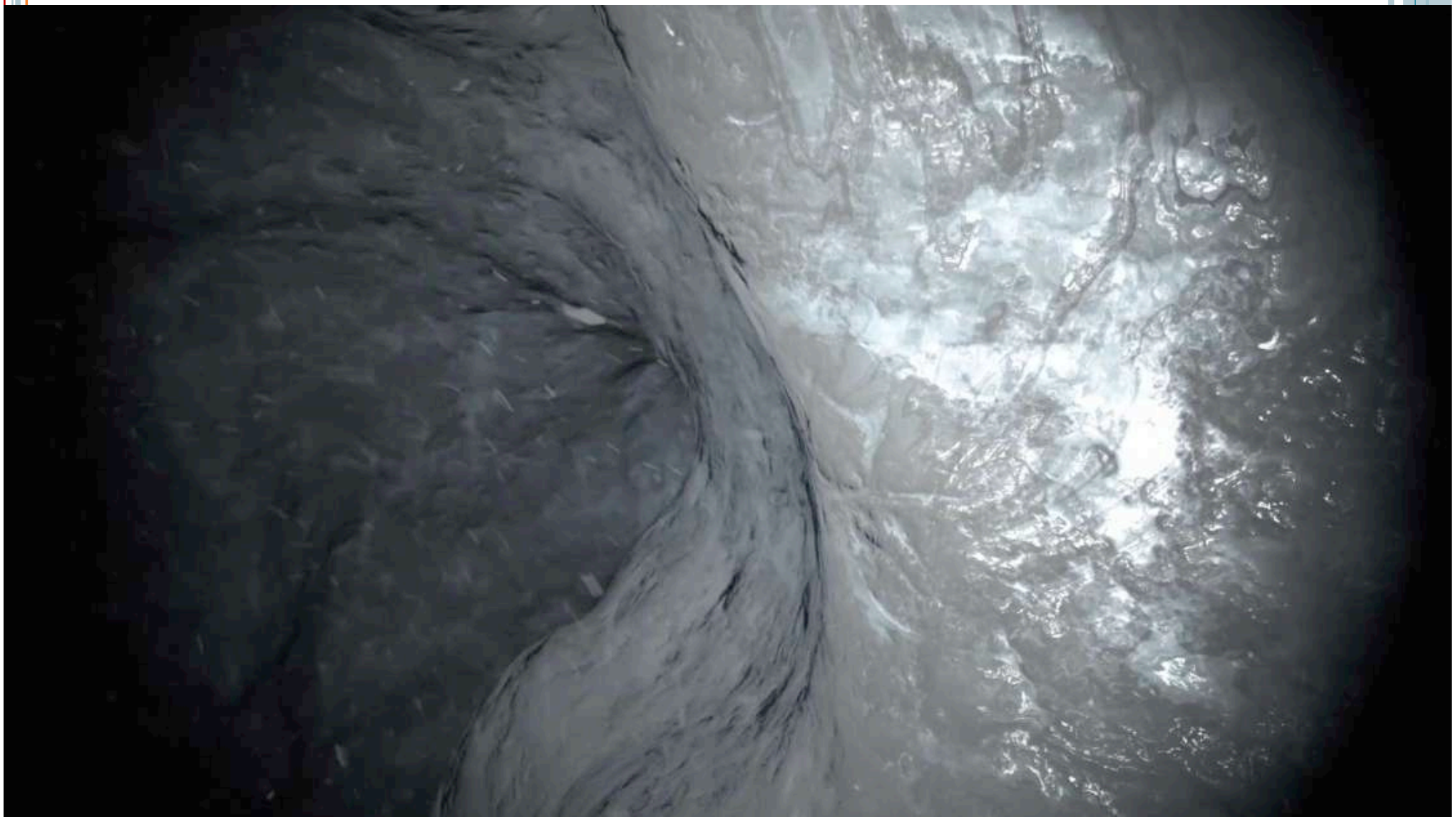






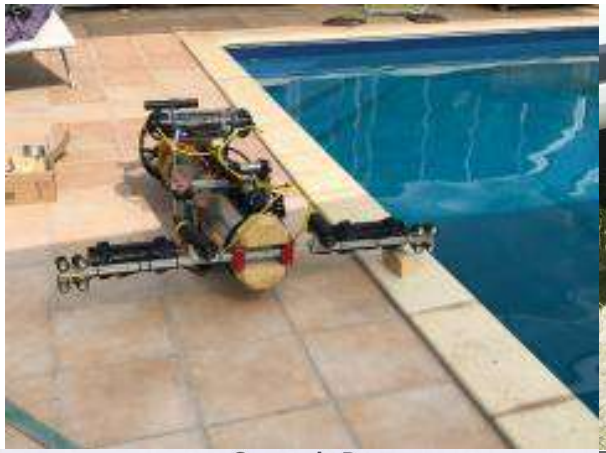
Fisrt Terrain Results

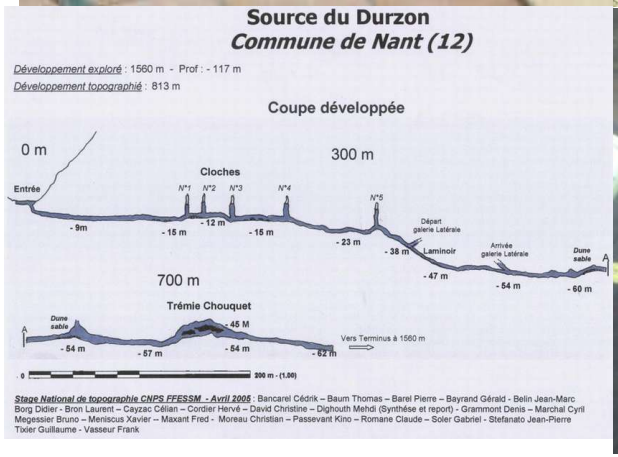
- Gourneyras, virtual visit



Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.



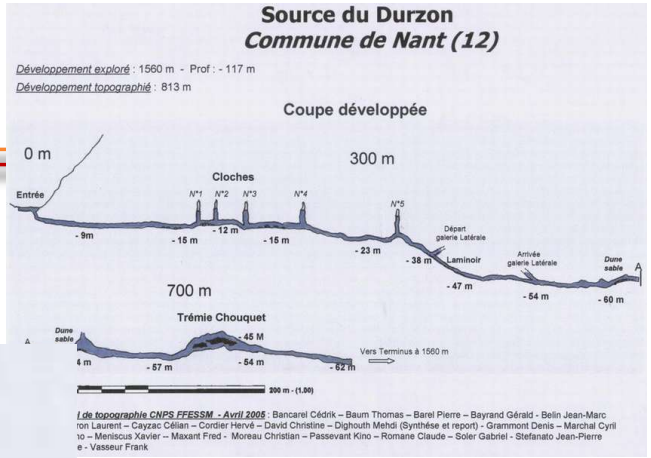


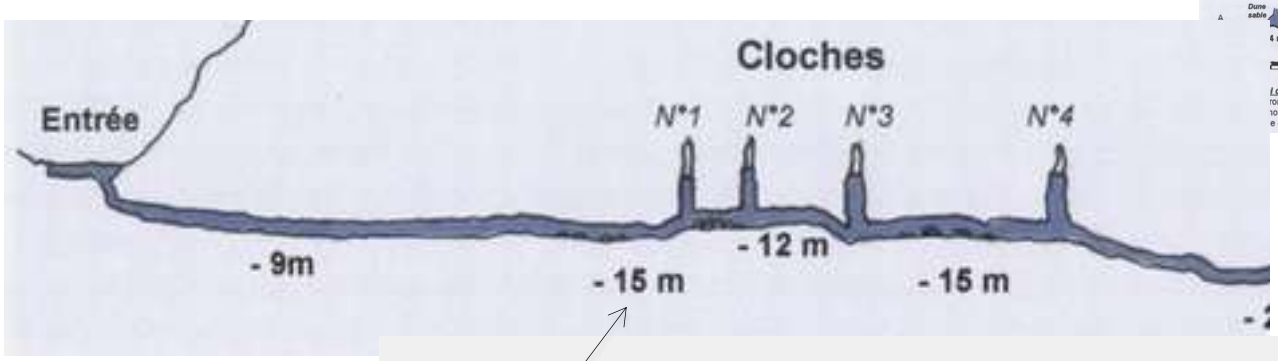
Fisrt Terrain Results

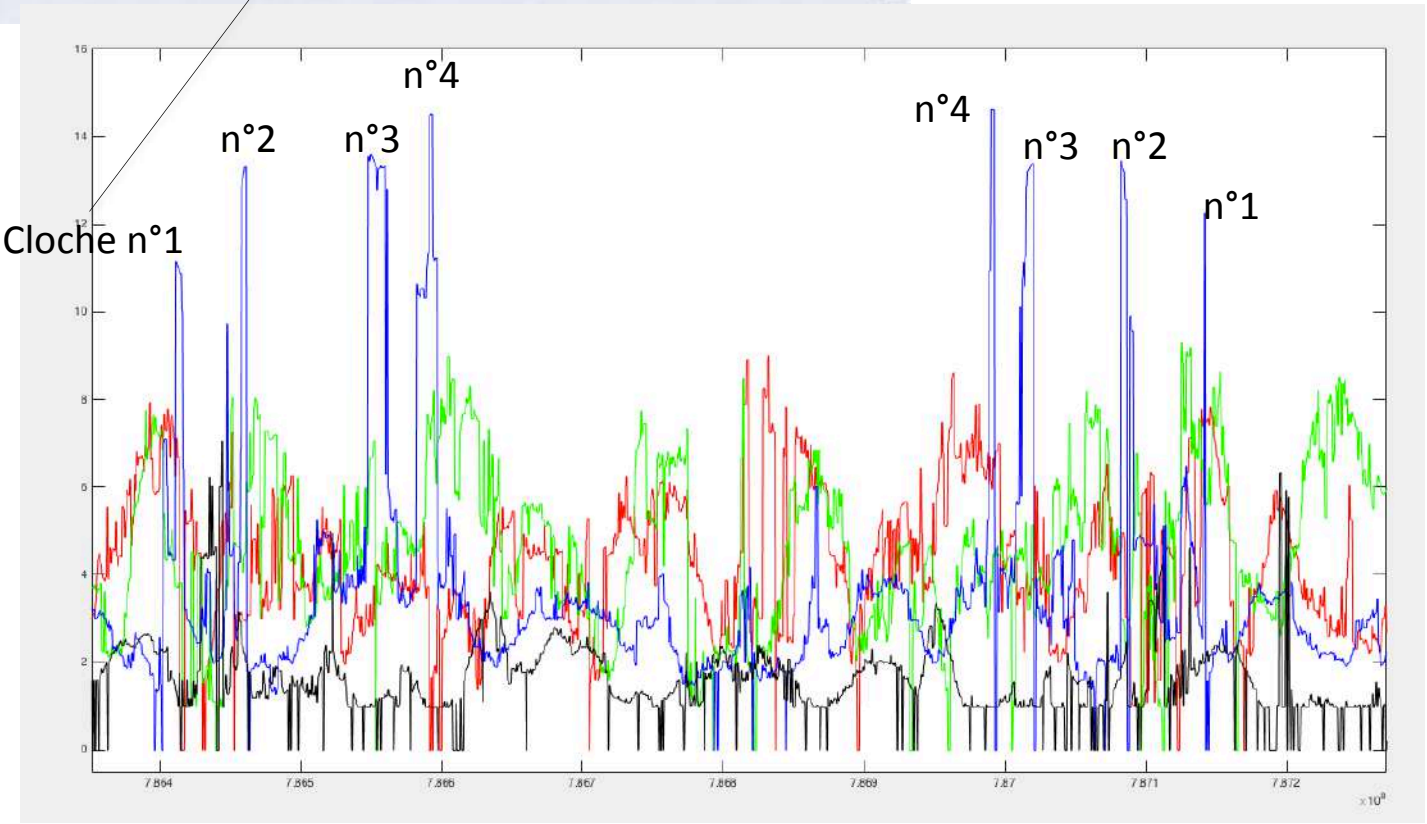
- Durzon, Nant, 24/06/2018.

Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.





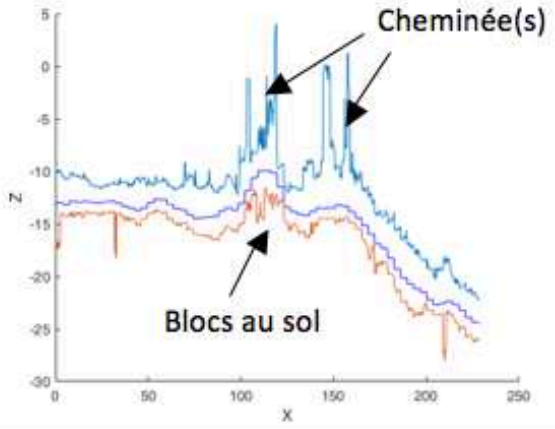
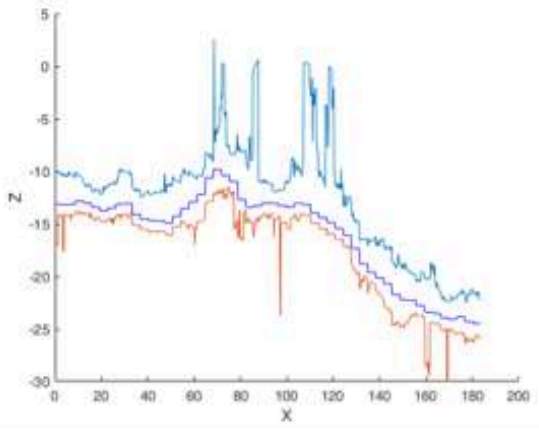
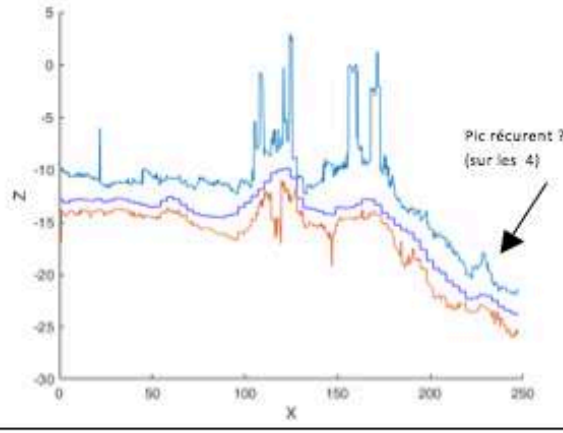
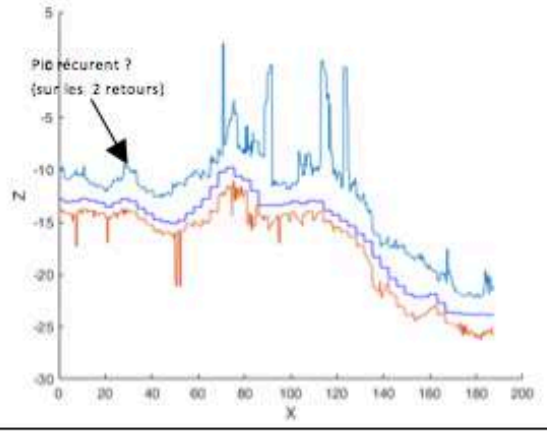


FISRT TERRAIN RESULTS

- Durzon, Nant, 24/06/2018.

« Vue de coté » (Echosondeurs Haut/Bas + Profondimètre)

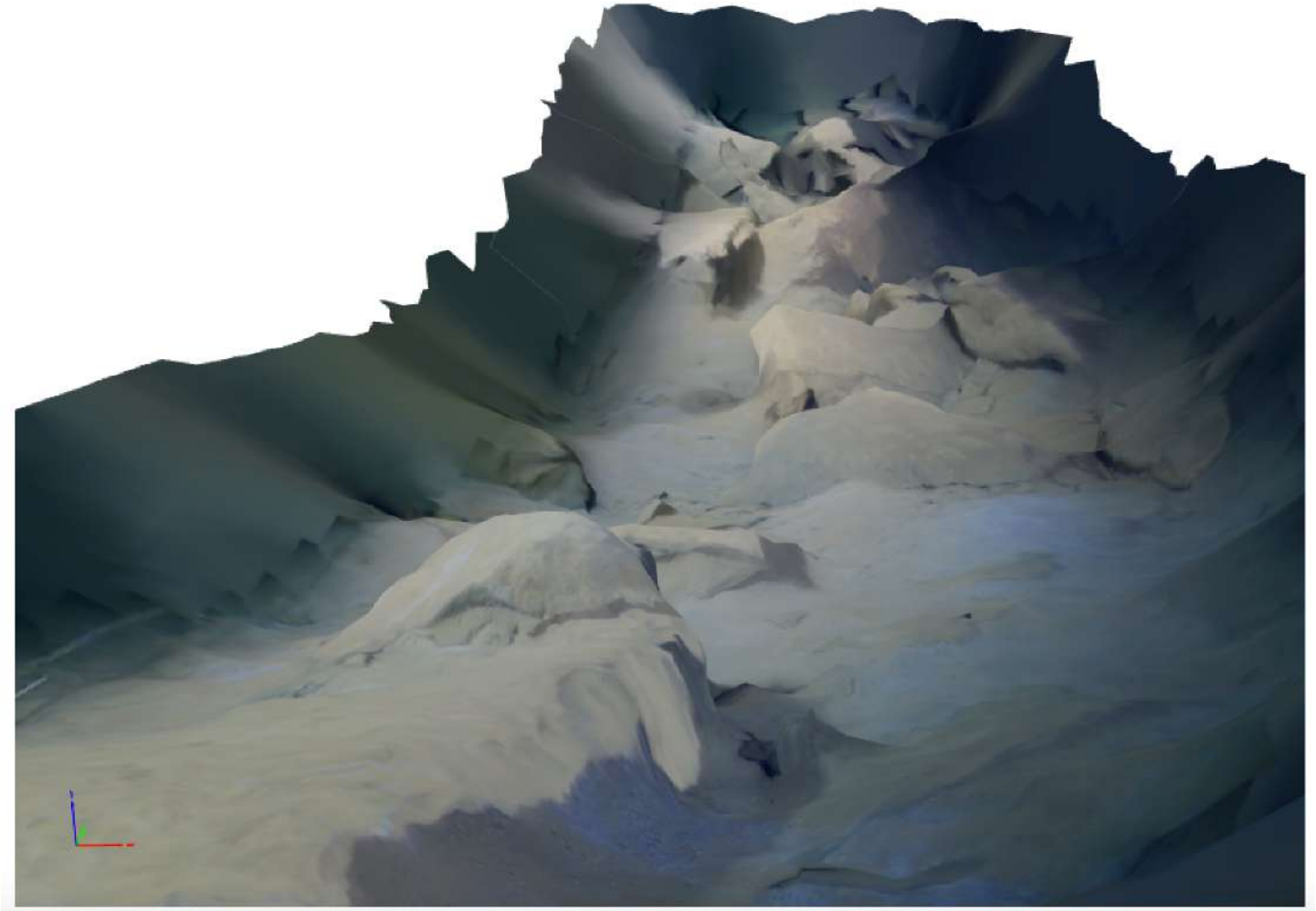
Données :

	Aller	Retour (inversé G/D)
1er		
2nd		

Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.

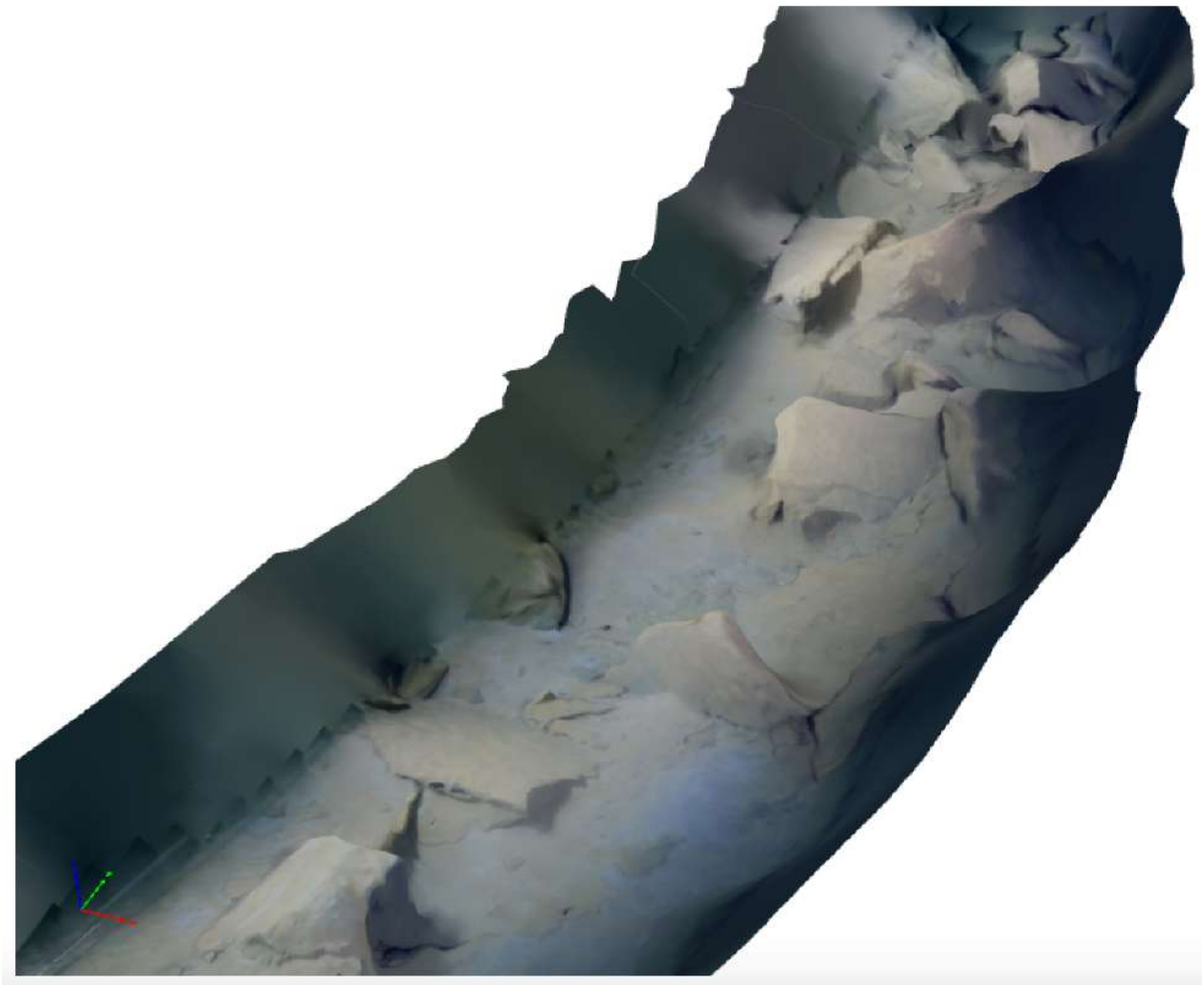
Photogrammetric reconstruction



Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.

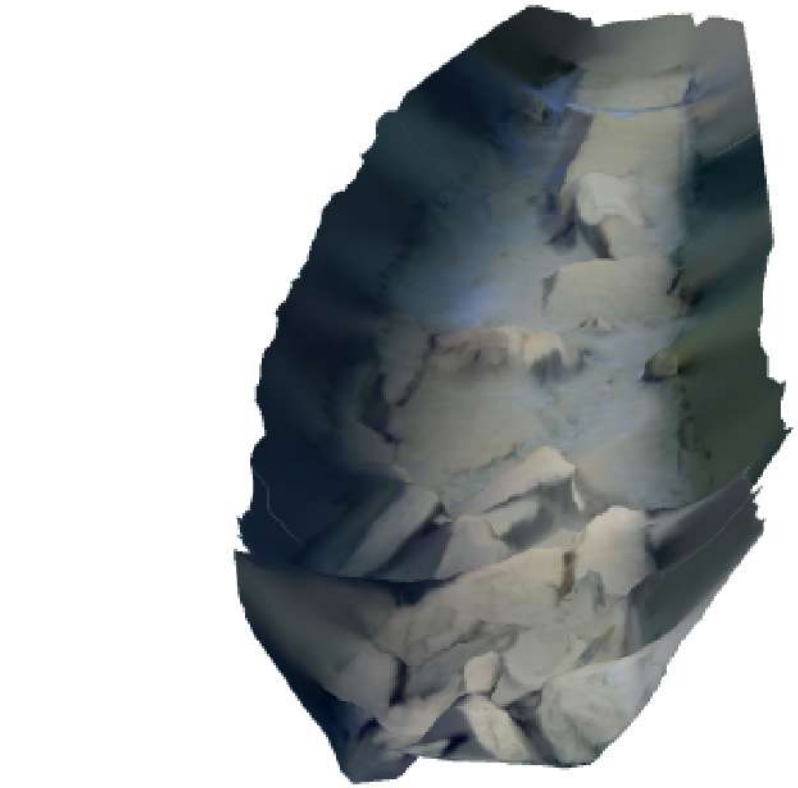
Photogrammetric reconstruction



Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.

Photogrammetric reconstruction



Fisrt Terrain Results

- Durzon, Nant, 24/06/2018.

Photogrammetric reconstruction

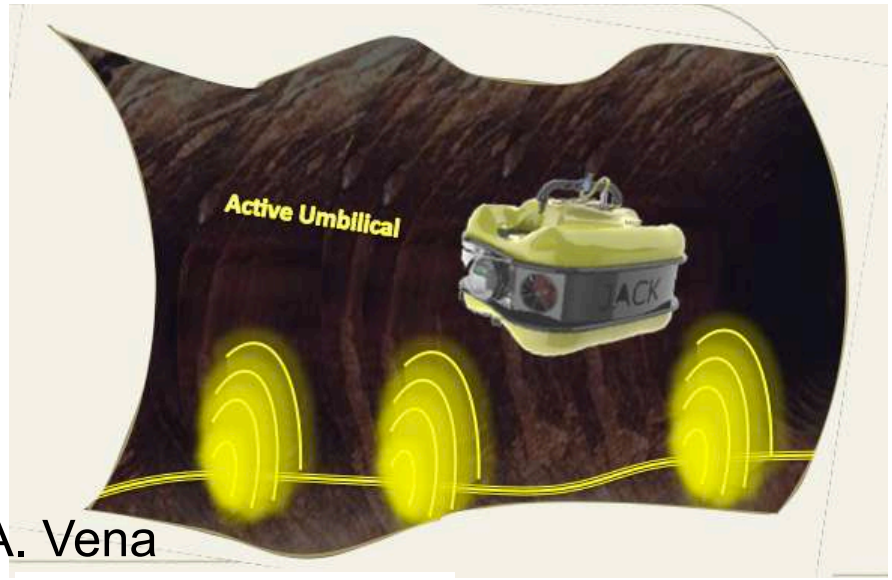
FISRT TERRAIN RESULTS

- Durzon, Nant, 24/06/2018.

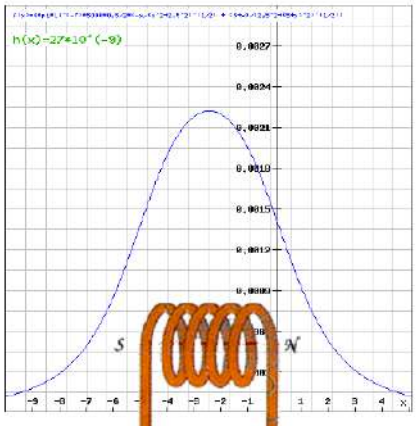
Partial photogrammetric reconstruction

Ongoing Actions

- New sensors for Aleyin (IES-LIRMM)

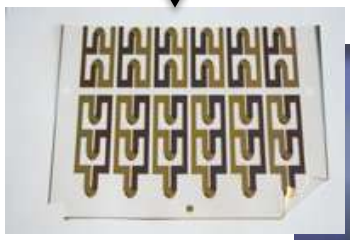


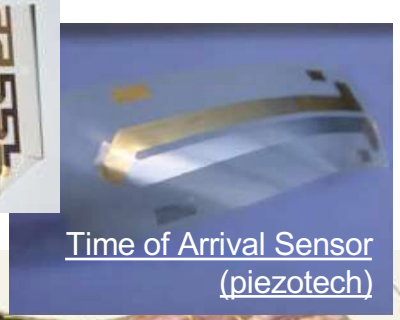
A. Vena



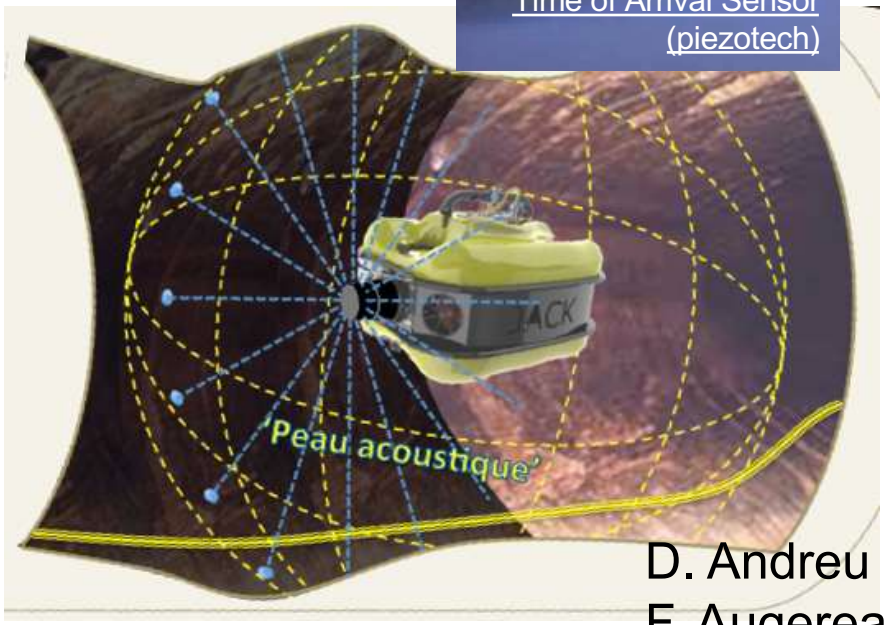
PIFE Y. Bastiaenssen

Protocole de stimulation





Time of Arrival Sensor (piezotech)

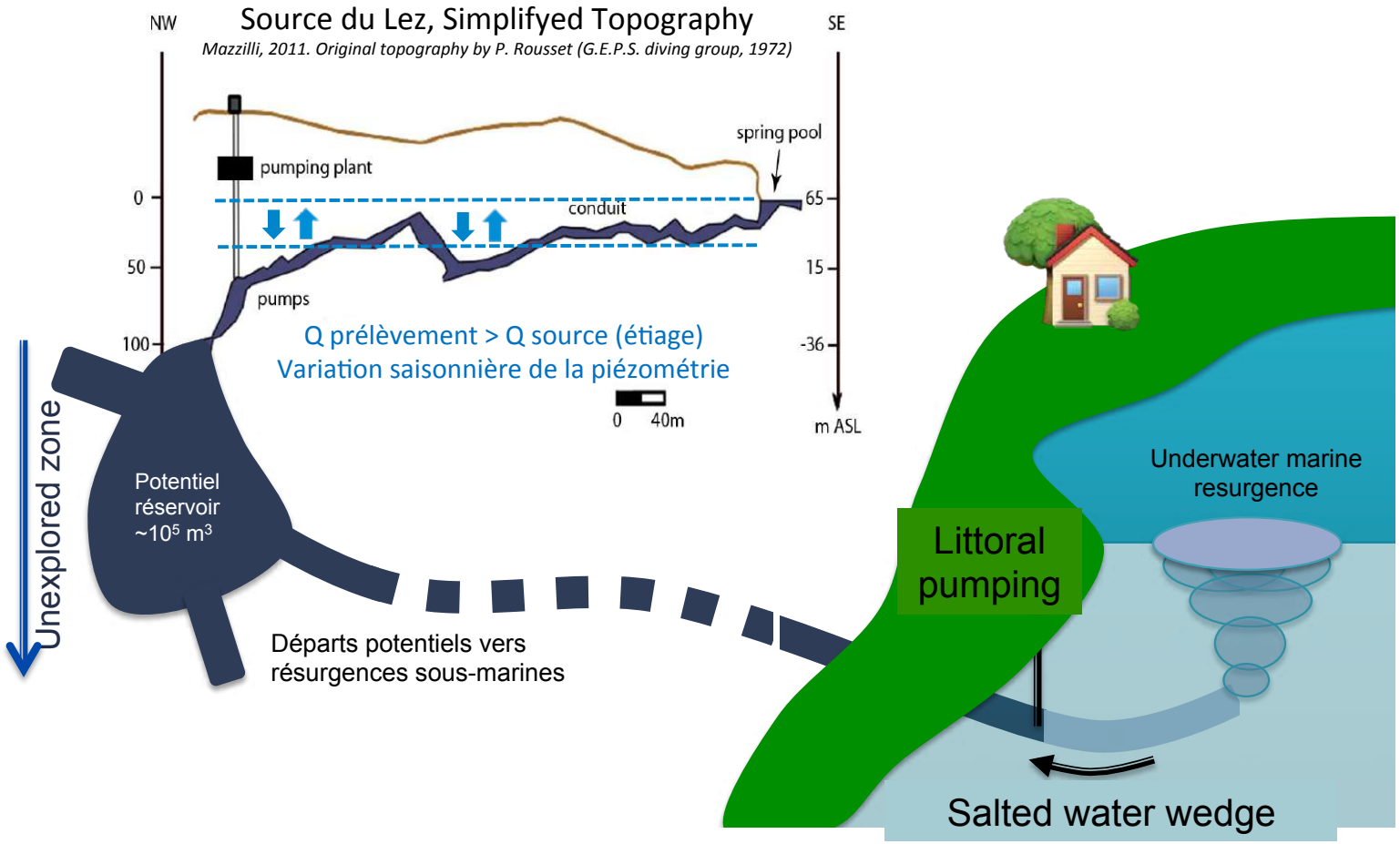


D. Andreu
F. Augereau

-> thèse M. Alarab (10/2018)

NEAR FUTURE : LEZ-2020

- Exploration of the Unknown Upstream Pumping Chamber



Near Future : The Anzar European Extension

LIRMM

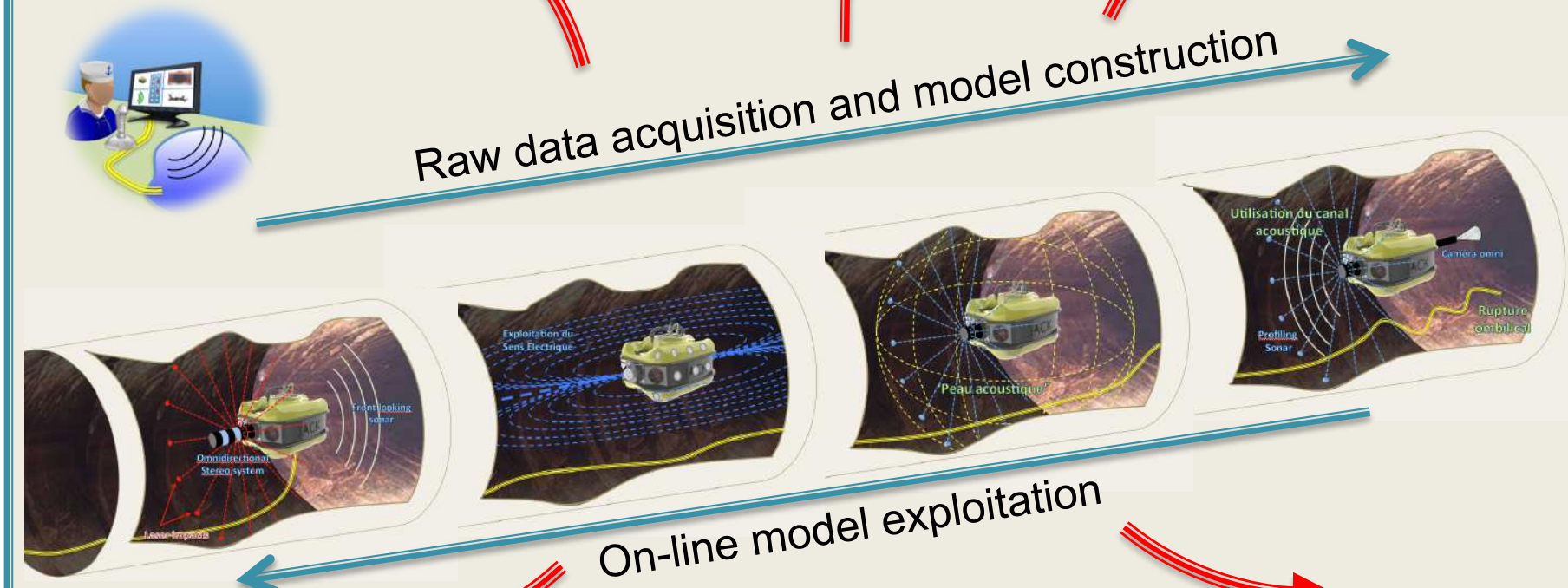
LEM Lille Economics Management — MRM Montpellier Research in Management

Business

HSM

Vector

Environnement



Env. Models, SLAM

End-Users

New sensors

IMAG Institut Montpellierain Alexander Grothendieck

brgm Géosciences pour une Terre durable

EDF

Montpellier Méditerranée Métropole

Hydrokarst Groupe

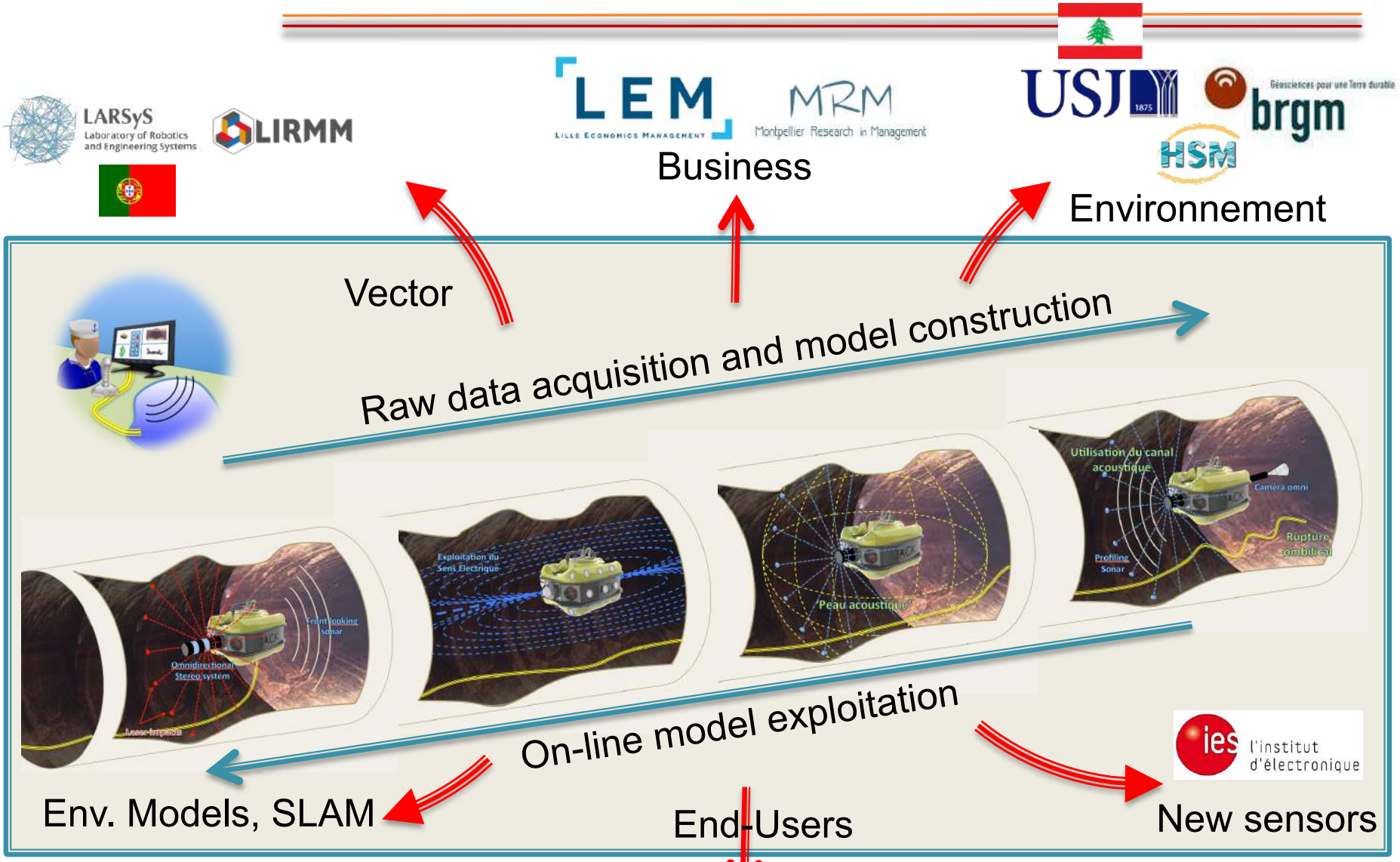
CENOTE

SyERA

REEDS

ies l'institut d'électronique

Near Future : The Anzar European Extension



Near Future : Seeking for International Collaborations

International Association of Hydrogeologists
the World-wide Groundwater Organisation

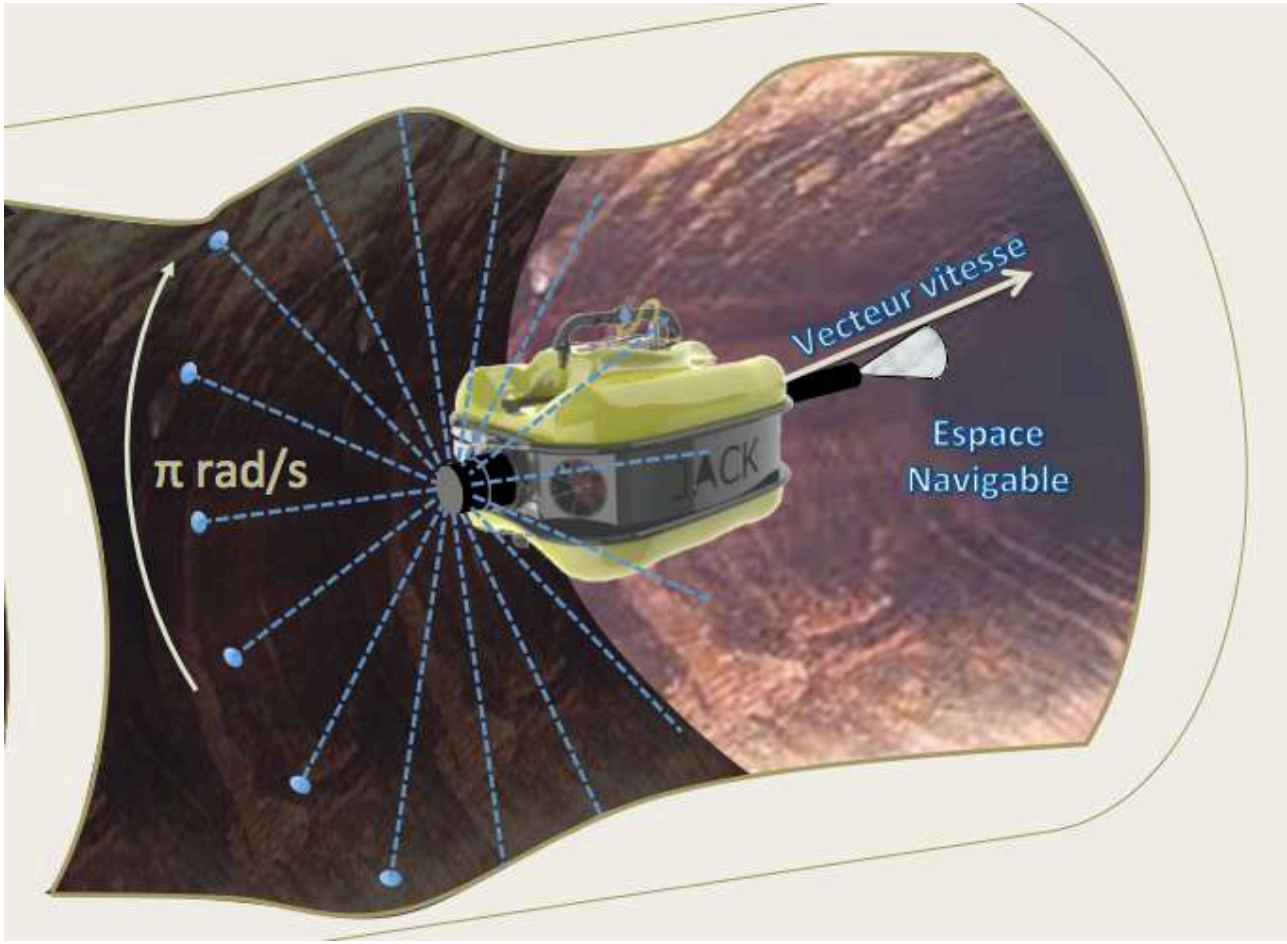
United Nations Educational, Scientific and Cultural Organization
International Hydrological Programme
UNESCO-IHP
ISARM Programme

igrac
International Groundwater Resources Assessment Centre

谢谢！

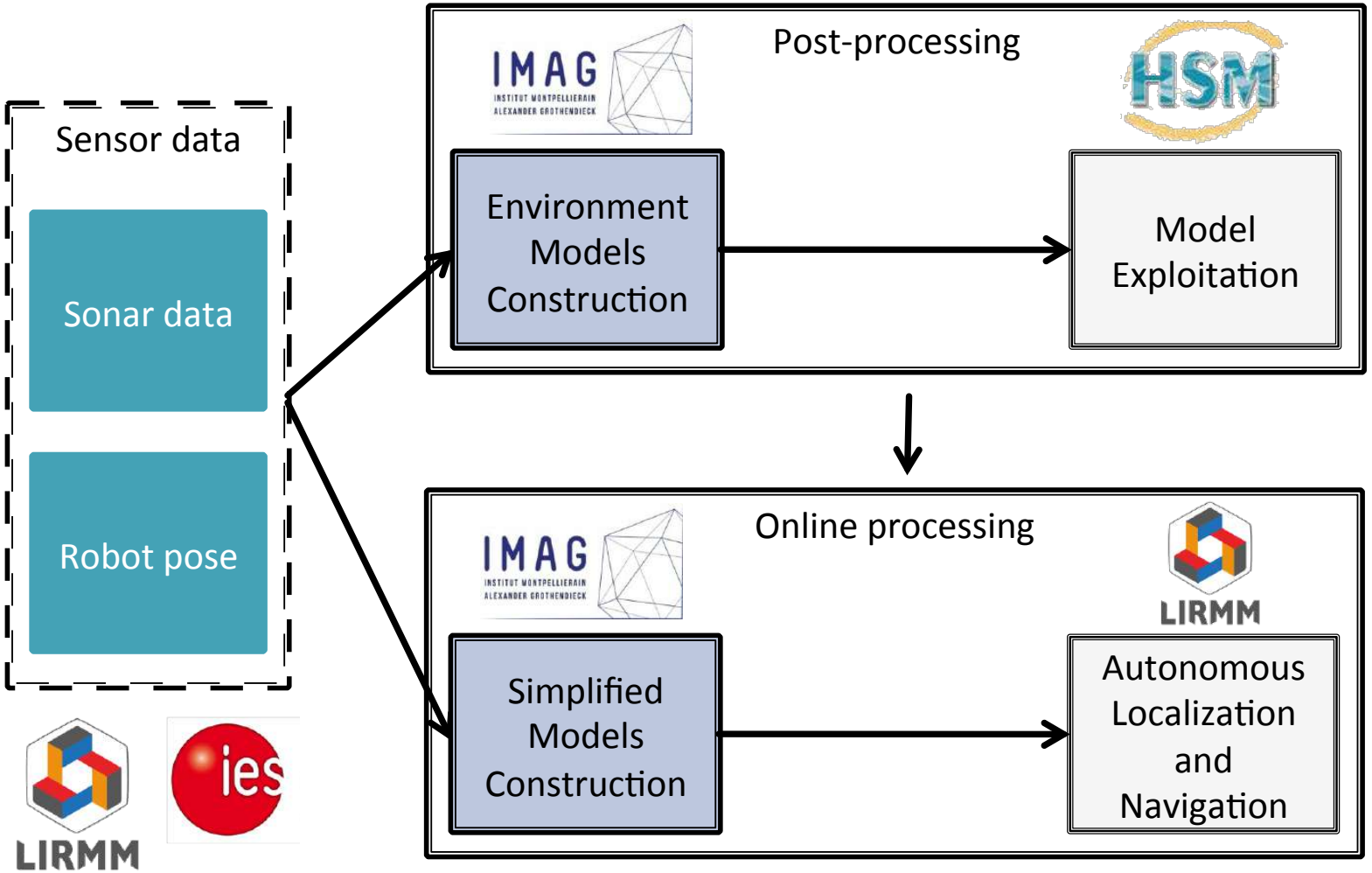
CHANTIERS SCIENTIFIQUES EN COURS

- Commande réactive orientée modèle de terrain



CHANTIERS SCIENTIFIQUES EN COURS

- Modèles et Navigation (Post-Doc LIRMM-IMAG)
  - From Sensors to Environmental models

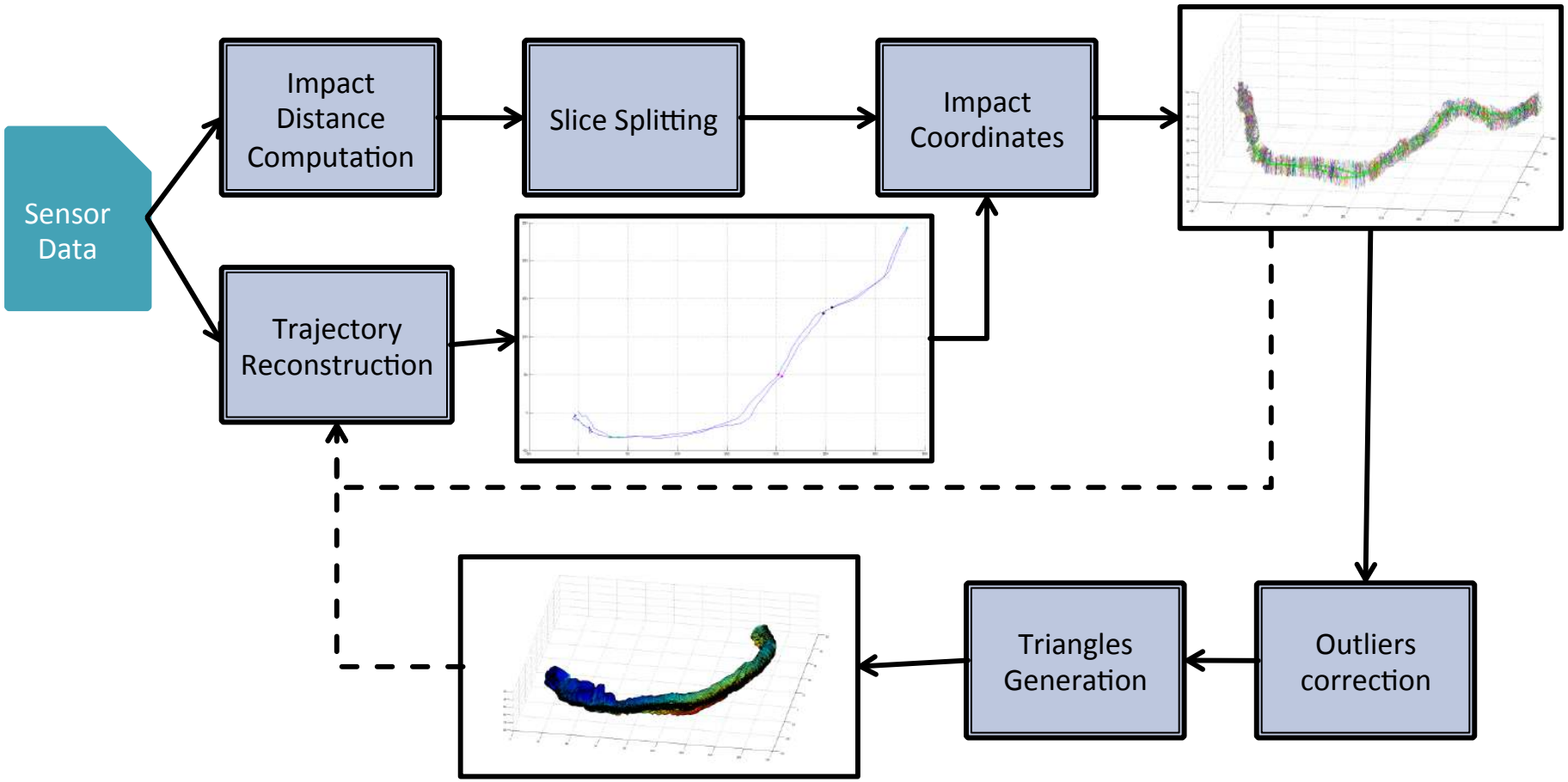


Chantiers scientifiques en cours

- Modèles et Navigation (Post-Doc LIRMM-IMAG)
  - Online Processing challenges
    - Producing a **simplified model** that can be used online for **autonomous navigation and localization**
    - Simplified model must contain **environment outline**, notable features (**AMERs***) while considering **uncertainty**
    - Should be used on the robot : **low computational power** requirements

CHANTIERS SCIENTIFIQUES EN COURS

- Modèles et Navigation (Post-Doc LIRMM-IMAG)
  - Online Processing Pipeline

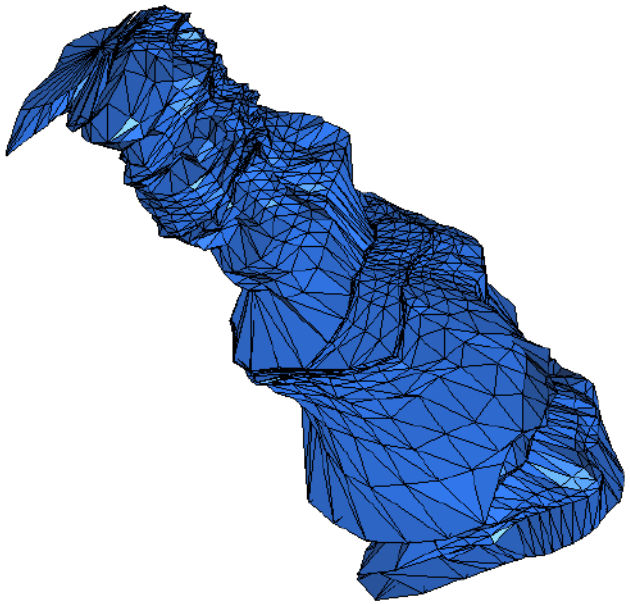


Chantiers scientifiques en cours

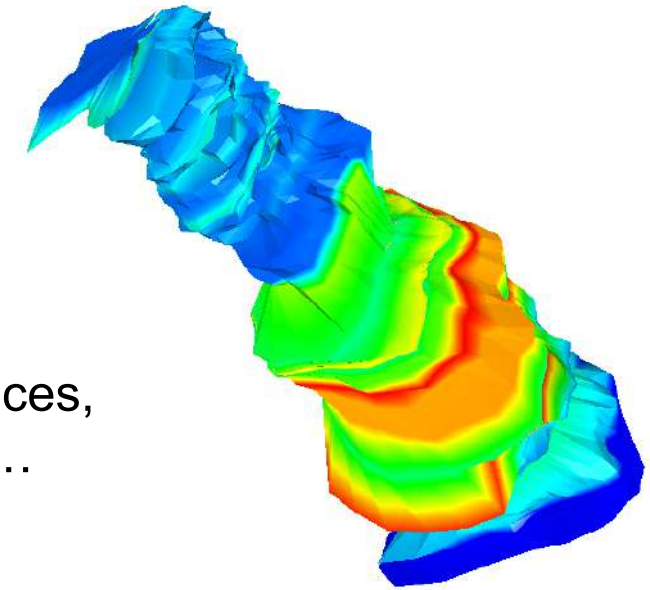
- Modèles et Navigation (Post-Doc LIRMM-IMAG)
  - Post-Processing Challenges
    - Dealing with **imprecision and uncertainties**
    - Use **prior knowledge or expert information** to remove uncertainties and/or check data consistency
    - **Automating** Triangles generation, Consistency check, uncertainties analysis, learning algorithms.

CHANTIERS SCIENTIFIQUES EN COURS

- Modèles et Navigation (Post-Doc LIRMM-IMAG)
  - Post-Processing : uncertainty management
  - Example of 3D triangular mesh generated from slices with confidence index. Index can also discriminate between :
    - Missing information (filled using local neighbours)
    - Outliers (inconsistent data corrected using local neighbours)



Extractions de données fonctionnelles :
Volume (1187 m^3), Surfaces,
Vitesses d'écoulements…



Carte des incertitudes

CONCEPTS ET OUTILS MATHÉMATIQUES POUR ALEYIN (IMAG)

Formalisation

Il s'agit d'identifier la distribution de probabilité de x incertain dans R^n à partir d'observations incomplètes et incertaines y_t (commande+capteurs) dans R^m, par extraction d'information et apprentissage:

x=(localisation+amer&cartographie&environnement physique)

$u_t = G(x(t,s))$

u états: solutions de modèles G=(hydro, salinité, turbidité, turbulence,…)

avec $x=F^{-1}(y(t,s))$

y(t,s) sorties spatiaux-temporelles de capteurs embarqués.

on supposera la nature de l'aléa sur x, y et u connue.

FSLAM : 'Functional' version of Simultaneous Localization & Mapping

Introduction de la modélisation physique (multi-physique hydro, à complexité réduite pour la phase online) lors de l'apprentissage et l'inversion (Bayesien fonctionnelle)

Contraintes de la phase online (pour navigation robot)

-Quasi temps réel pour la reconstruction en cohérence avec les capacités d'acquisition (utilisation de modèle à complexité réduite: Venturi-Bernoulli-Poiseuille)

-Information cachée, apparaît lors du retour du robot

-Acquisition hélicoïdale de l'information spatiale (2.5m/s)

-Nécessité de modèle géométrique à complexité réduite

Phase offline:

-Grande quantité d'information, mais temps de traitement non contraint (HPC)

-Modélisation plus complexe possible (traitement du signal) en lien avec les hydrologues

B. Mohammadi, A. Mas, R. Zapata

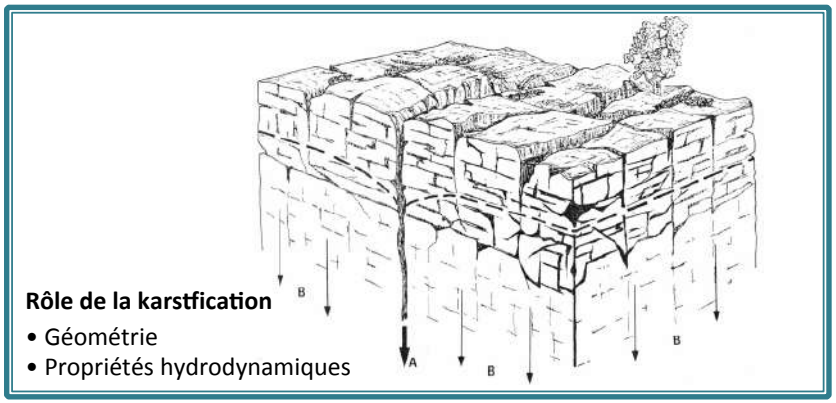
MODÉLISATION DE LA KARSTOGÉNÈSE

Contrôles hydrogéologiques

Contrôles géologiques

Un flux d'eau agressive

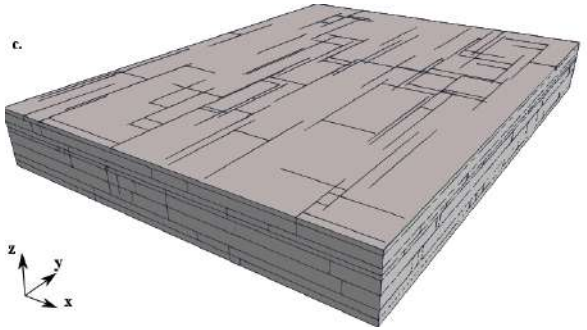
Massif carbonaté

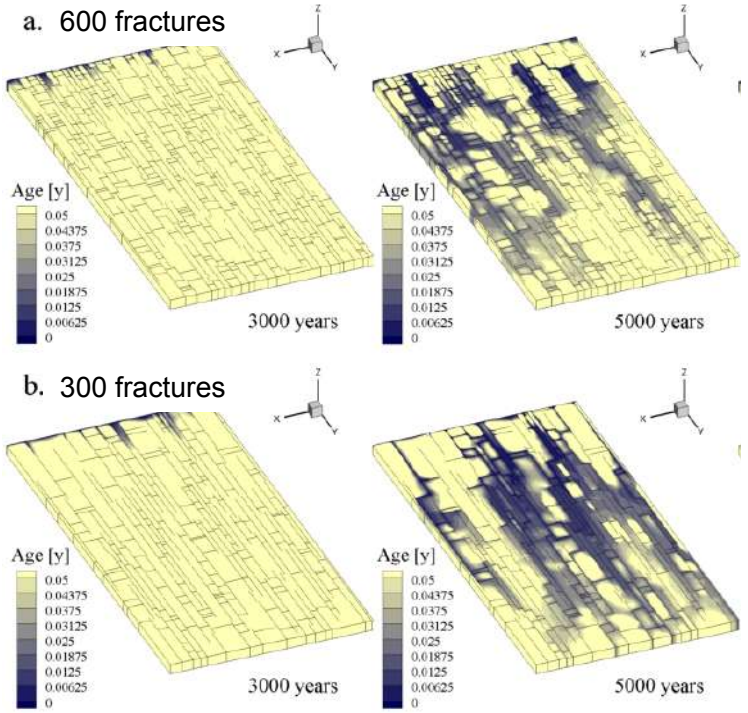


Rôle de la karstfication

- Géométrie
- Propriétés hydrodynamiques

Structure et hydrodynamique





PRINCIPAUX CONTRÔLES DES PROCESSUS DE KARSTIFICATION

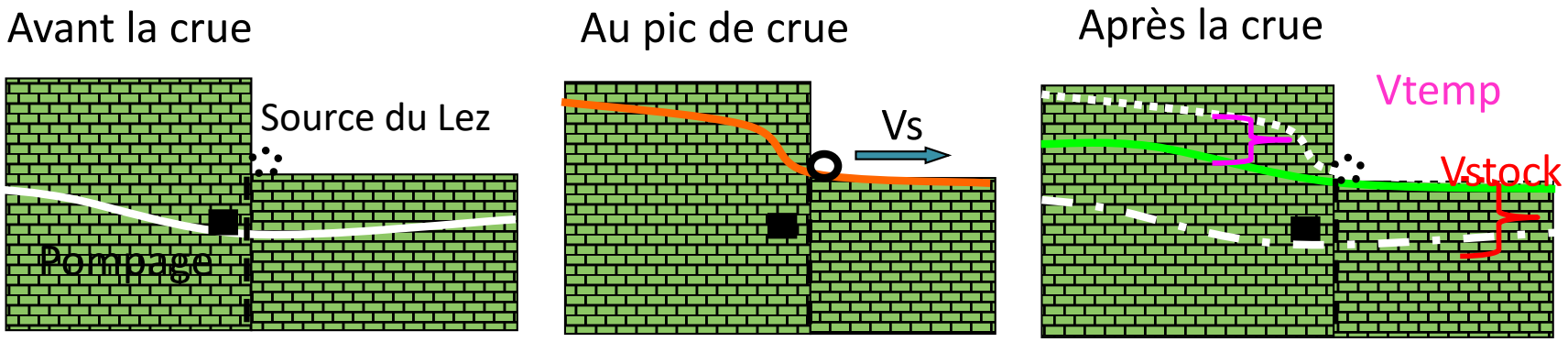
Thèse: A Lafare (2011)

LES ENJEUX

- Incidence des pompages pour l'alimentation en eau des populations (Montpellier Métropole)

Pompage à la source du Lez : Dépression piézométrique

Augmentation de l'espace disponible pour les eaux météoriques infiltrées



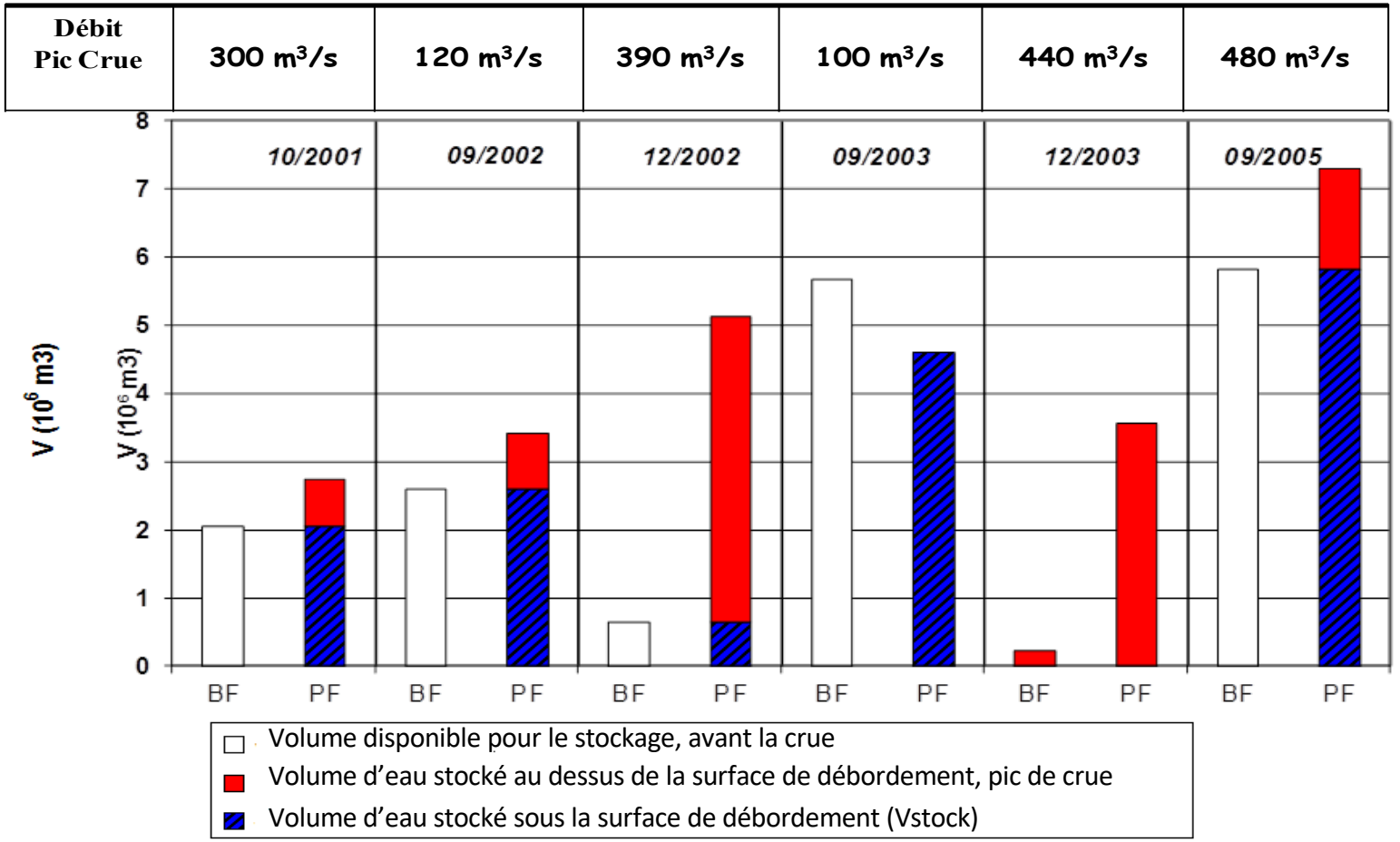
Vtemp volume d'eau emmagasiné temporairement au dessus de la *surface de débordement*

Vstock volume d'eau emmagasiné sous la *surface de débordement*

Porosité effective du karst : ~ 0.2 %

LES ENJEUX

- Stockage des précipitations dans le karst



Estimation du volume d'eau emmagasiné dans l'aquifère karstique ( )

Évènements de Septembre : Fort emmagasinement

Évènements de Décembre : Faible emmagasinement

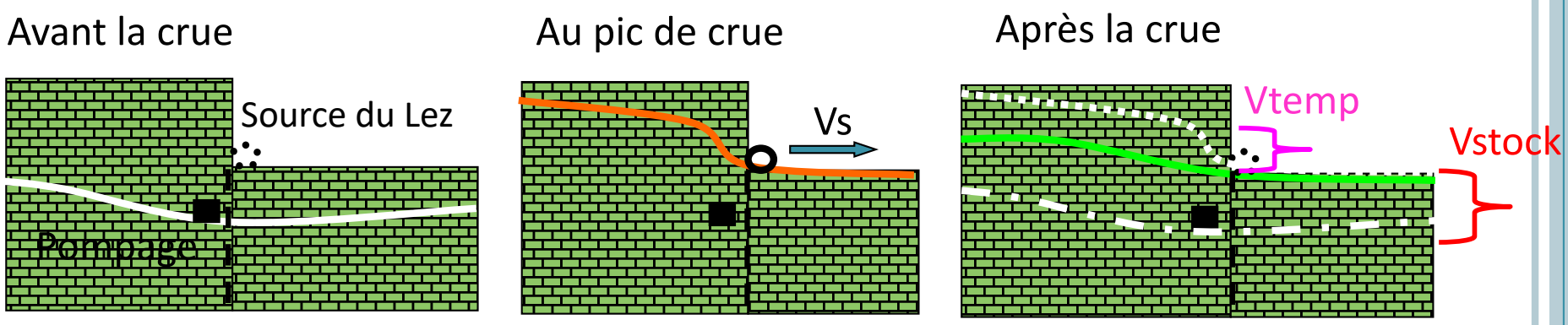
Jourde, et al. (Environmental Earth Sciences, 2013)

LES ENJEUX

- "Gestion active" de la ressource en eau

Pompage à la source du Lez : Sollicitation des réserves renouvelables

Augmentation de l'espace disponible pour les eaux météoriques infiltrées



Sollicitation de la ressource

Renouvellement de la ressource

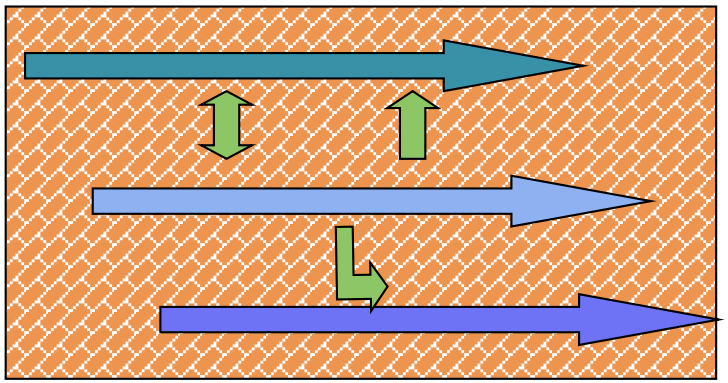
Stockage d'eau par le karst jusqu'à ~ 7 M m^3
Rôle de "barrage écrêteur de crues"

Jourde, et al.
(Journal of Hydrology 2014)

CONSÉQUENCE DES PROCESSUS DE KARTIFICATION

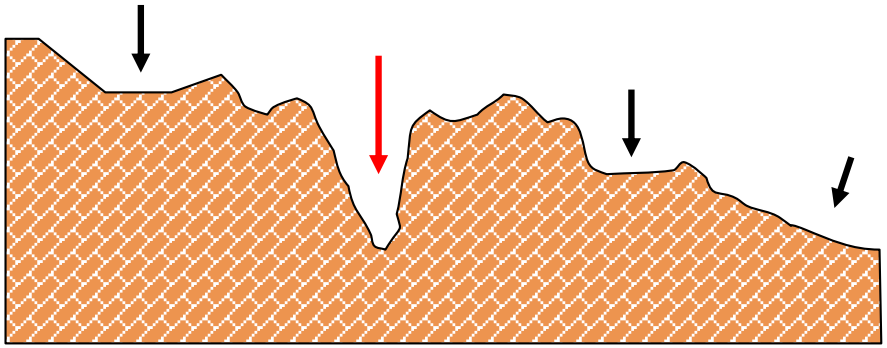
Les réseaux spéléologiques

- La structuration horizontale
- La structuration verticale



Les surfaces karstiques

- Paléo-surfaces aplanies
- Incisions en canyons reculées et vallées périphériques

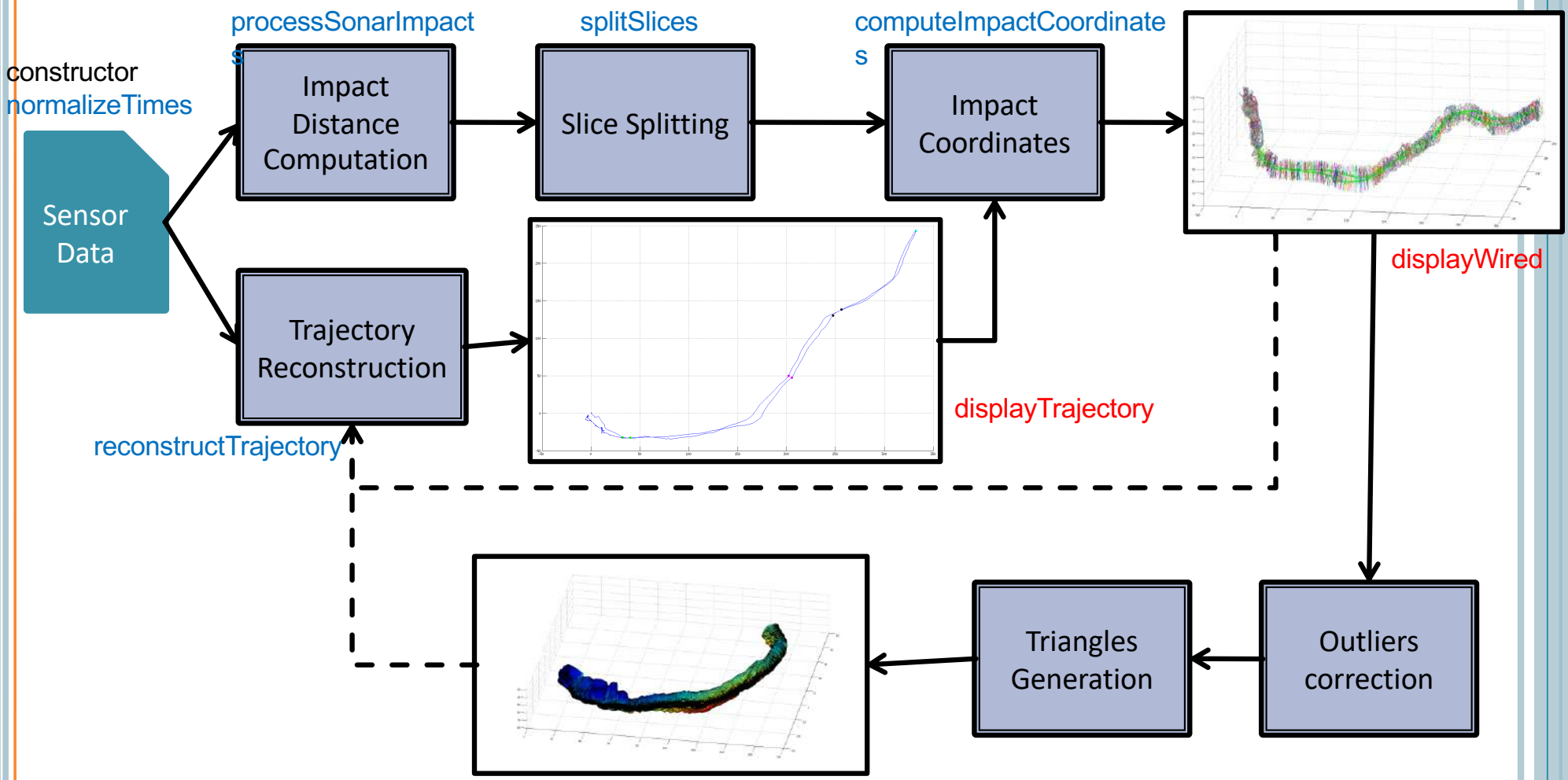


NIVEAU DE BASE (contrôle le potentiel de karstification)
Point topographique le + bas de l'affleurement karstique


Algorithmes et calculs
Modélisation
Données
Systèmes-modèles et mesures
Labex NUMEV
6"E, 11-14/07/2016

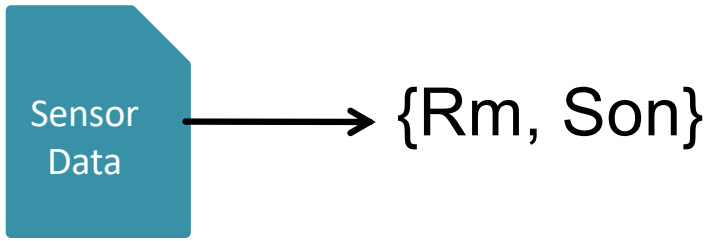

ALEYIN
PLONGÉESOUT
Gourneyras, 43° 51'36.5"N 3° 31'38.6'
IMAG
ies
l'institut d'électronique
HSM
LIRMM

Post-Processing Pipeline
Matlab matching



All mentionned methods are part of the **ExperimentGourneyras** object.
Except constructor all other methods are called in process or displayResults

SENSOR DATA



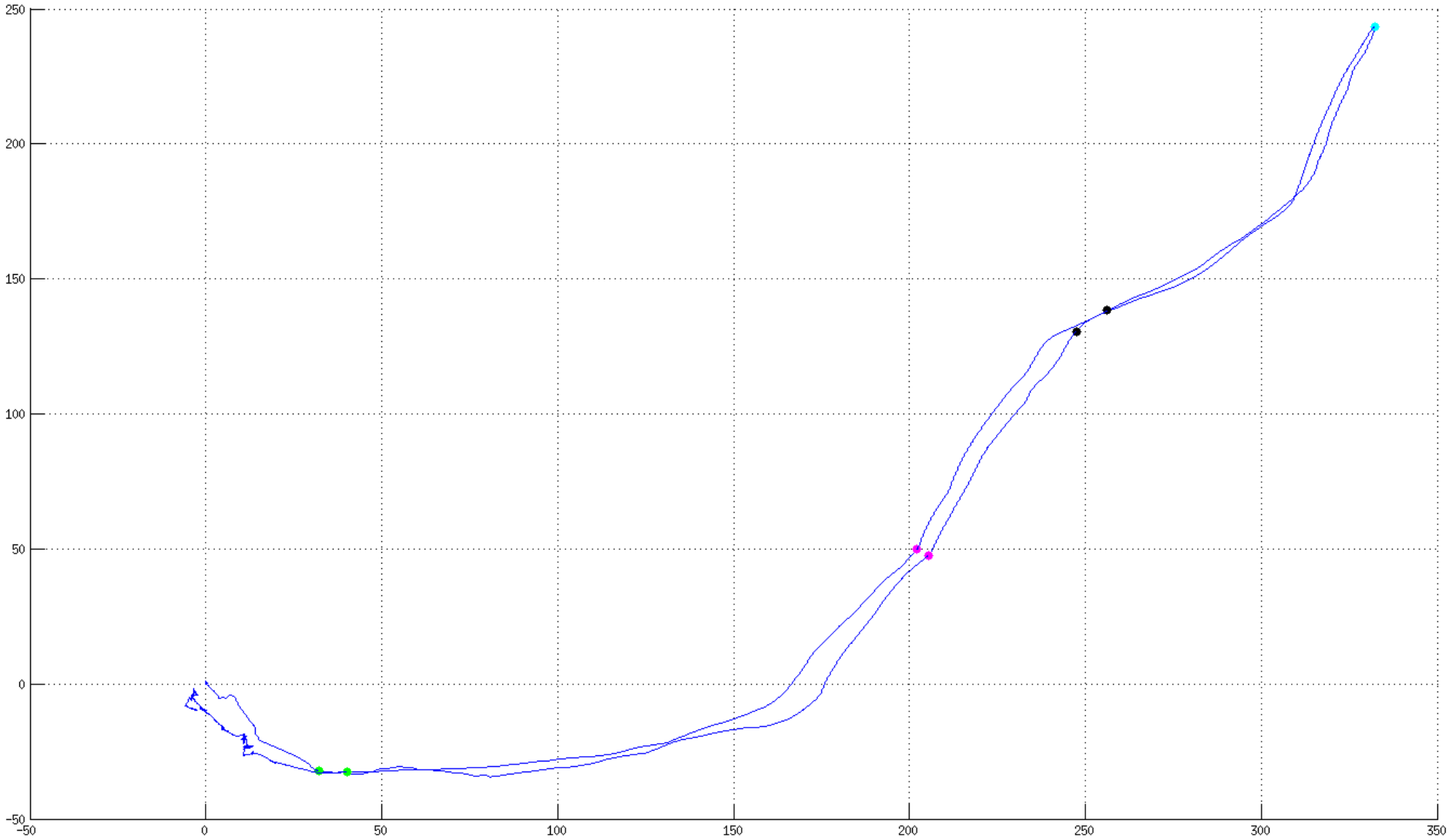
- Robot Motion : Rm = {t_rm, u, v, w, phi, theta, psi, z, t_wp, ID_wp}
  - Time (t_rm)
  - Speeds in sensor frame (u, v, w)
  - Orientation in world frame (phi, theta, psi)
  - Depth in world frame (z)
  - Waypoints (t_wp, ID_wp)
- Sonar measurements : Son = {t_son, alpha, range, scanline}
  - Time (t_son)
  - Ray Angle (alpha)
  - Sensor Range (range)
  - Scanline (Echo array : echo_amplitude = f(distance))

Trajectory Reconstruction

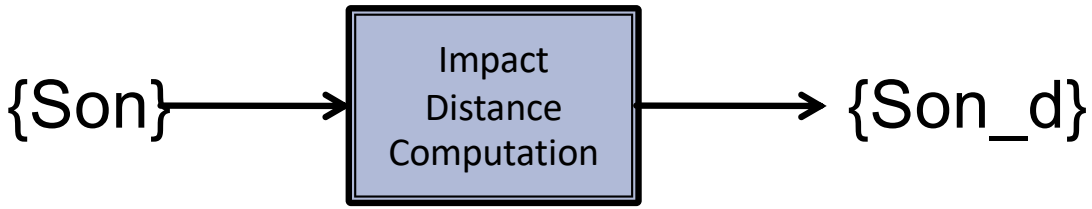
- Trajectory : Tr = Rm ∪ {dx, dy, dy, x, y, z, x_wp, y_wp, z_wp}
  - Speeds in world frame (dx, dy, dz)
  - Coordinates in world frame (x, y, z)
  - Waypoint coordinates (x_wp, y_wp, z_wp)

- Waypoints are used to improve trajectory

Trajectory Reconstruction



IMPACT DISTANCE COMPUTATION



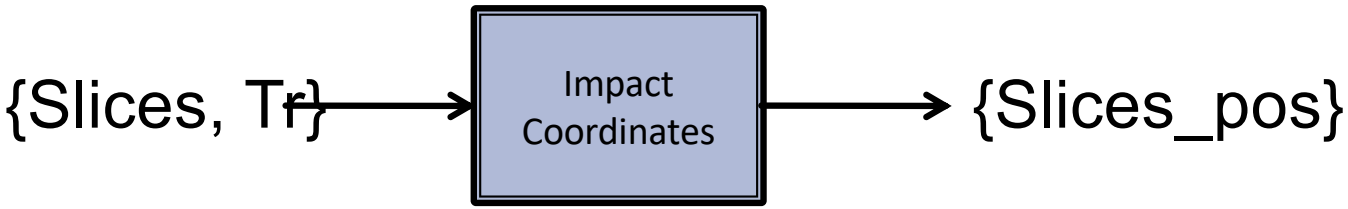
- Sonar measurements : Son_d = {t_son, alpha, range, dist}
  - Time (t_son)
  - Ray Angle (alpha)
  - Sensor Range (range)
  - Distance (dist)

- Scanline is converted to distance

SLICE SPLITTING

- Slices : N slices x M impacts (avec N*M ≈ dim(Son_d))
- Division based on ray angles
- Each slices'impact has the same structure as Son_d

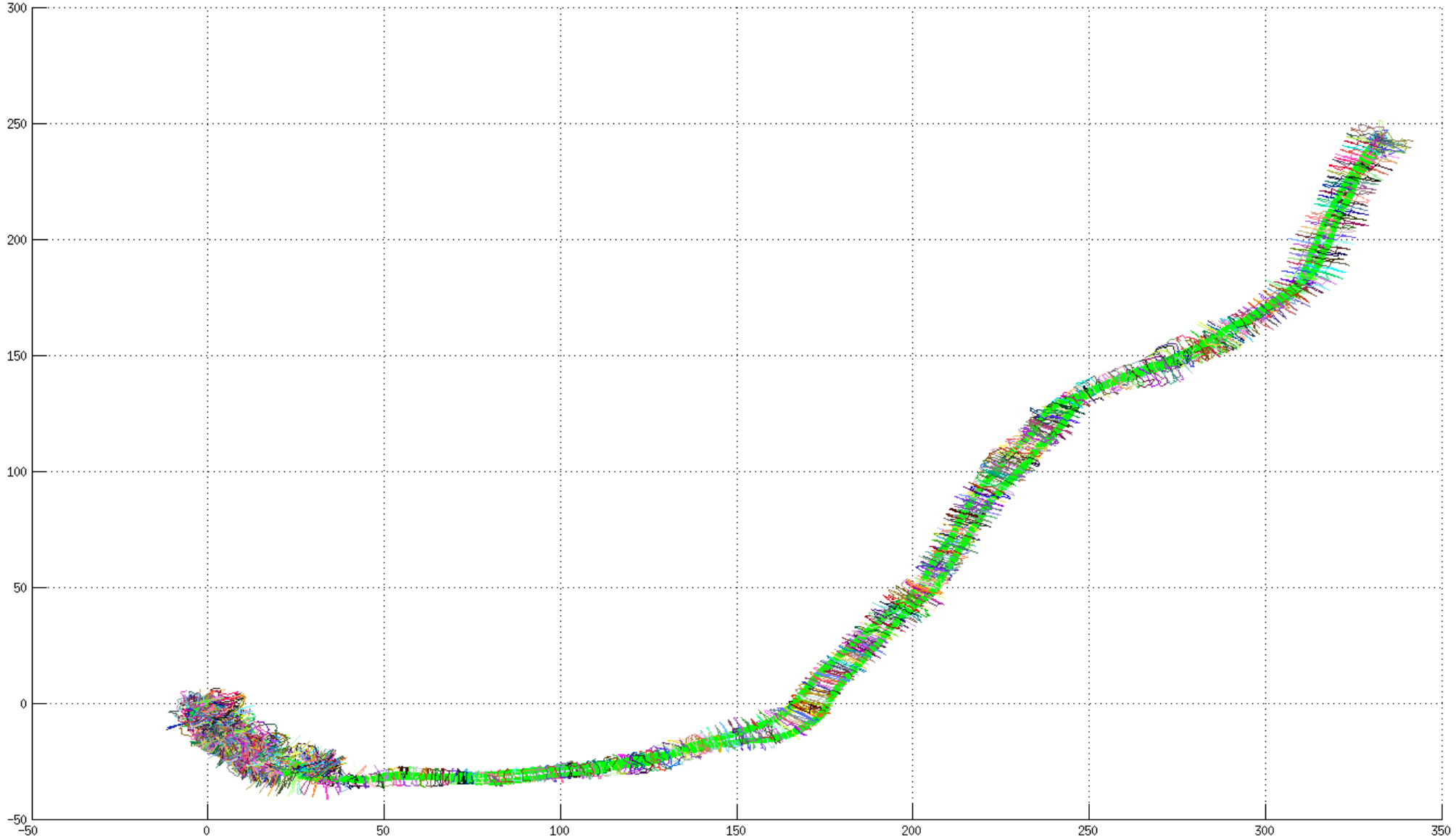
Impact Coordinates



- Slices_pos : N slices x M impacts defined as {t_son, alpha, range, dist, x_rob, y_rob, z_rob, phi_rob, theta_rob, psi_rob, x_imp, y_imp, z_imp}
  - Robot pose (x_rob, y_rob, z_rob, phi_rob, theta_rob, psi_rob)
  - Impact coordinates (x_imp, y_imp, z_imp)

- Compute 3D coordinates of each impact based on robot trajectory
- 3D Point cloud or « Wire » representation
- Can it be used (automatically) to improve trajectory ?

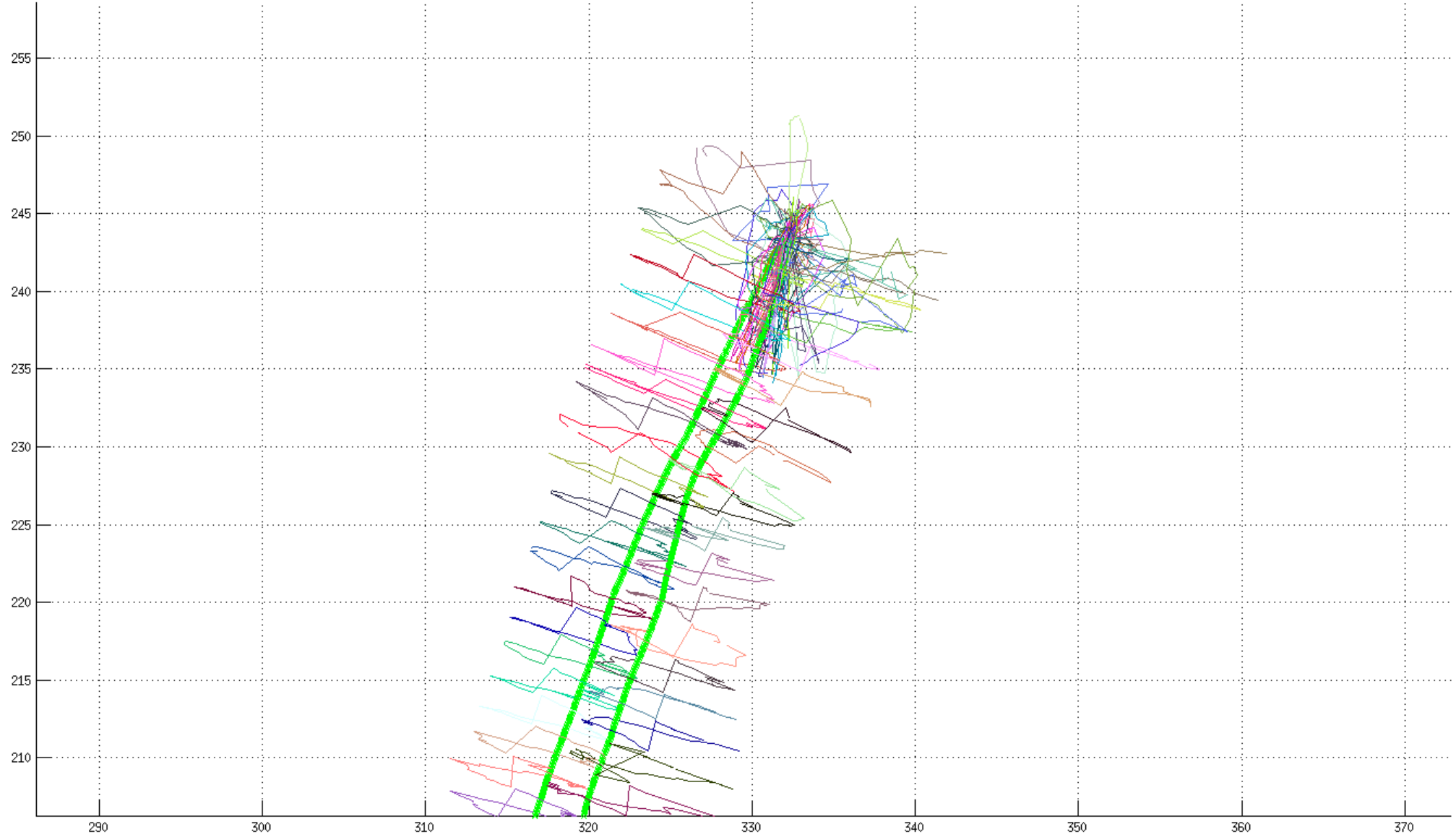
Impact Coordinates



Outliers Correction

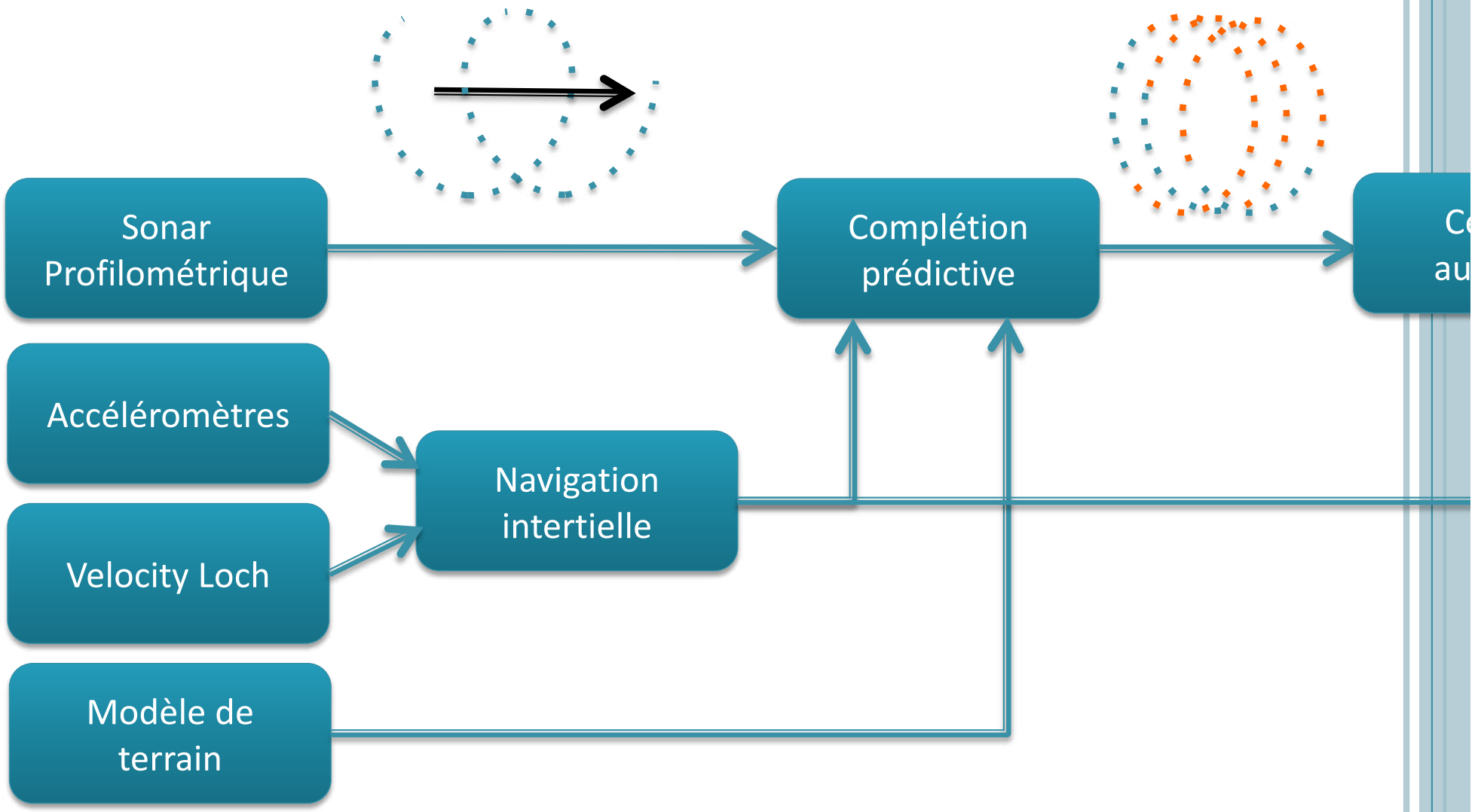
- 18% of undetected points + outliers
- « Fill the Gaps » or ignore these points in reconstruction ?

Triangles Generation

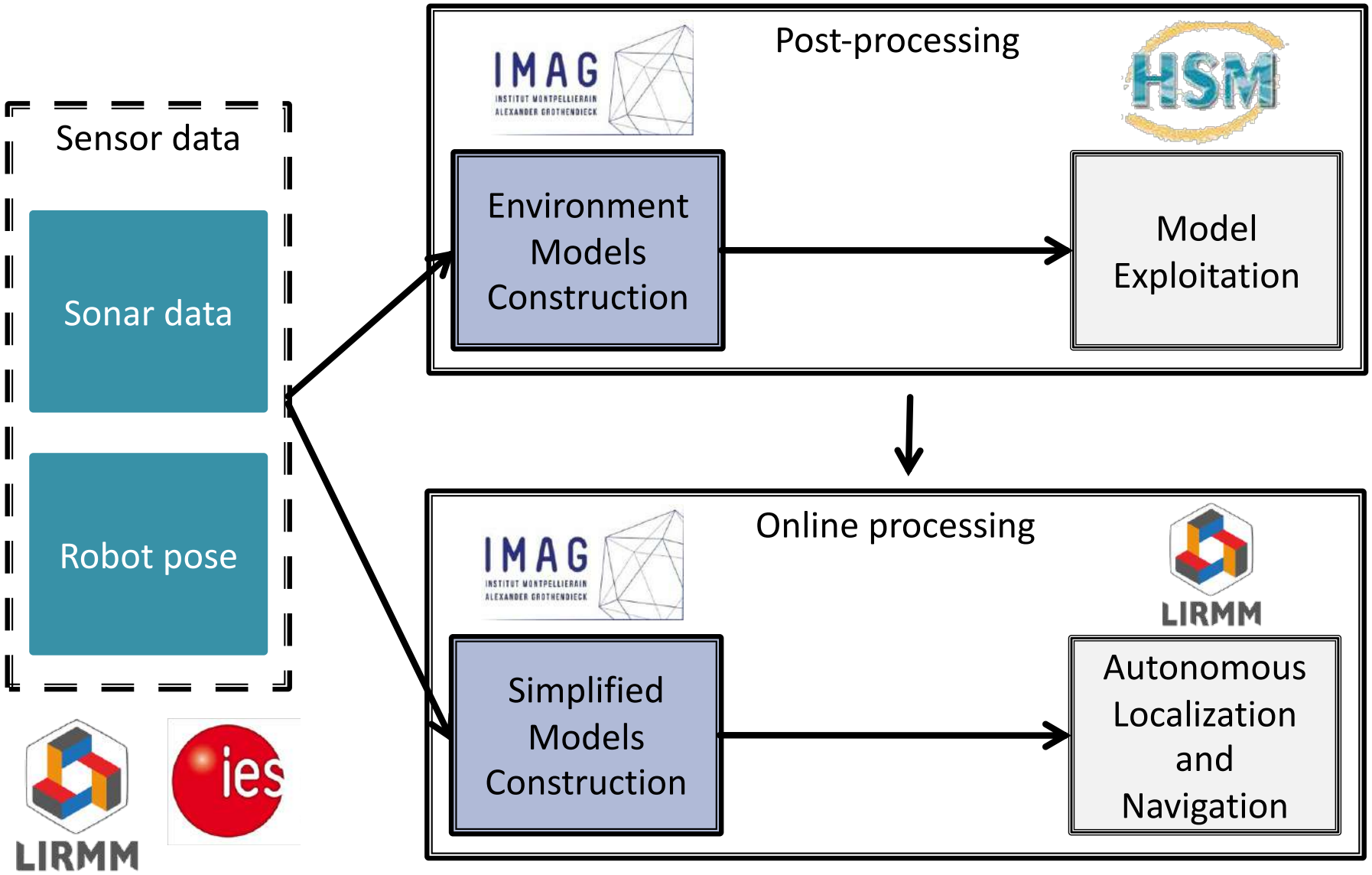


CHANTIERS SCIENTIFIQUES EN COURS

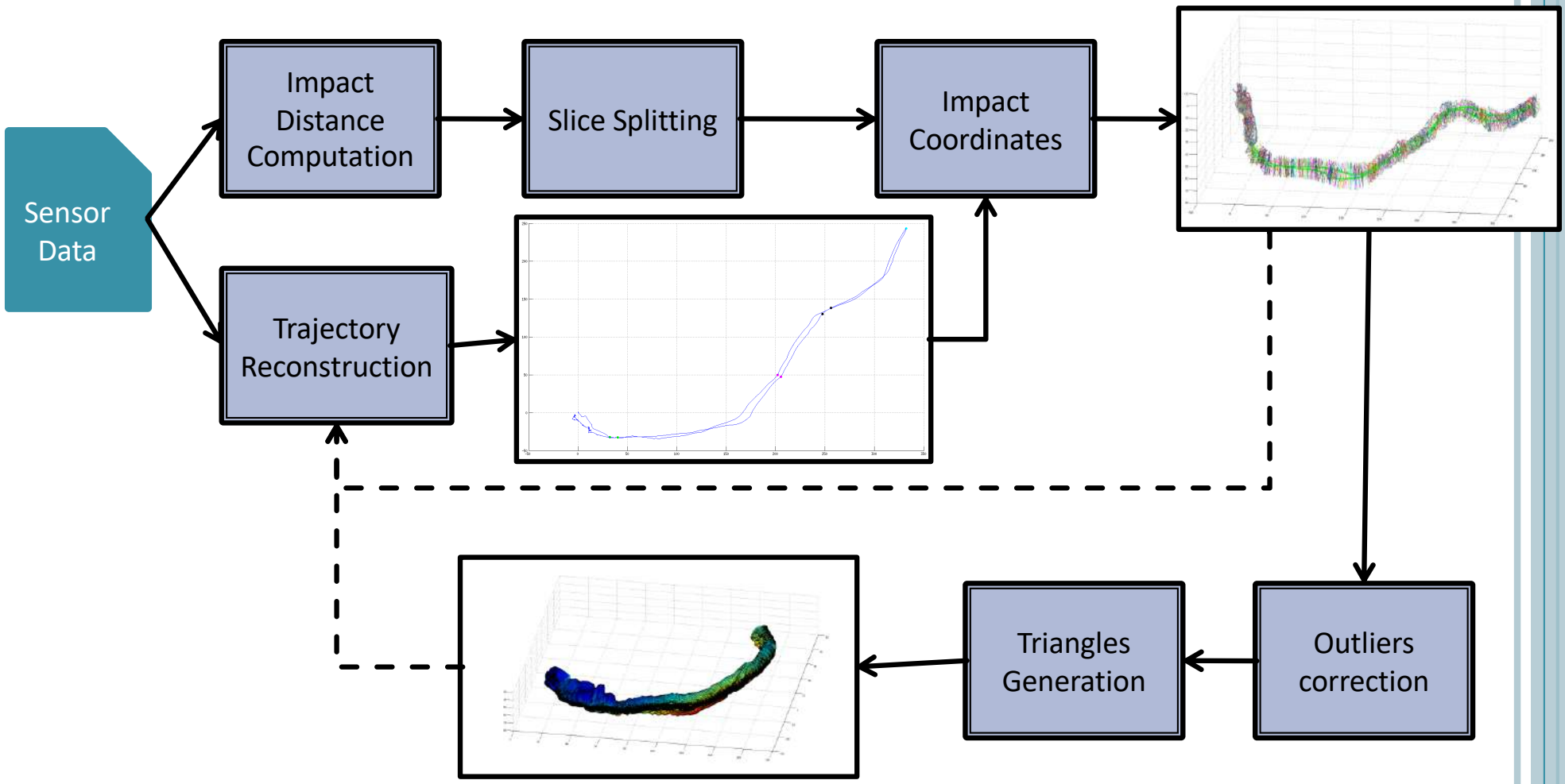
- Commande réactive orientée modèle de terrain



From Sensor data to Environmental Models

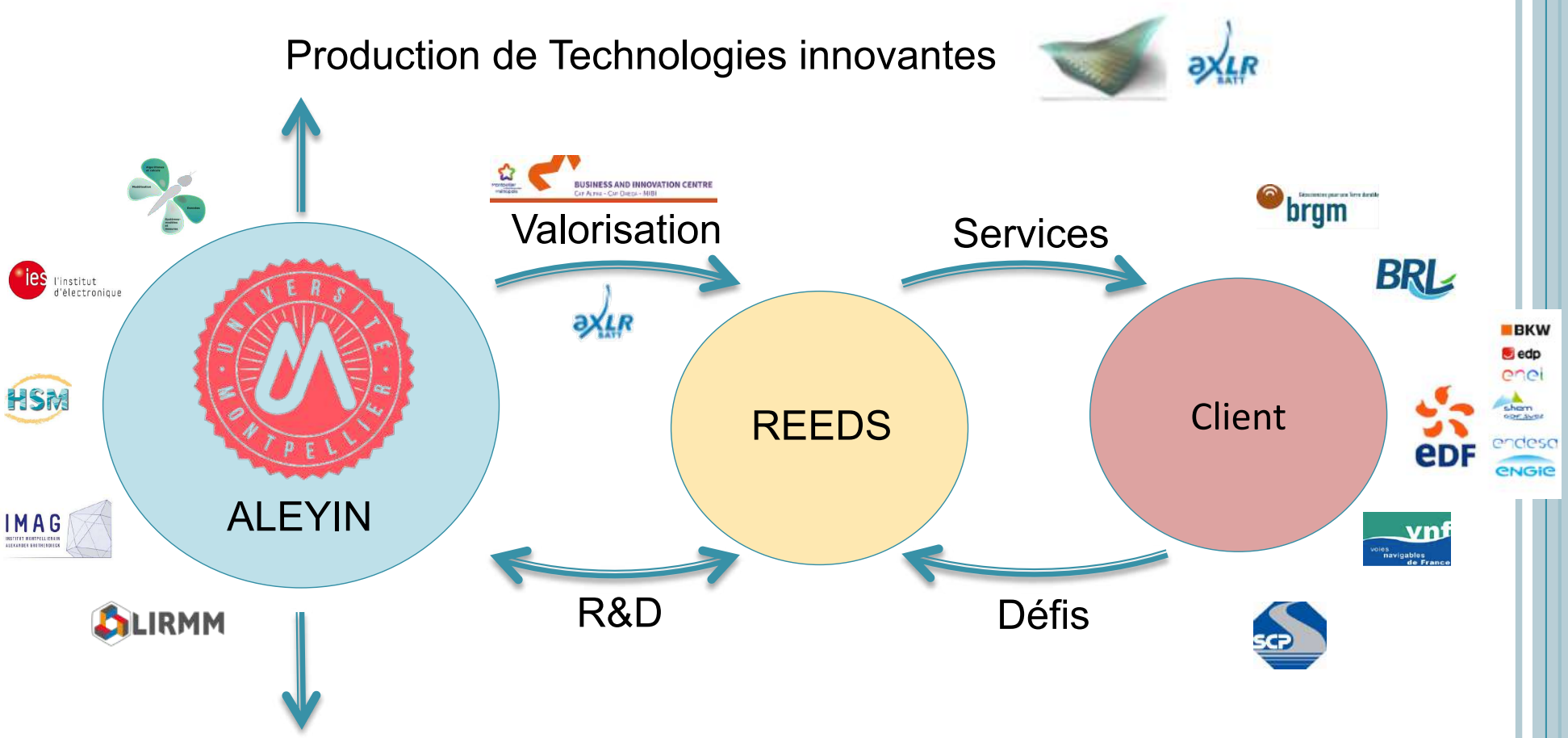


POST-PROCESSING : PIPELINE



LA TRANSDISCIPLINARITÉ COMME TERRAIN DE L'INNOVATION

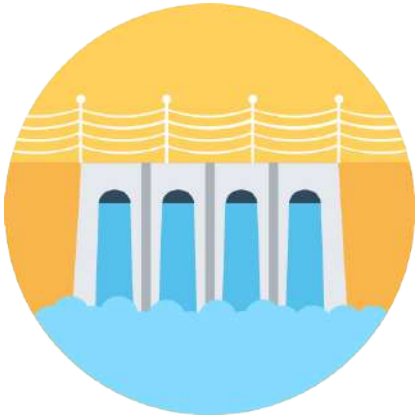
- les objets-frontières (*boundary objects*)



VALORISATION : STARTUP REEDS

- REEDS : Transférer les savoirs et savoir-faire académiques vers de nouveaux services d'inspection subaquatique en environnement confinés.

Canaux et voies navigables



Barrages et infrastructures hydrauliques

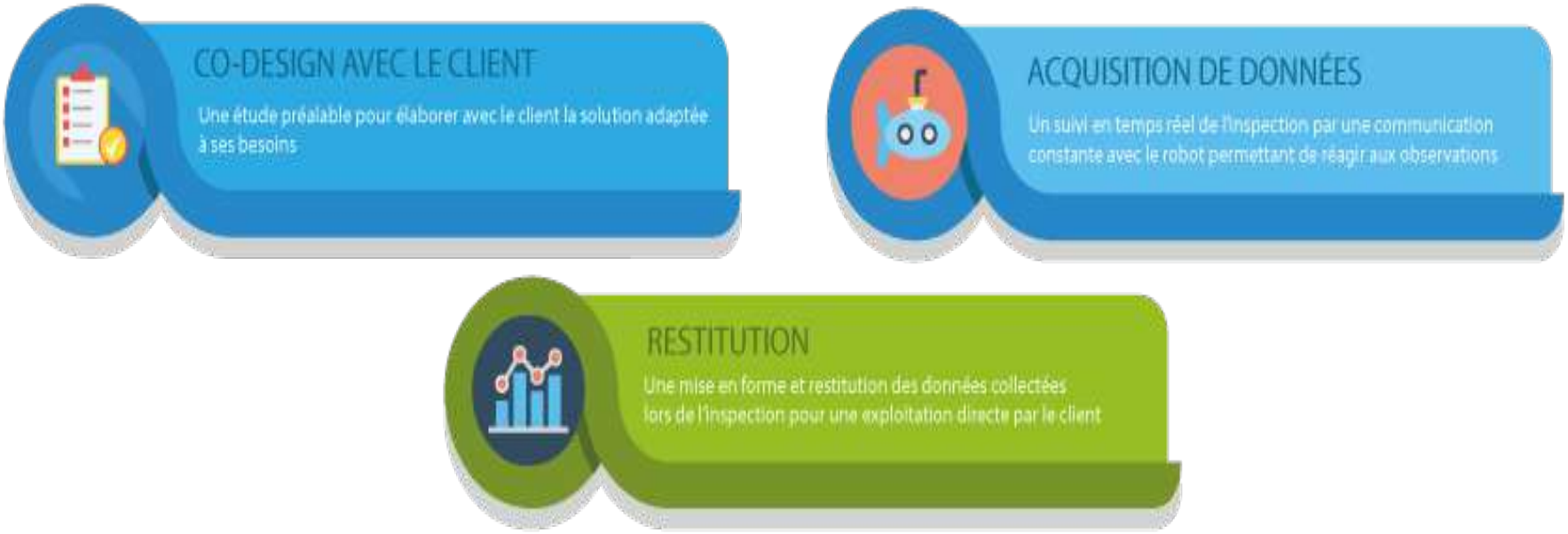
Galeries immergées

Karst et conduites naturelles

- Services à forte Valeur Ajoutée
  - Acquisition de données en env. difficiles
  - Modélisation fiable et pertinente
  - Diminution du risque & coût de la donnée

VALORISATION : L'OFFRE DE REEDS

Grâce à sa maîtrise de l'ensemble des maillons de la chaîne de valeur et sa conception modulaire, REEDS propose une prestation sur mesure.



REEDS travaille également auprès des exploitants de structures comme SCP (Société du Canal de Provence) qui ouvre ces ouvrages pour valider ces solutions

VALORISATION : L'OFFRE DE REEDS

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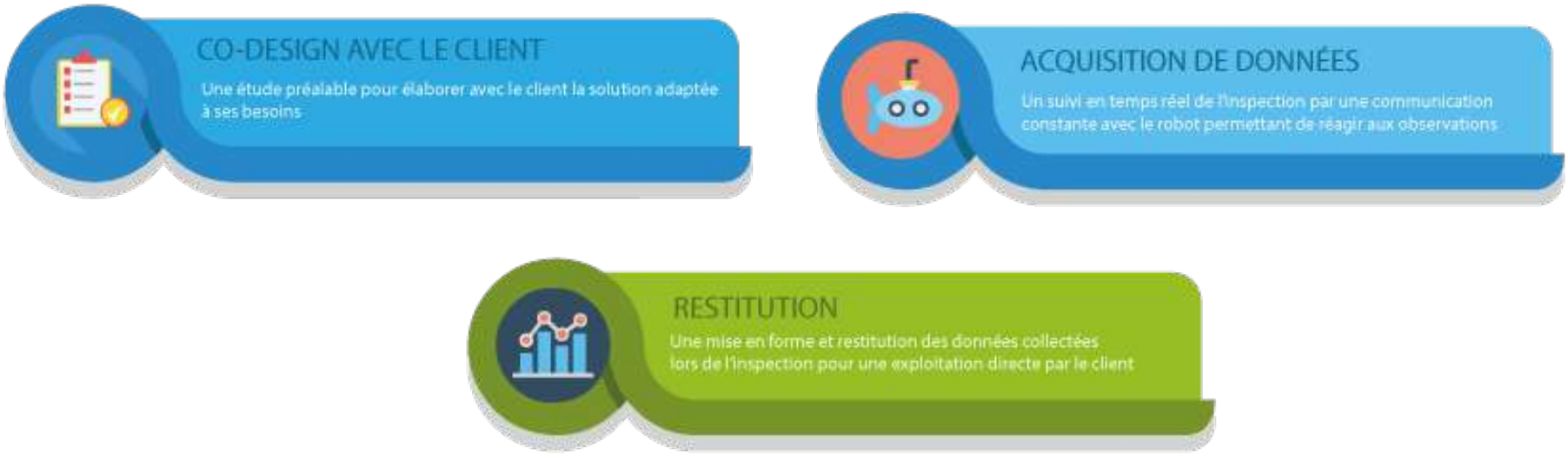
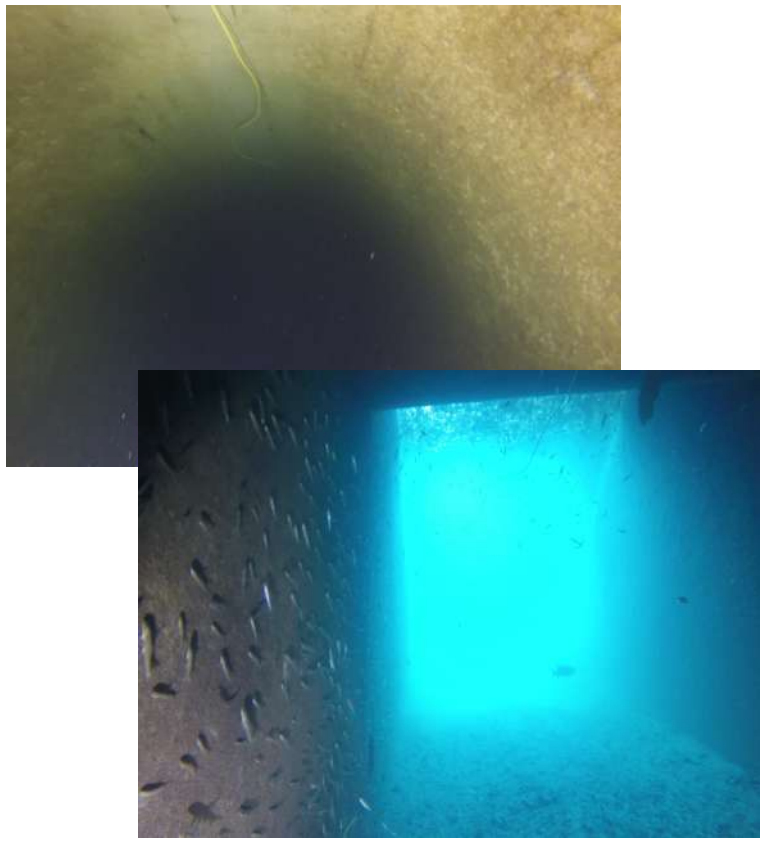


- REEDS travaille également auprès des exploitants de structures comme SCP (Société du Canal de Provence) qui ouvre ces ouvrages pour valider ces solutions

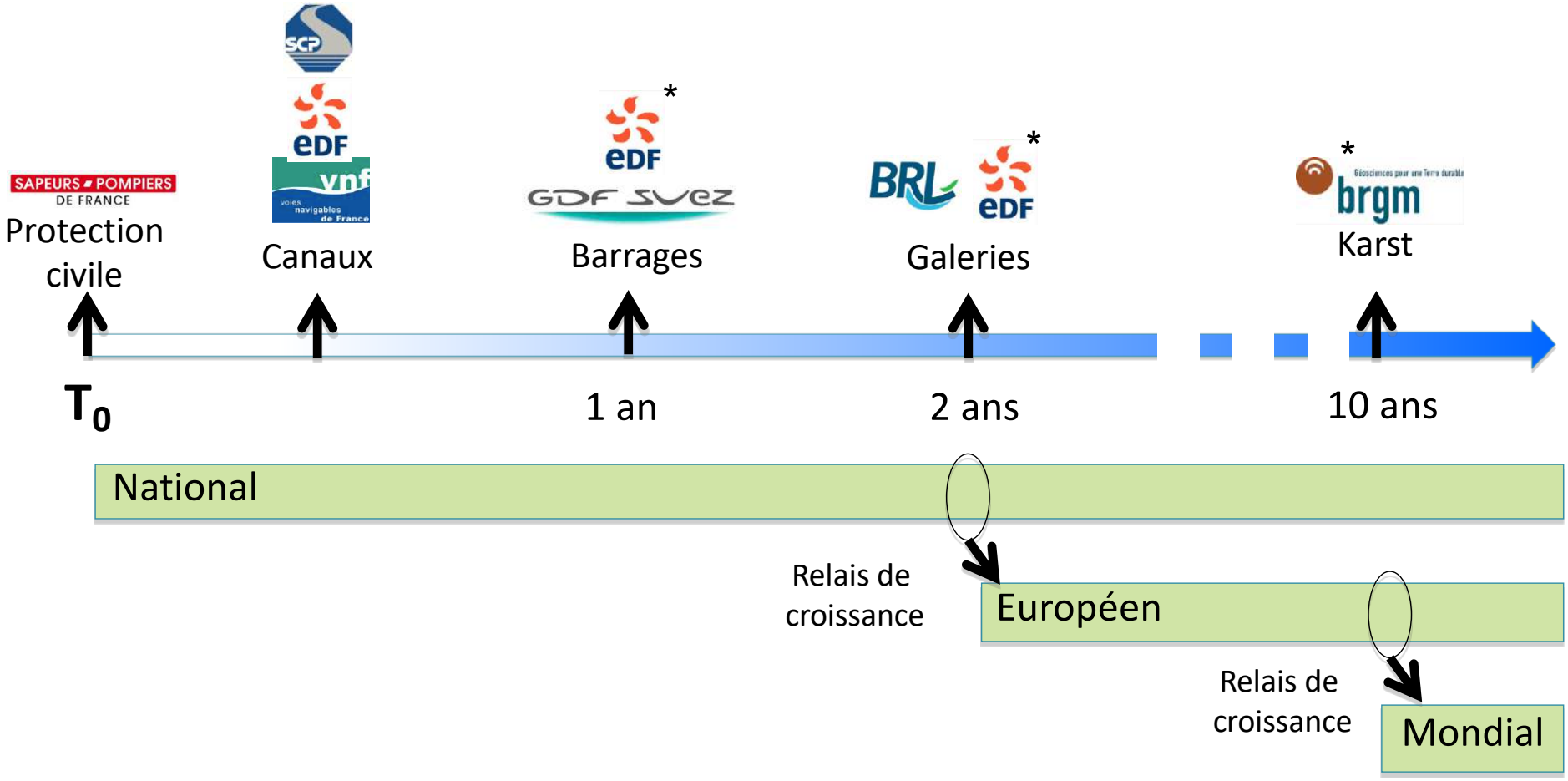
VALORISATION : LA R&D AU CŒUR DE REEDS

- Un site d'expérimentation mis à disposition par la société du canal de Provence
  - 3 km de canaux ouverts
  - 11 km de galeries fermées

SOCIETE DU CANAL DE PROVENCE
ET D'AMENAGEMENT DE LA REGION PROVENÇALE

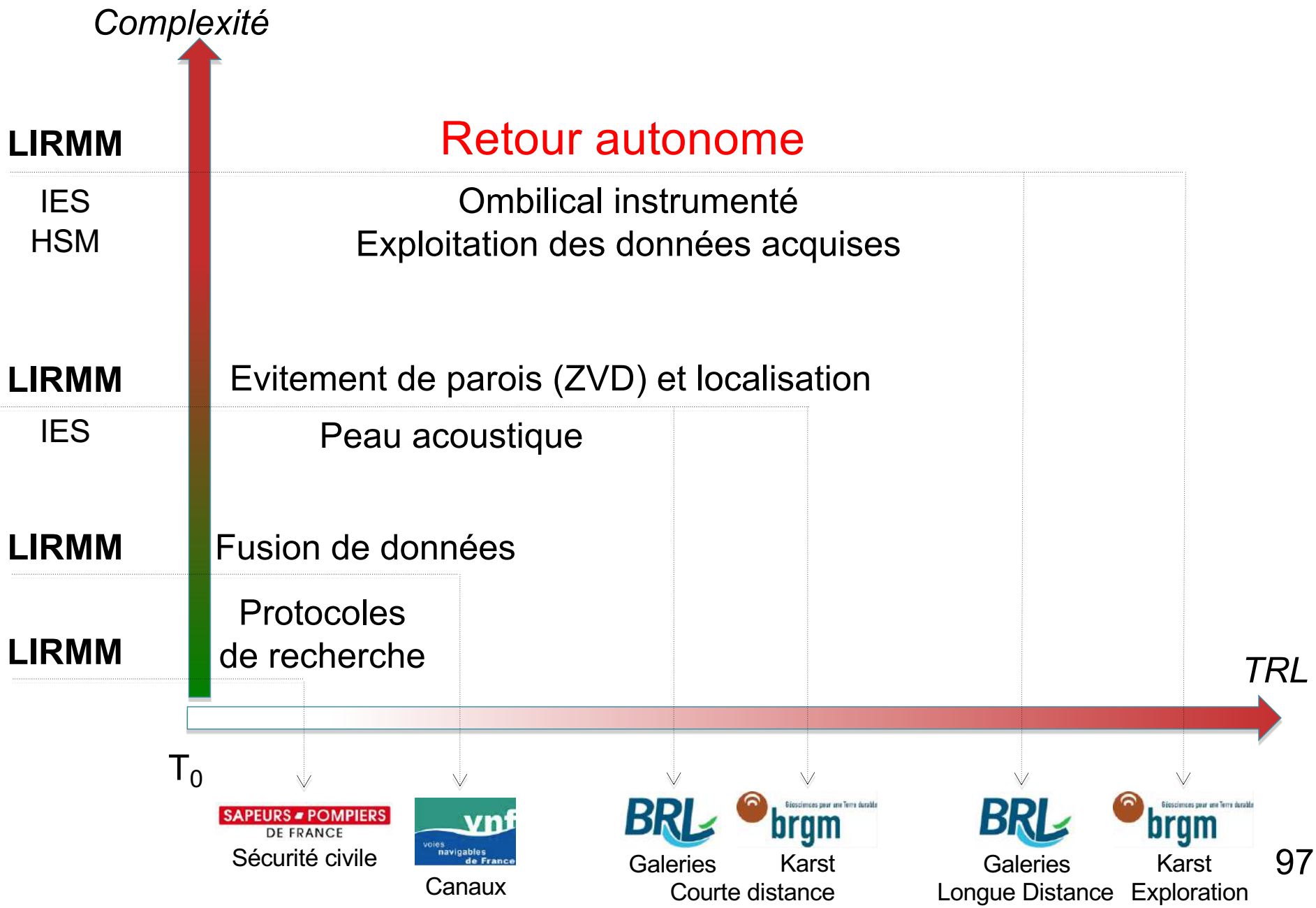


REEDS : DES MARCHÉS DE NICHE ATTAQUÉS PROGRESSIVEMENT

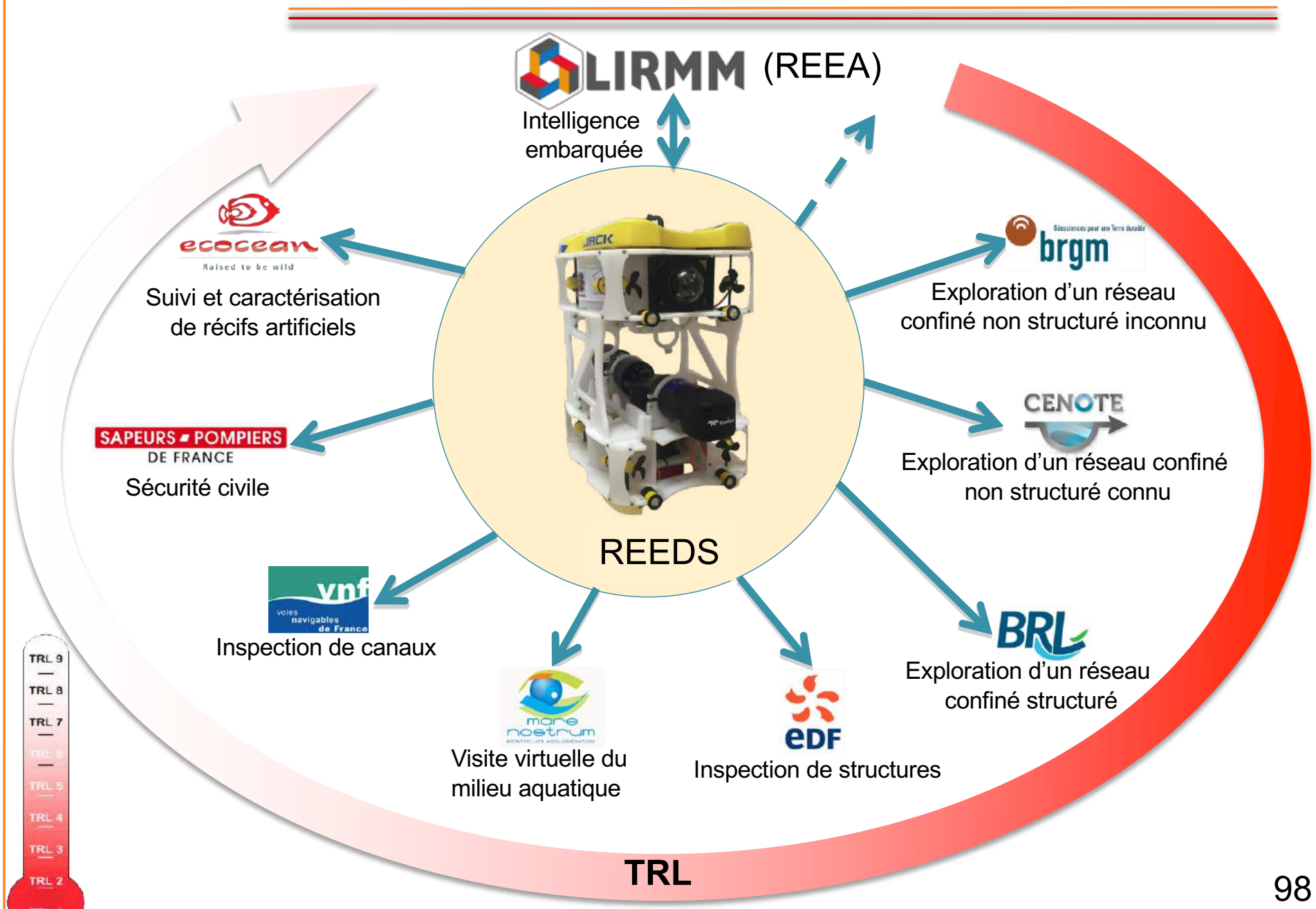


* Partenaires Aleyin (Projet Étendard Numev)

REEDS : VERROUS TECHNOLOGIQUES IDENTIFIÉS



REEDS : SEGMENTATION DU MARCHÉ



VALORISATION : L'ÉQUIPE REEDS

Une équipe complémentaire :

Lionel LAPIERRE Référant Scientifique Sénior	Benoît ROPARS Scientifique (Ph.d) Technologie	Luc ROSSI Expert technique Technologie	Bruno PIGNARD Business developer Entreprise	Saïd YAMI Référant Scientifique Sénior

Collaborateurs académiques:

David ANDREU Enseignant Chercheur Conseiller	Hervé JOURDE Enseignant Chercheur Intervenant

PERPSECTIVES

- Extension du réseau de partenaires
  - Académiques
    - Appel de coopération PRIMA (2018 ->)
      - France, Italie, Espagne, Portugal
    - Actions billatérales
      - Vietnam, Europe de l'est.
  - Implication des industriels partenaires
    - EDF, BRGM, CNP, VNF…
    - Repérage et ouverture de sites industriels
    - Contractualisation des collaborations (LabCom…)
- Validation centrage autonome
  - Mission de terrain 01/2018
    - Gourneyras, Durzon…

BUILDING PROJECT : 4 INGREDIENTS OF SUCCESS

- Pave new research avenues
  - Transdisciplinarity : a very strange alchemy
- Impact territory
  - Local coherency : regional application of global interest
- Network people of goodwill
  - Technological-scientifical-Industrial-Financial Consortium coherency : towards creation of new services.
- Raise funds
  - Financial aspect : when bottom – up tracks top – down.

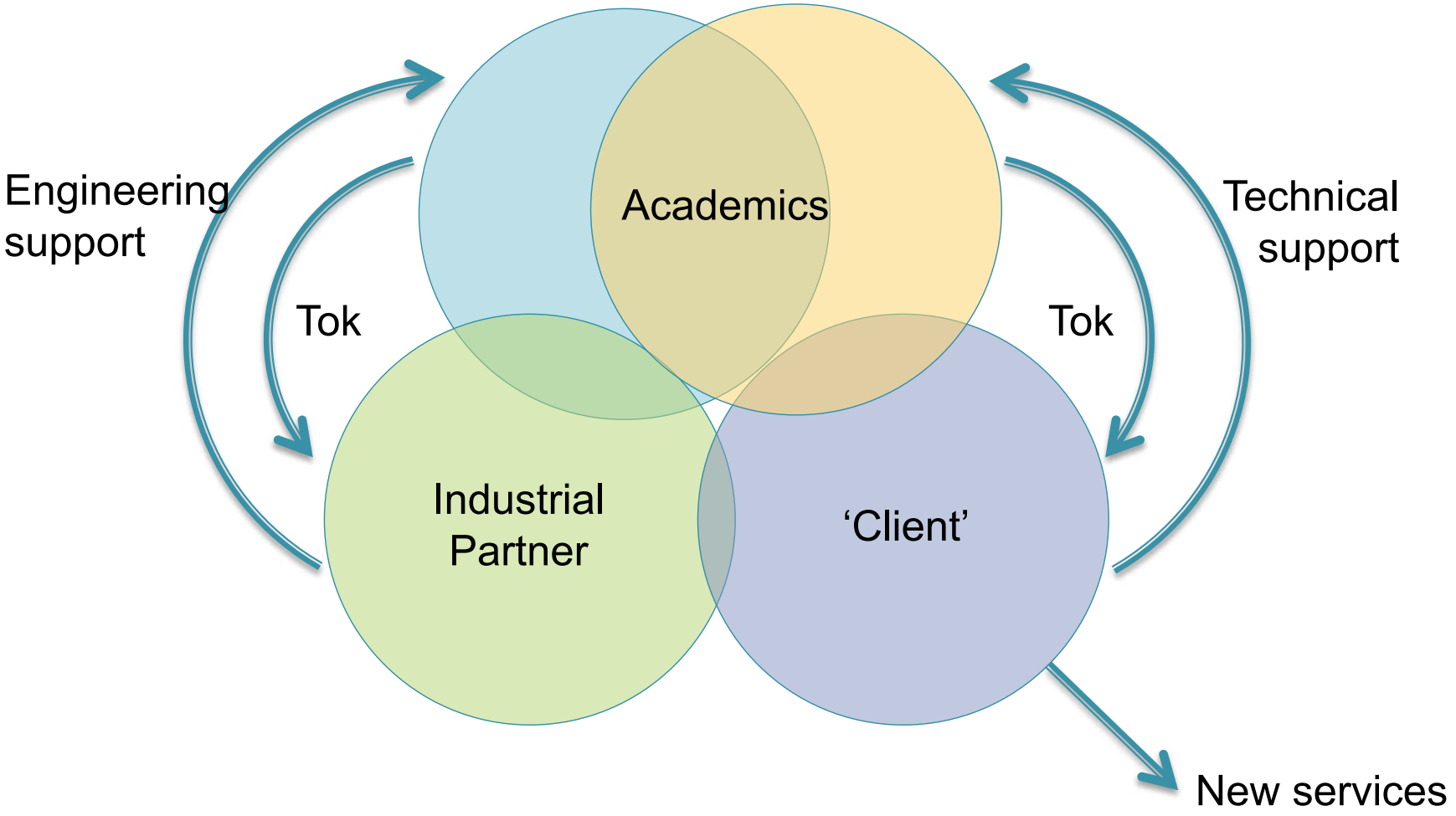
TRANSDISCIPLINARITY

- Breaking the disciplinary barriers
  - 1. Learn different scientific languages, tools and objectives
  - 2. Circumvent overlapping regions of interest
  - 3. Assimilate partner(s) objective(s)
  - 4. Revisit your science with a brilliant co-advised PhD student
- Co-design
- Opportunity is at interface

IMPACT TERRITORY

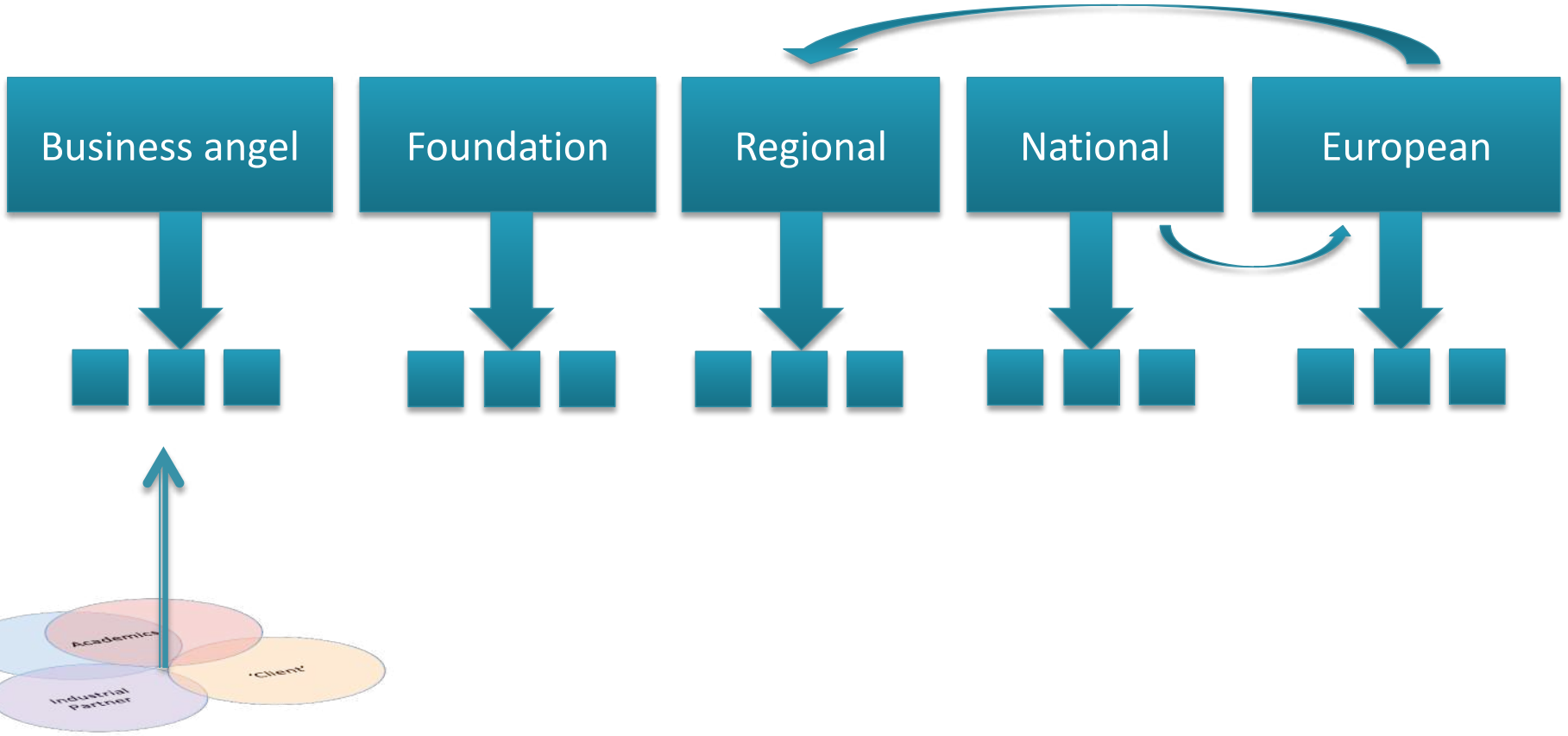
- Local coherency
  - 1. Integrate territory strategy
  - 2. Map local needs and actors
  - 3. Identify unseen and unquestionable applications
  - 4. Intersect with actors needs (new services)
- Route for innovation is known, and crowded, within specific discipline
  - Cross disciplines
  - Services requiring transdisciplinary TOK.

NETWORK PEOPLE OF GOODWILL



RAISE FUNDS

- When Bottom – up tracks Top – down



Deep Karsts in the Midi de la France