Advancement on Tomographic Research of Underground and large STructures with Muographic Expertise project (TRUST-ME)
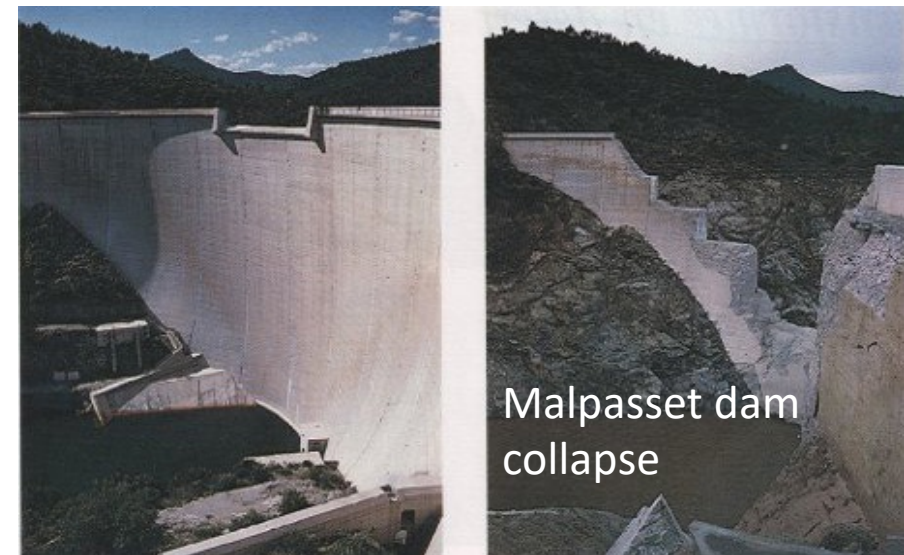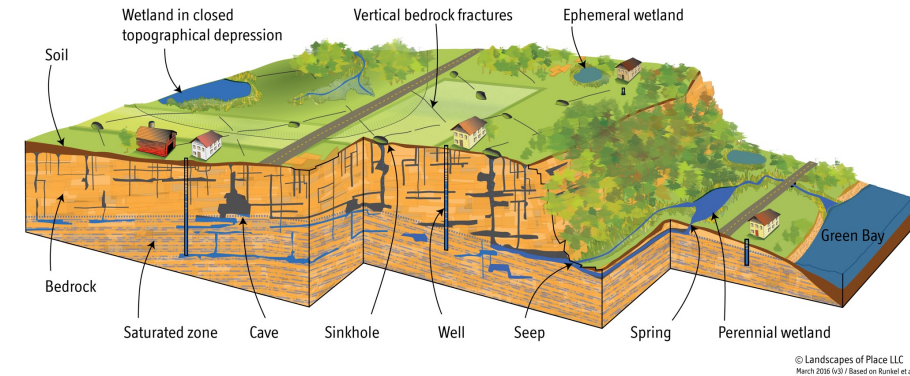
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LSBB
Laboratoire Souterrain à Bas Bruit
Low Noise Inter-Disciplinary Underground Science & Technology

cnrs

AVIGNON UNIVERSITÉ

symmetrymagazine.org

Project centered on sustainable water management

- Survey of groundwater in aquifers
  - Climate change, demographic growth cause increasing need for water
  - 25% of world population depends on groundwater from karstic reservoirs
- Hydraulic structures
  - 85% of dams have reached the end of their lifespan
  - 200 dam failures between 2000 and 2009
  - Existing monitoring techniques are limited
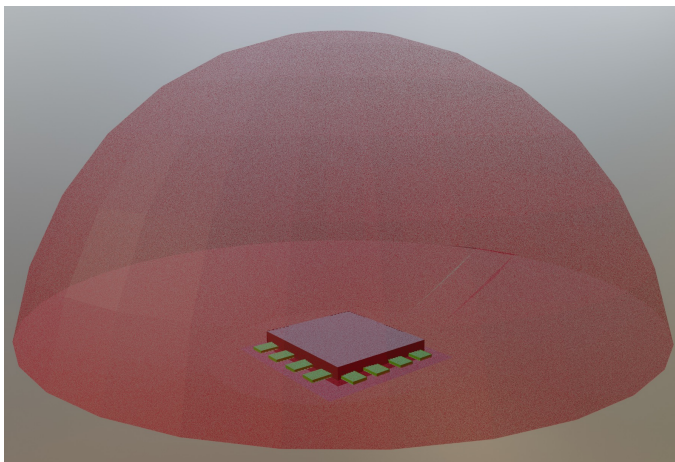- Project focuses on muography to complement existing geophysics imaging techniques
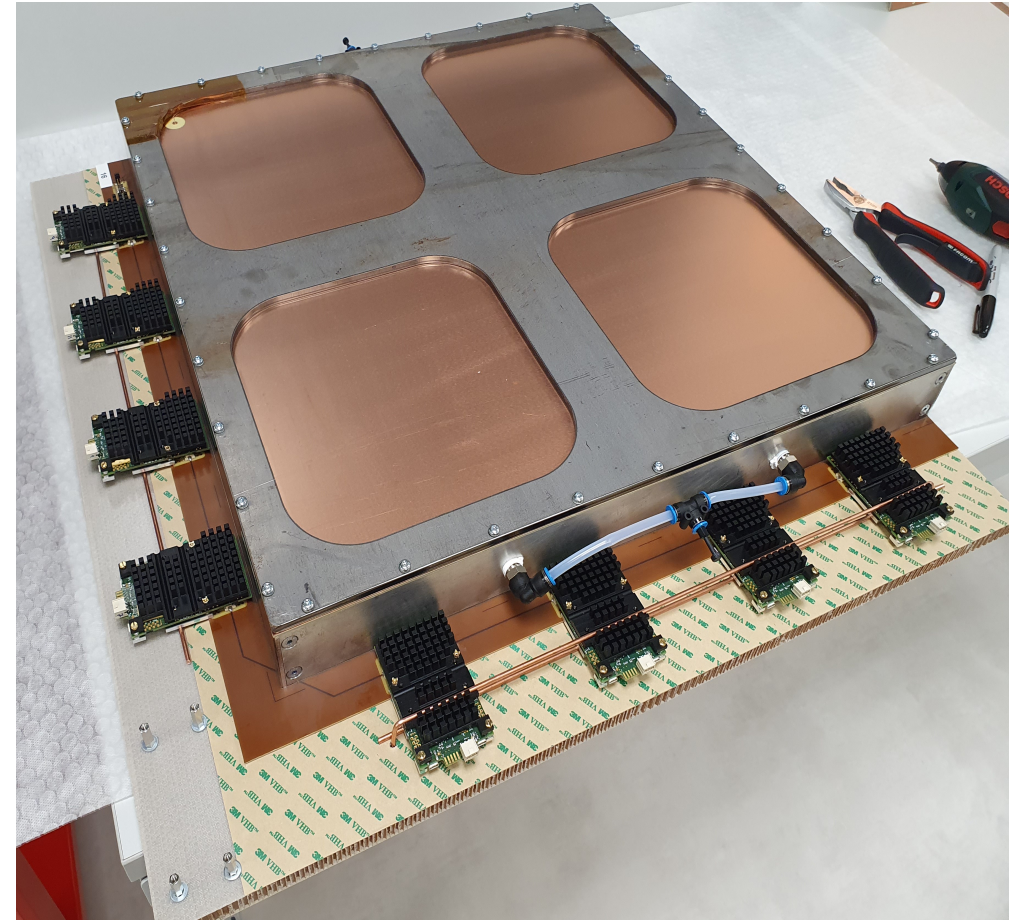

Malpasset dam collapse

ac-aix-marseille.fr
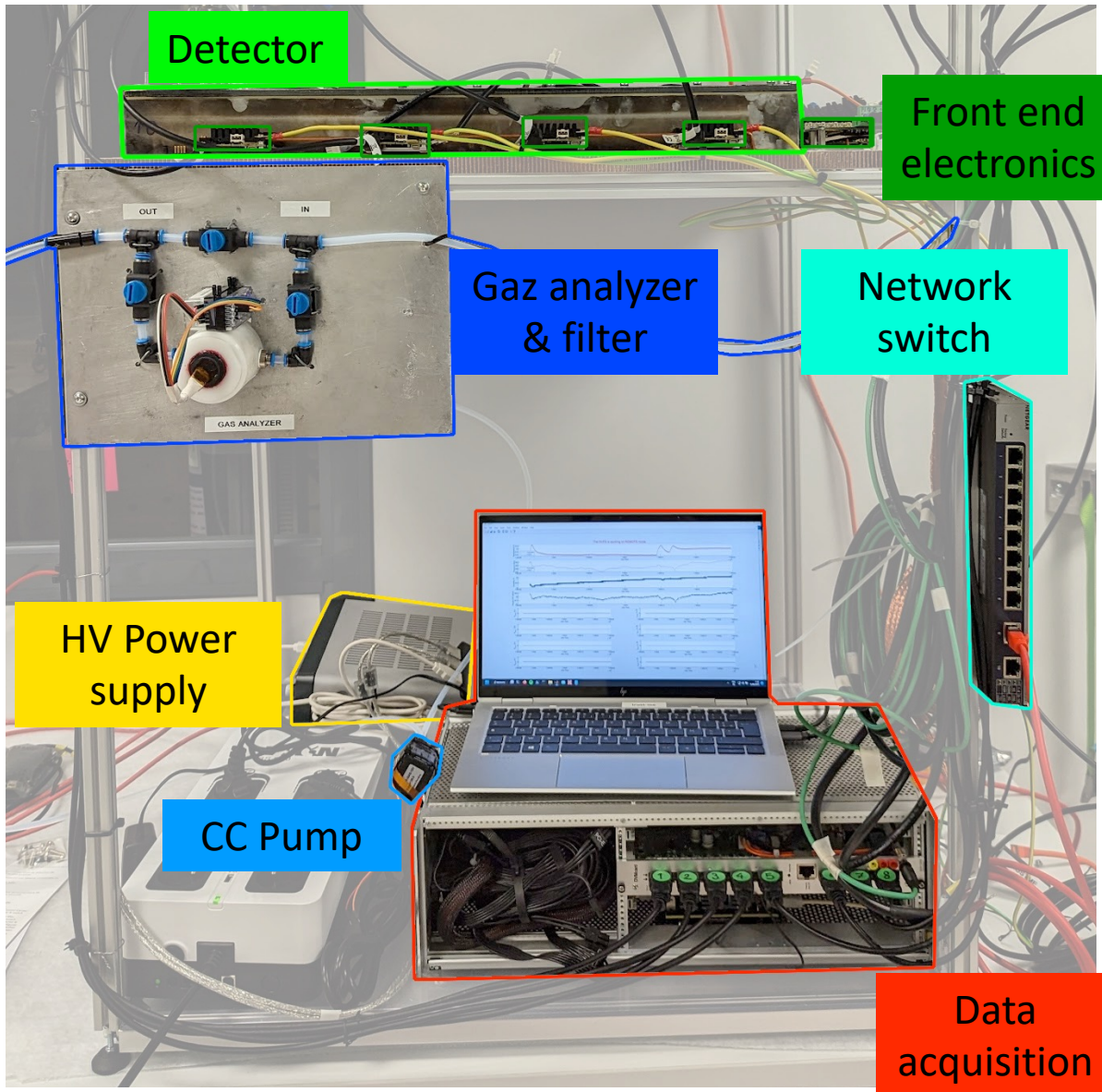
MUST² detector upgrade

- New version of the *MUon Survey Tomography based on Micromegas detectors for Unreachable Sites Technology* muon tracker (MUST², patented in 2015)
- Improved angular resolution, new features, more cost-efficient
- Network configuration capable
- Simultaneous acquisition of several points of view for 4D tomography
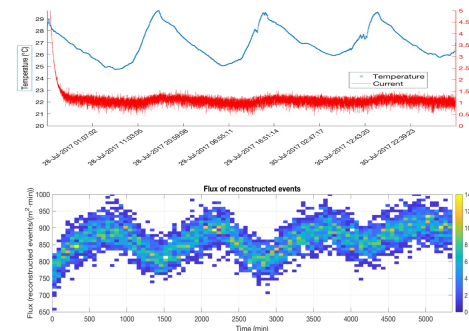- Wide FOV (~170º zenith and 360º azimuth)

FOV of the detector

MUST^2 detector upgrade

Detector

Front end electronics

Gaz analyzer & filter

Network switch

HV Power supply
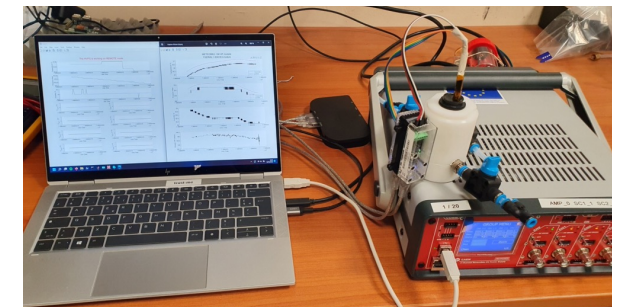
CC Pump

Data acquisition

- Lightweight detector, 60 × 70 × 10 cm, 20 kg
- Peripherals are remote-capable
- Versatile, autonomous, compact and scalable
- Real-time gas analysis to adjust voltage

Gas analyzer system: reads temperature and gas quality in the closed circuit, then allows real-time gain and gas control
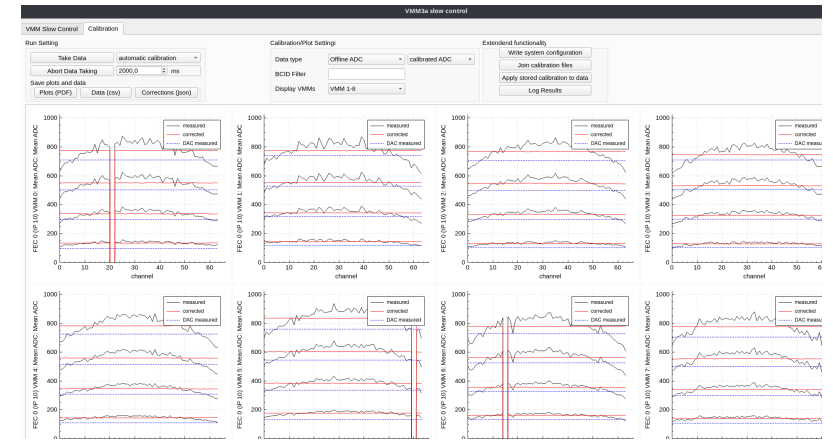

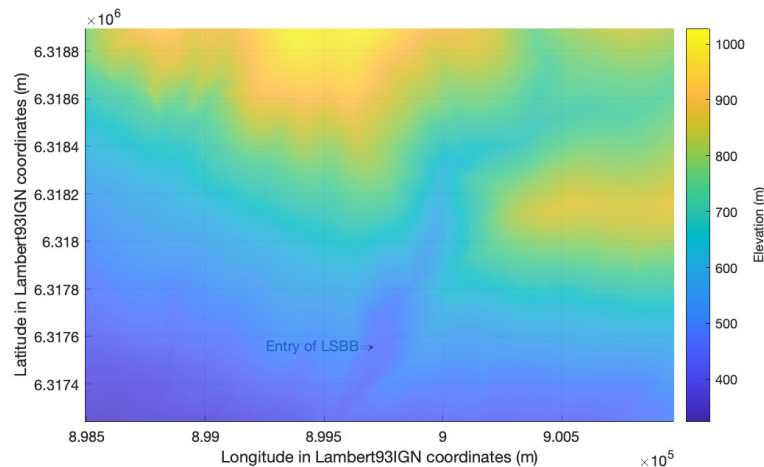Reconstructed events from gas moniitoring

Gain of high-voltage power supply adjusted automatically

Ongoing software development

Software aspect of the project include:

- Calibration and configuration of the detector using RD51 software

- Reconstruction of muon trajectories inside the detector

- Network configuration of the detector and acquisition system
  - Use of multiple detectors for temporal 3D imaging

- Modeling of mid-sized targets for detector characterization
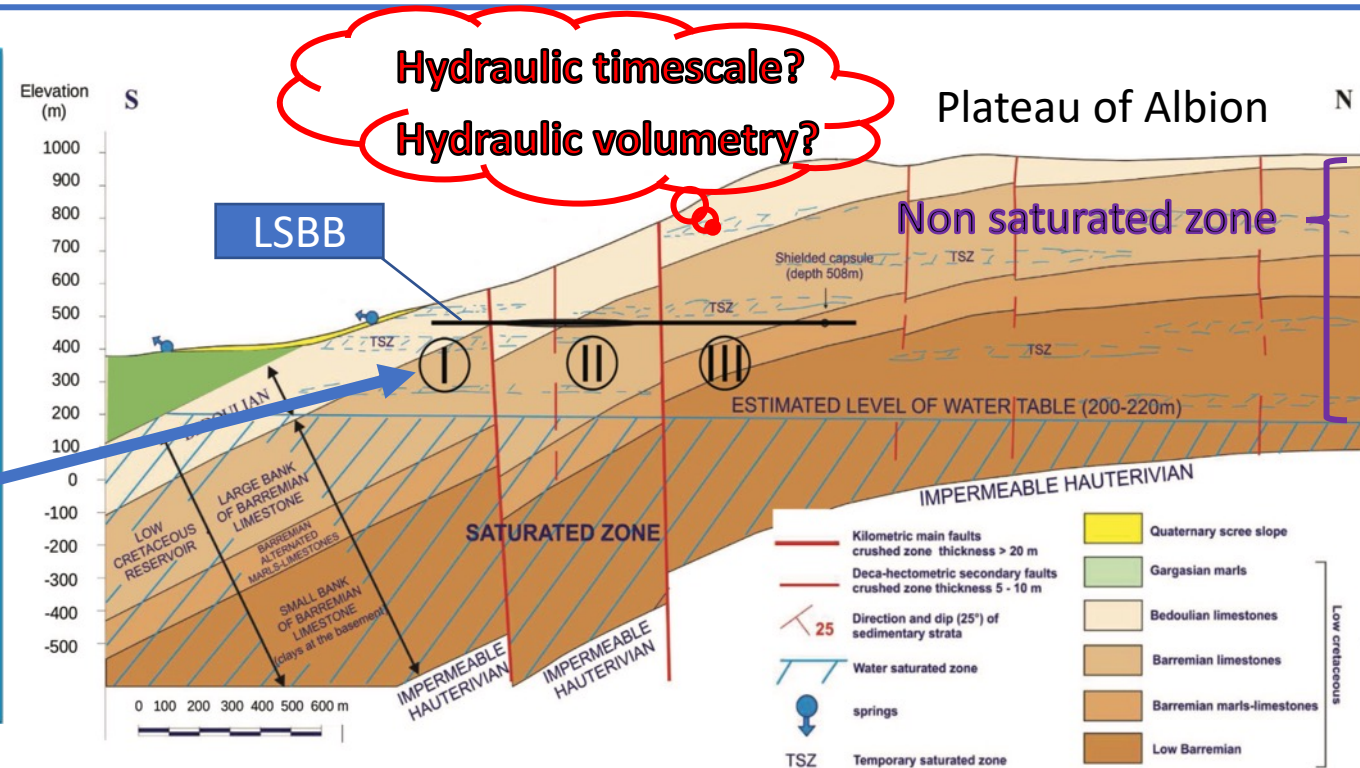 - Topographic, 3D models generated using photogrammetry & LIDAR

Calibration of VMM3a cards
using Slow Control software
Dorothea Pfeiffer – Lucian Scharenberg
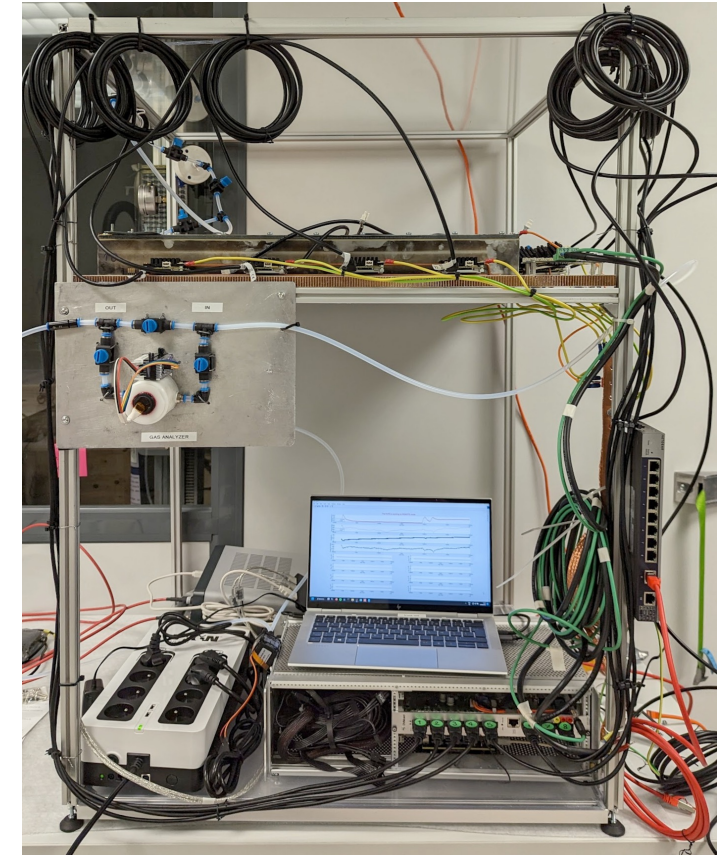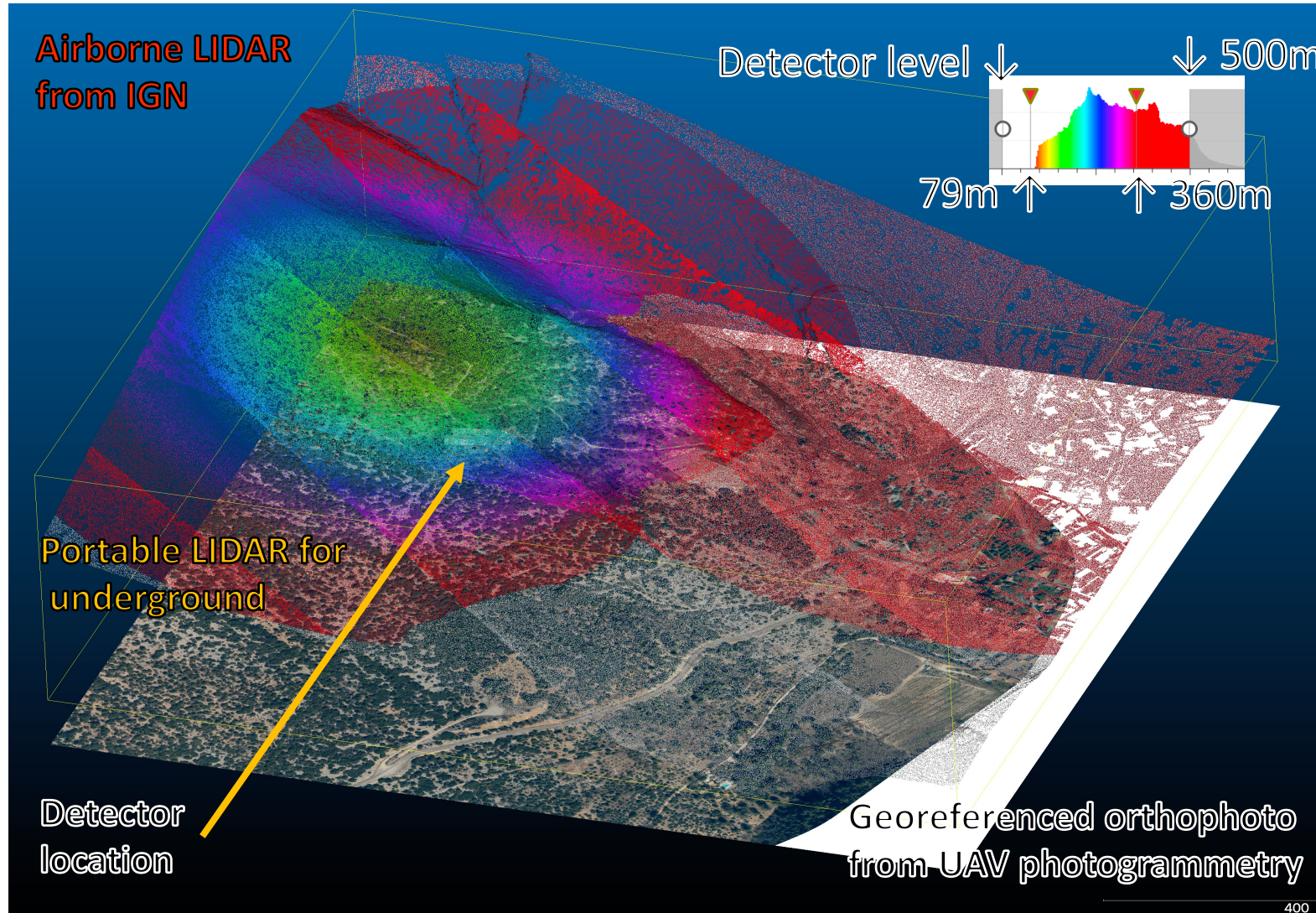

Elevation map of LSBB from
airborne LIDAR

Study case: underground monitoring

- Low background noise underground laboratory: pilot site of the project, possibility to deploy detectors elsewhere

- LSBB located in the non-saturated zone above water table

- Rainwater collected by Plateau of Albion feeds Fontaine de Vaucluse

- Underground muon tomography gives insight about aquifers

- Distances from detector to surface (1cm accuracy in length)
- Off ground points classified

Airborne LIDAR from IGN

Detector level ↓   ↓ 500m

79m ↑   ↑ 360m

Portable LIDAR for underground

Detector location

Georeferenced orthophoto from UAV photogrammetry

400

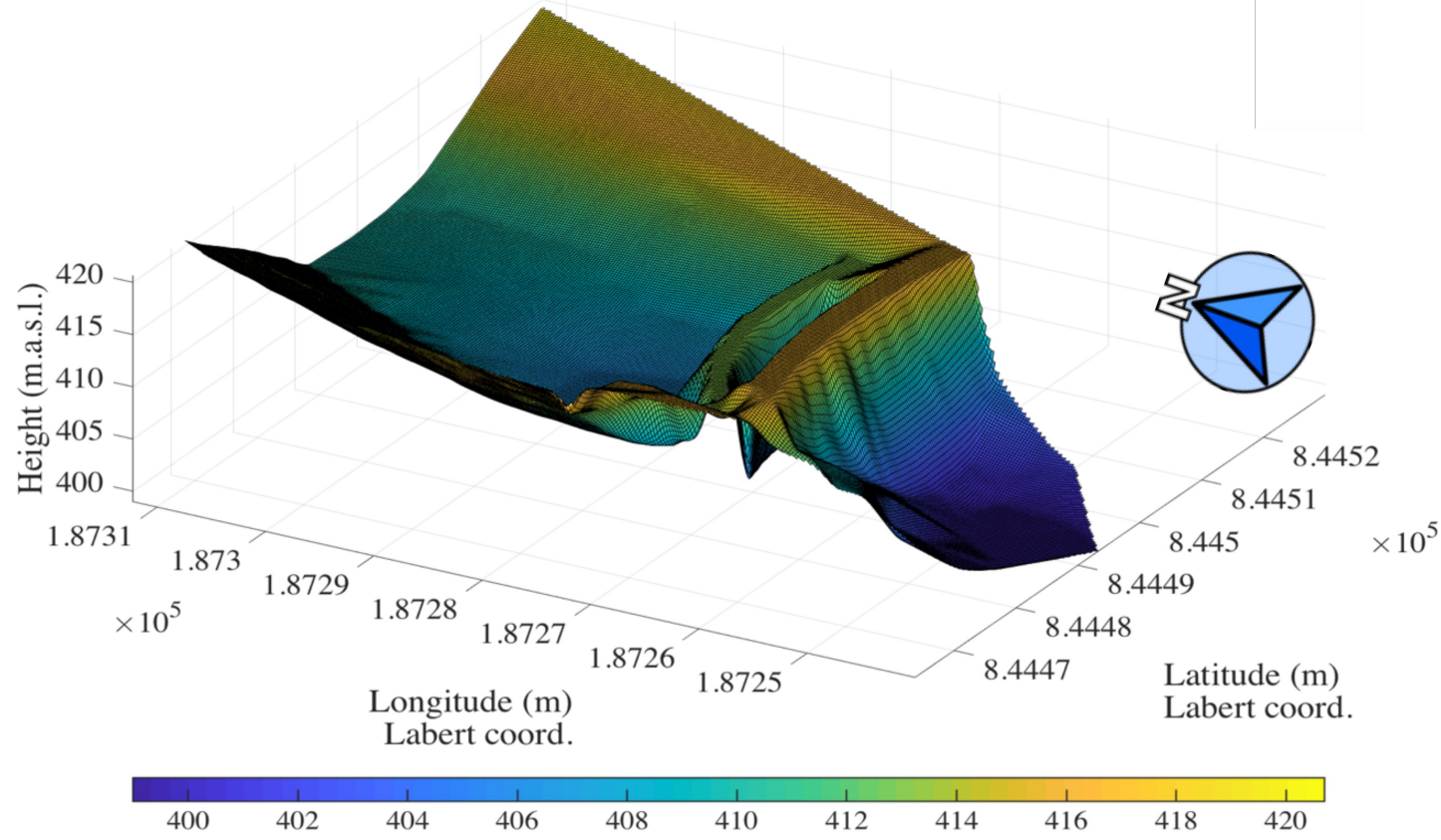Necessary for accurate modeling of muon flux attenuation on detector location

Study case: dam
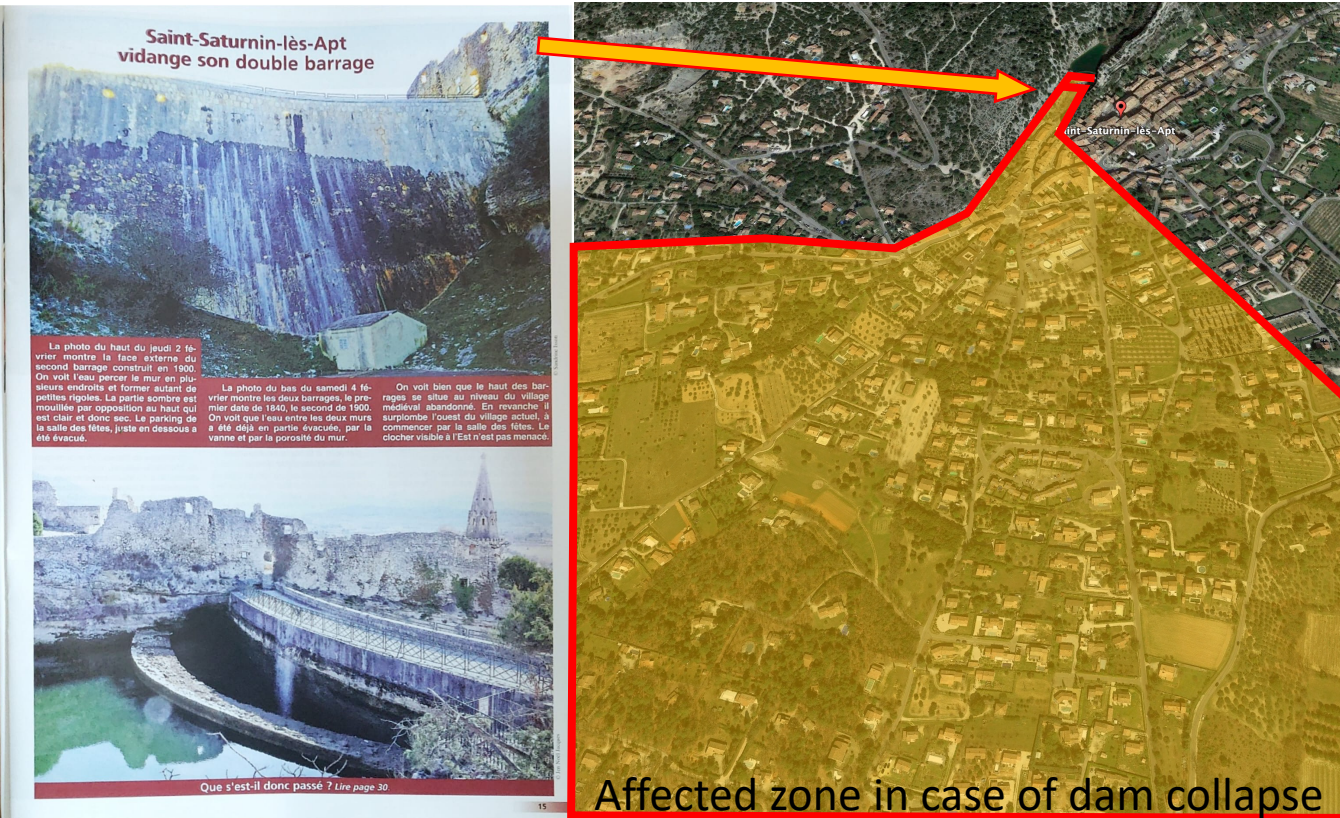
Topographic survey

October 2006
Unknown accuracy

3D Model

October 2017
Based on the topographic survey
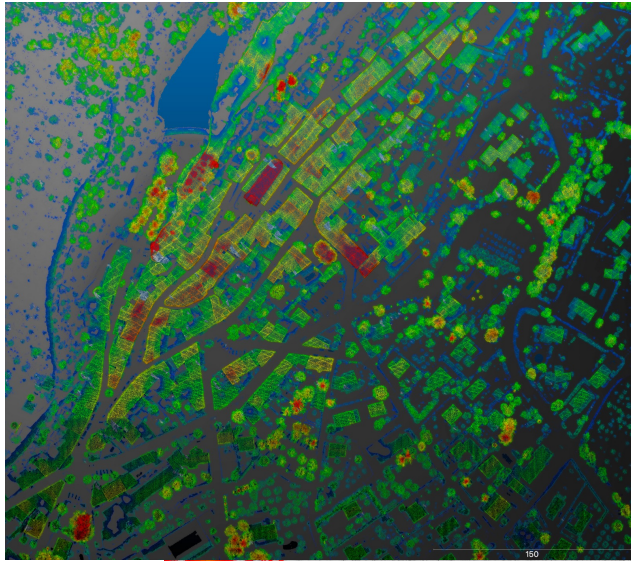Resolution 1 point/m²
Size 297x441m
Interpolation artifacts

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Study case: dam

February 2023: Dangerous incident during the dam monitoring

Saint-Saturnin-lès-Apt
vidange son double barrage

La photo du haut du jeudi 2 février montre la face externe du second barrage construit en 1900. On voit l'eau percer le mur en plusieurs endroits et former autant de petites rigoles. La partie sombre est mouillée par opposition au haut qui est clair et donc sec. Le parking de la salle des fêtes, juste en dessous a été évacué.

La photo du bas du samedi 4 février montre les deux barrages, le premier date de 1840, le second de 1900. On voit que l'eau entre les deux murs a été déjà en partie évacuée, par la vanne et par la porosité du mur.

On voit bien que le haut des barrages se situe au niveau du village médiéval abandonné. En revanche il surplombe l'ouest du village actuel, à commencer par la salle des fêtes. Le clocher visible à l'Est n'est pas menacé.

Que s'est-il donc passé ? *Lire page 30.*

Affected zone in case of dam collapse

- Periodical dam monitoring required by regional agency.
- Local council (owner) commissions the monitoring to the concession holder.
- Concession holder outsources a borehole drilling for structure analysis.
- Borehole technicians ask for dam plans, they do not exist as the double dam structure is over 200 years old.
- Owner authorizes the drilling as the monitoring is legally enforced.
- Borehole damages the dam exhaust and the dam front starts to leak, weakening the whole structure.
- Emergency procedure triggered to empty the reservoir.
- Emptying doesn't work as sediment has clogged the drain system.
- The old submerged dam holds the water weight and can cause a hydraulic ram.
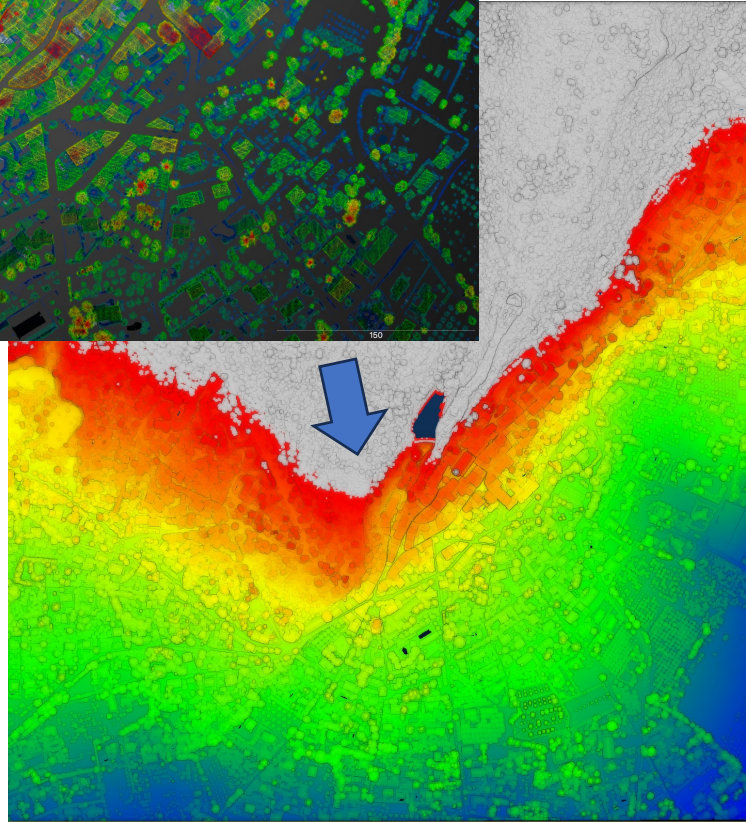- Firefighters deploy motor pumps to empty reservoir (3 days).

Study case: dam

Airborne LIDAR for village

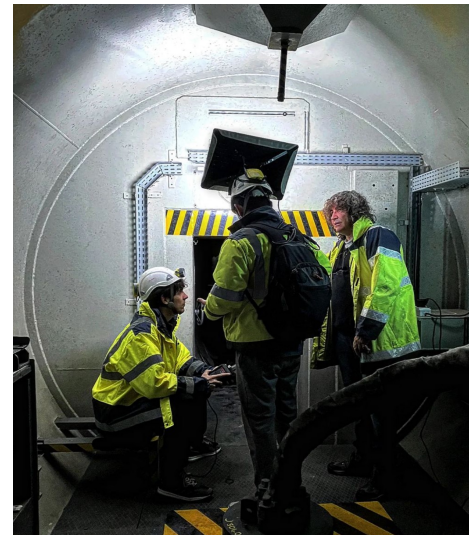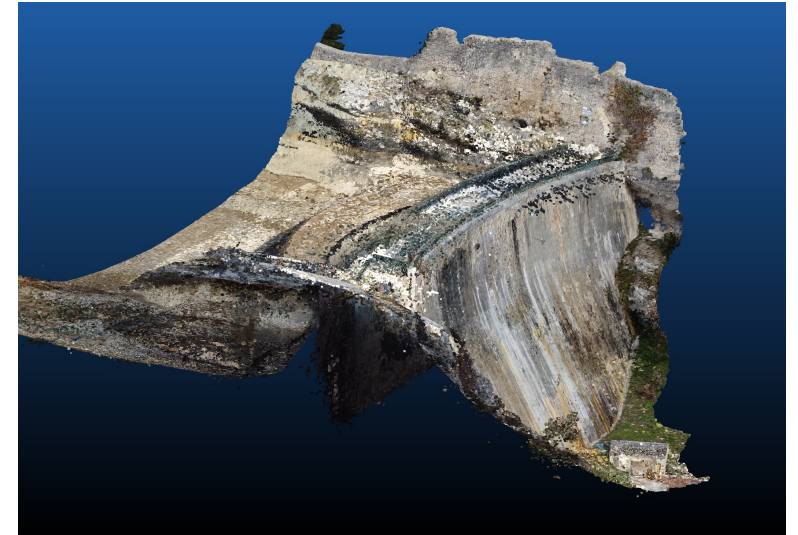Airborne photogrammetry for empty reservoir

DJI Mavic 3E

2021
Raw data by IGN
https://geoservices.ign.fr/lidarhd

Mobile LIDAR for dam & underground spaces

Study case: dam

Map of sedimentation
between 2006 and 2023

Capacity of 2006: ~11 000m³
Capacity of 2023:   ~9 735 m³
Loss of 11.5% of capacity

Cross-section of the dams

2,5 m of sediment over the drain

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Study case: dam

New data campaign using photogrammetry

Distance: 4.35
ΔX 0.51 ΔXY 3.57
ΔY ΔYZ 2.54
ΔZ -2.49 ΔZY 4.32

Detector location

FOV = 10° from horizon

Cross-section of double dam

Apparent thickness (m) Empty dam
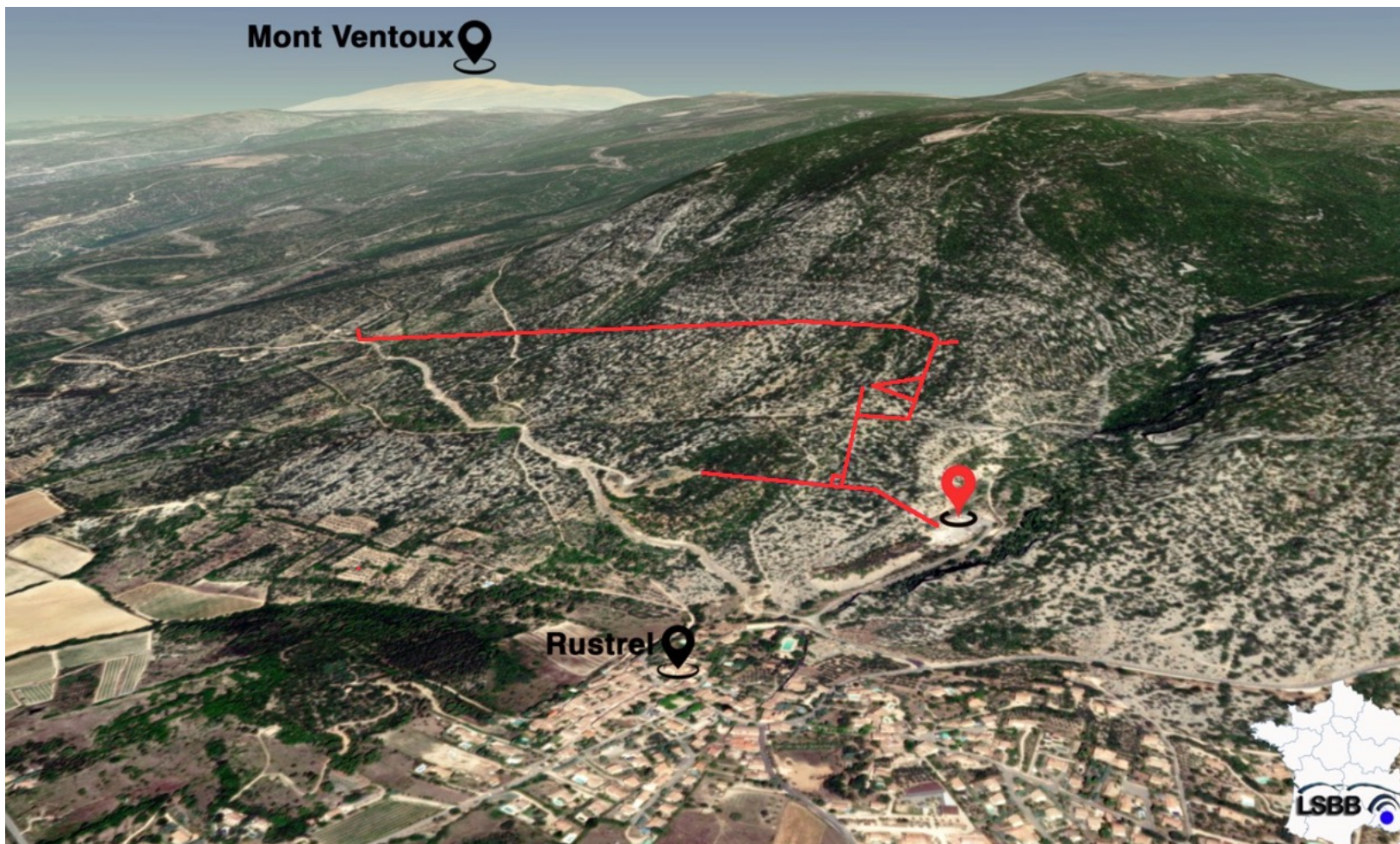
Simulated apparent thickness of the dam from the detector location

Lázaro Roche, I. A Compact Muon Tracker for Dynamic Tomography of Density Based on a Thin Time Projection Chamber with Micromegas Readout. *Particles* 2021, *4*, 333-342. https://doi.org/10.3390/particles4030028

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TRUST-ME | Muographers 2023

Thank you for your attention

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Acknowledgements