REMOTE SENSING AND HYDROGEOPHYSICS FOR HYDROGEOLOGICAL CONCEPTUAL MODELS OF HARD ROCKS

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with contribution of Dr J.Roy

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Presentation plan

- Need for reliable conceptual models (CM);
- Description of the Sardon hard rock study area
- Remote sensing for CM of hard rocks;
- Hydrogeophysics for CM of hard rocks;
- Conclusions

Conceptual models of hard rocks

- Role of hard rocks in water supply;
- Importance of conceptual models;
- Old vs new concept;

From a new hydrogeological conceptual model for hard rock aquifers to enhanced practical applications (survey, management of the water resource, modeling, protection, etc.)

P. Lachassagne[1*], Ahmed Sh.[2], B. Dewandel[1], N. Courtois[1], F. Lacquement[3], Maréchal J.C.[1], Perrin J.[4], Wyns R.[3]

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What is needed and can be provided by non-invasive methods (RS and hydrogeophysics)?

- Geometry of a system (identification of major faults and fracture systems, water table, aquifer boundaries etc.)
- System parameterization (flow and storage properties of a system)
- Spatiotemporal fluxes

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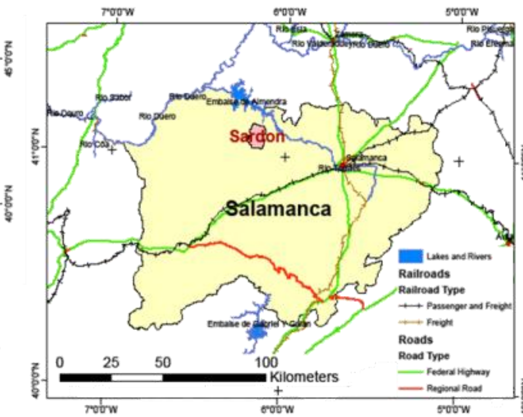
OBJECTIVE

HARD ROCK STUDY CASE - SARDÓN CATCHMENT

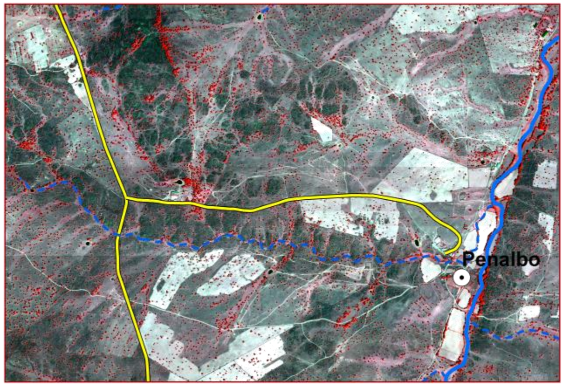
- Semi-arid climate
- weathered and fractured granite
- shallow water table (~2 m)
- limited human influence on water resources
- 22 years continuously operating monitoring network

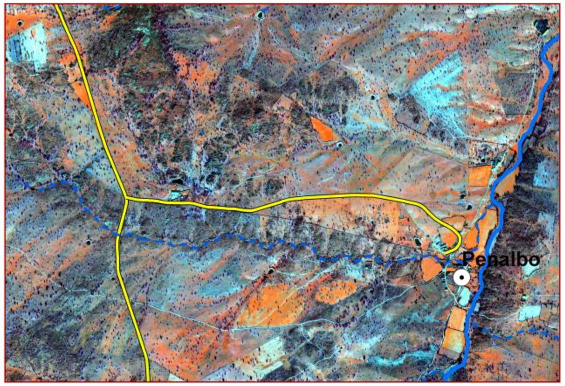


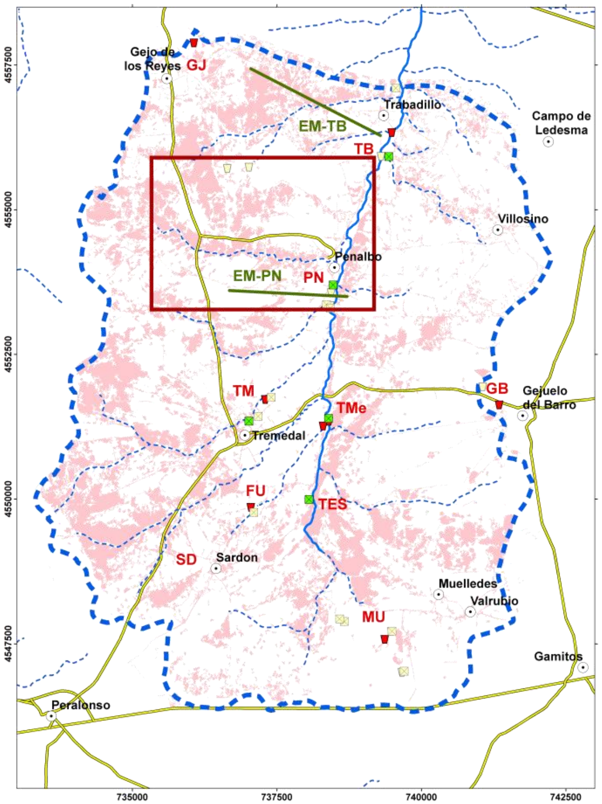
Sardon catchment – dry & wet seasons

REMOTE SENSING CONTRIBUTION TO CONCEPTUAL MODELS

Remote sensing for soil and outcrop mapping







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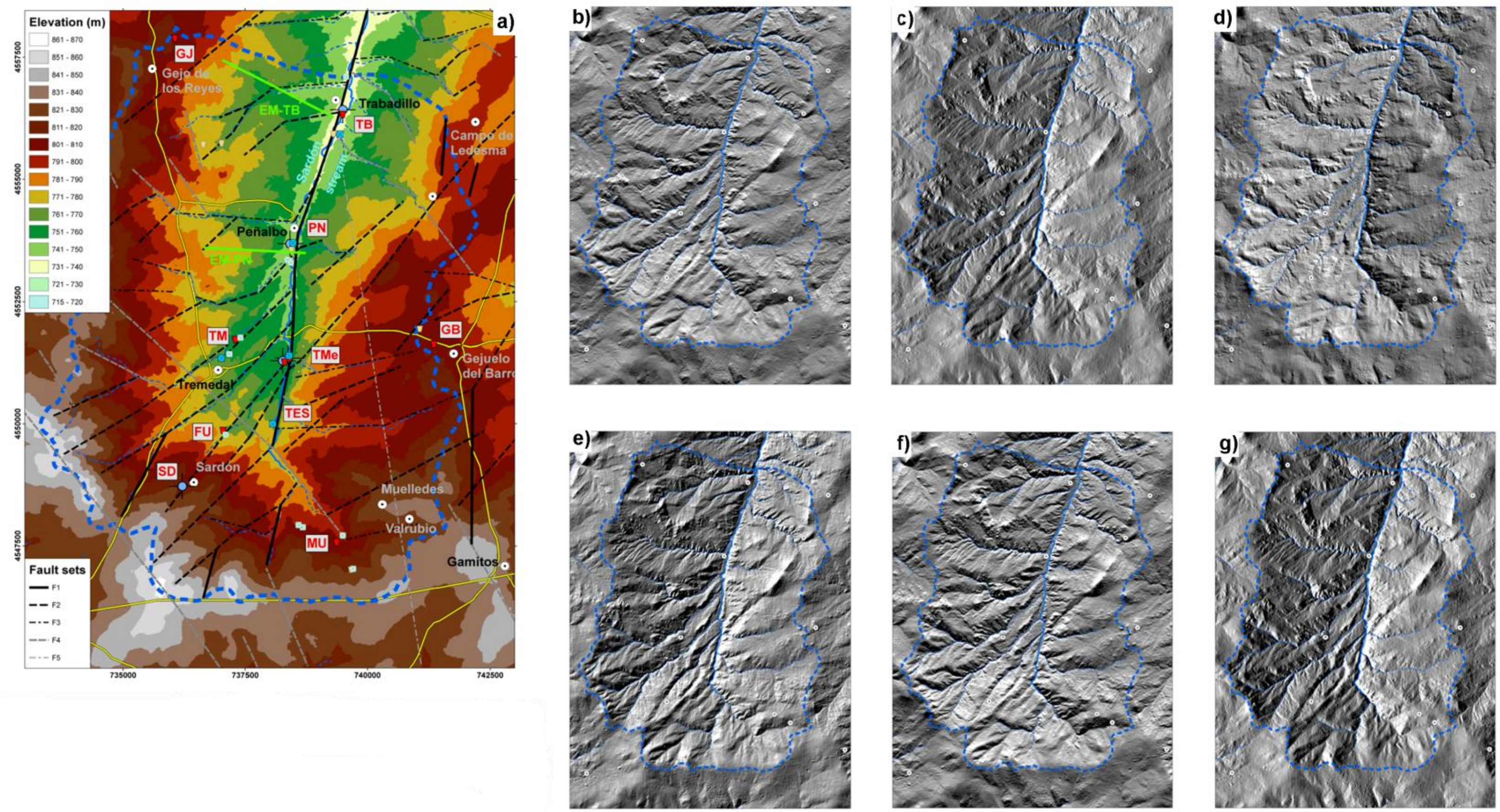
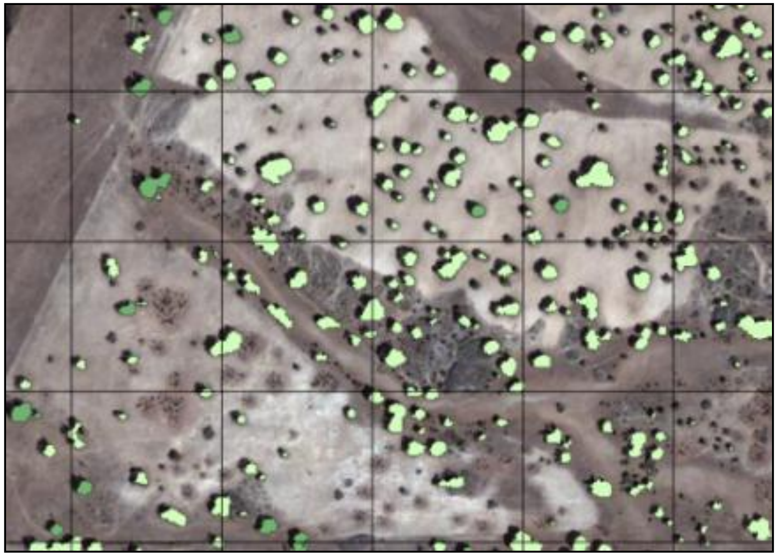
Remote sensing for fracture mapping



Francés, A.P., Lubczynski, M.W., Roy, J., Monteiro Santos, F.A. and Mahmoudzadeh, M.R. (2014) Hydrogeophysic
and remote sensing for the design of hydrogeological conceptual models in hard rocks - Sardón catchment, Spain. I
Journal of applied geophysics, 110 (2014) pp. 63-81.

Remote sensing identification of tree canopies for tree transpiration and interception mapping



Reyes-Acosta, J.L. and Lubczynski, M.W. (2013) Mapping dry - season tree transpiration of an oak woodland at the catchment scale, using object - attributes derived from satellite imagery and sap flow measurements. In: Agricultural and forest meteorology, 174-175, pp. 184-201.

Tanvir-Hassan, Ghimire, and Lubczynski (2016) Remote sensing upscaling of interception loss from isolated oaks: Sardon Catchment case study, Spain. In review in Journal of hydrology.

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Other remote sensing applications

- Rainfall;
- Evapotranspiration
- Soil moisture
- Subsurface (GW) water storage

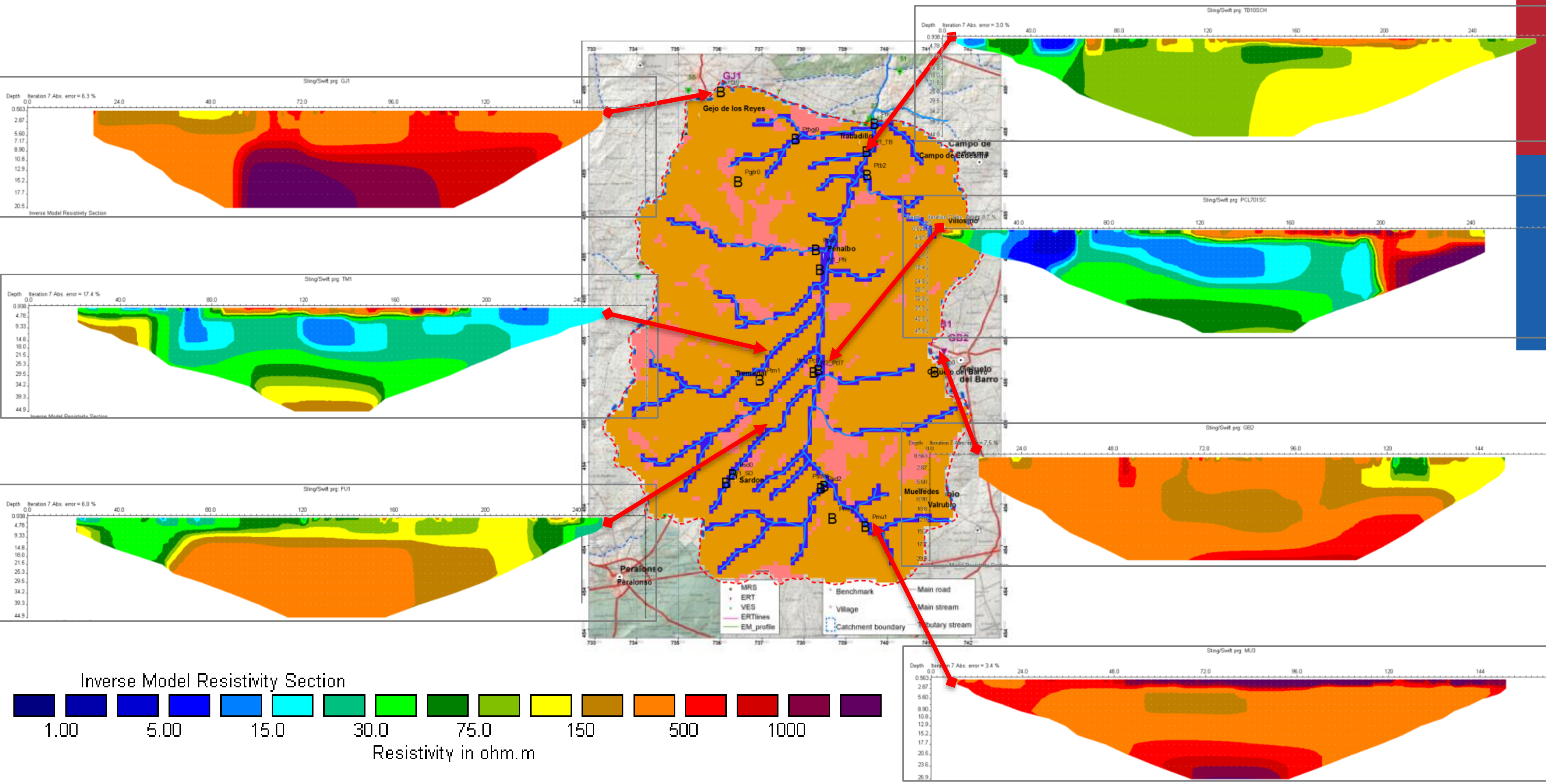
HYDROGEOPHYSICS CONTRIBUTION TO CONCEPTUAL MODELS

Groundwater table depth with GPR

Ground penetrating radar (GPR) in its standard implementation

Mahmoudzadeh, M.R., Francés, A.P., Lubczynski, M.W. and Lambot, S. (2012) Using ground penetrating radar to investigate the water table depth in weathered granites : Sardon case study, Spain. Journal of applied geophysics, 79 p. 17-26.

ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT)



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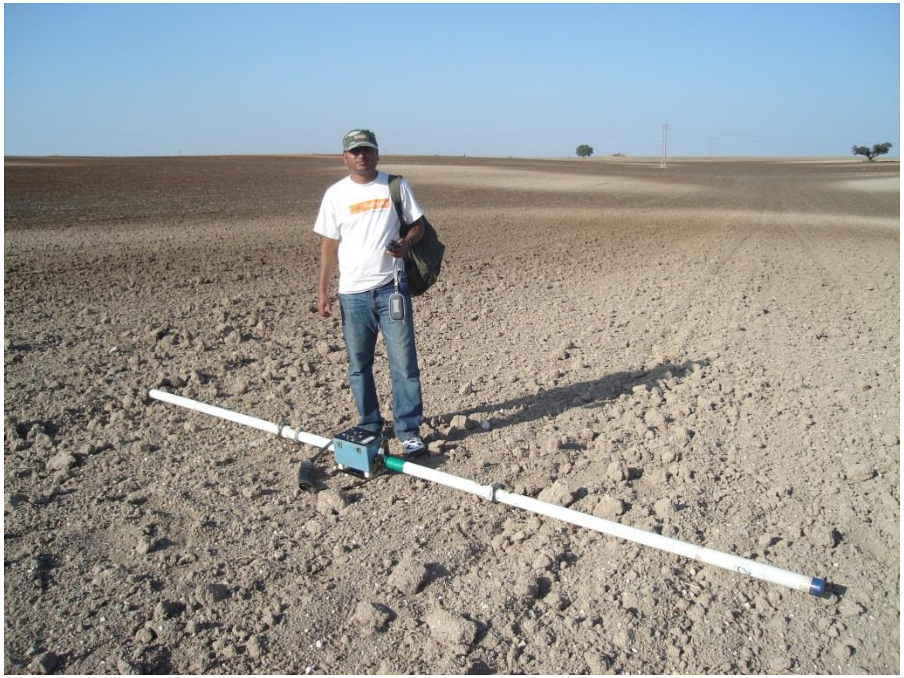
Top soil thickness with electromagnetic methods



EM31

EM34

Francés, A.P. and **Lubczynski, M.W.** (2011)Topsoil thickness prediction at the catchment scale by integration of invasive sampling, surface geophysics, remote sensing and statistical modeling. Journal of hydrology, 405 (2011)1-2 pp. 31-47.

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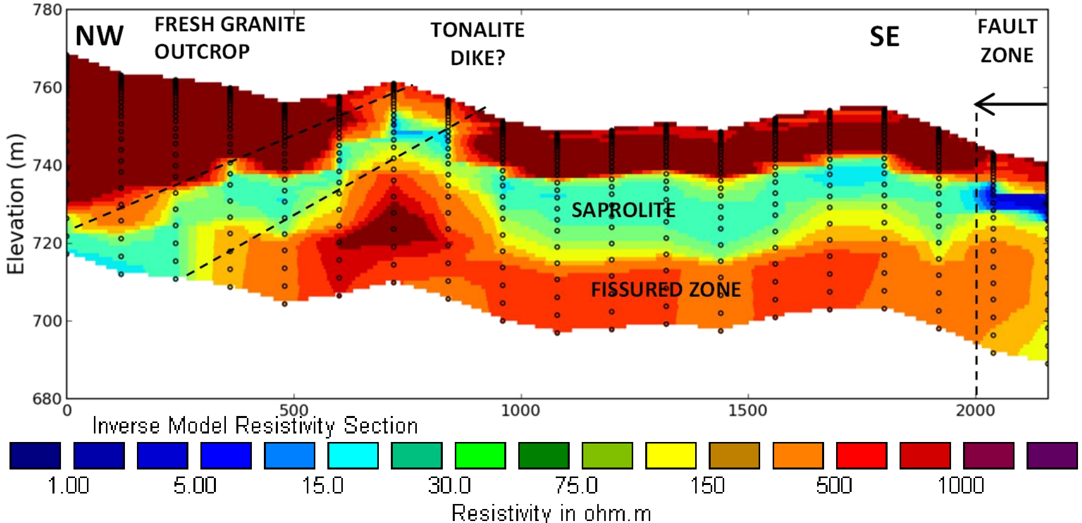
Hydrostratigraphic layering with MaxMin

Multi-frequency (444 Hz to 56 kHz) EM in horizontal coplanar loops system (Slingram) on a rigid frame

Francés, A.P., Lubczynski, M.W., Roy J., Santos F.A.M., and Mahmoudzadeh M.R. (2014). Hydrogeophysics and remote sensing for the design of hydrogeological conceptual models – Sardon Catchment, Spain. *Journal of Applied Geophysics*, 110, pp. 63-81.



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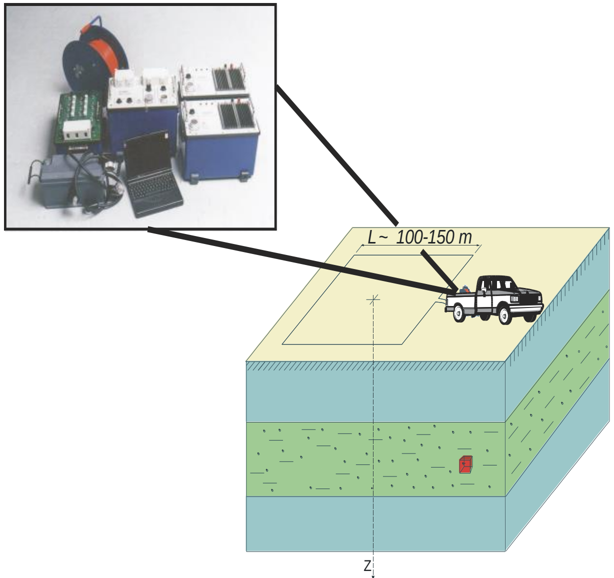
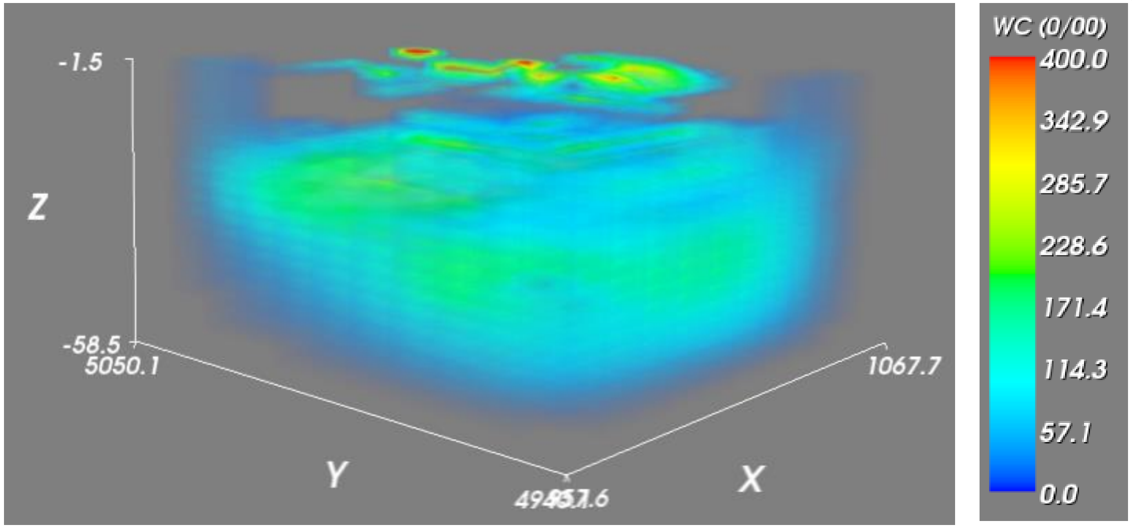
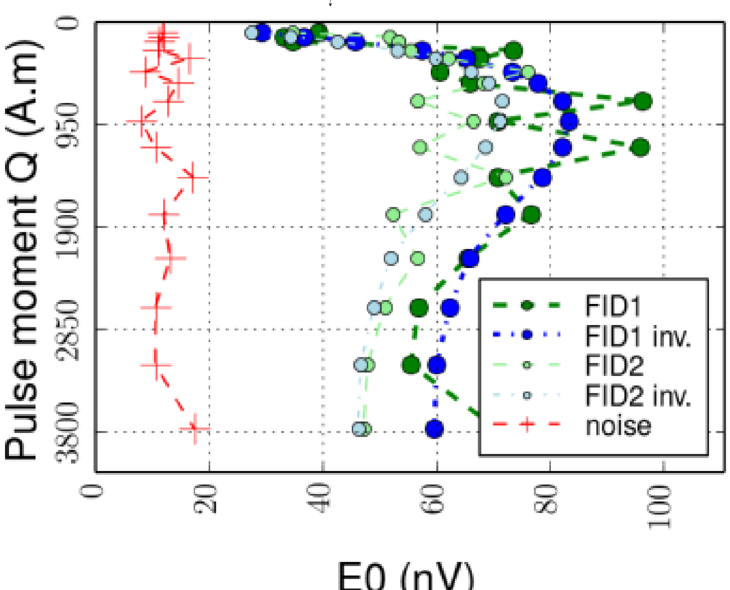
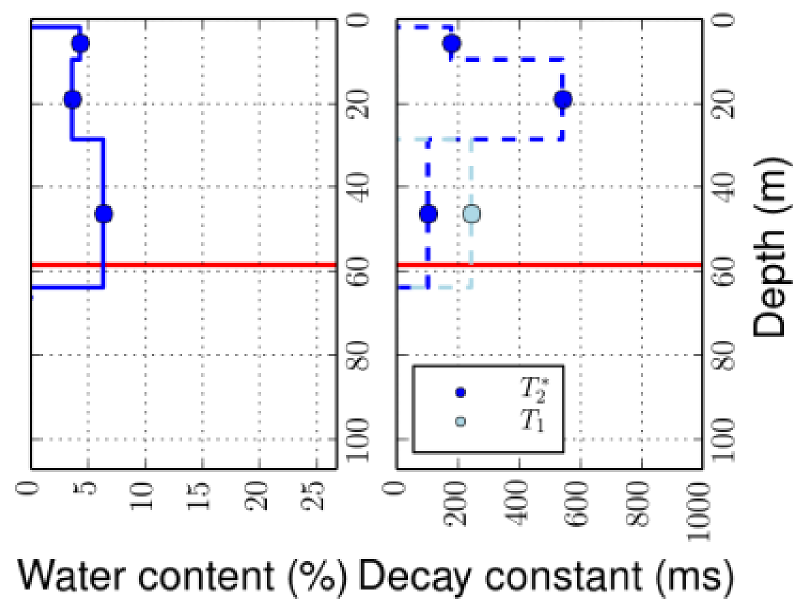
Magnetic Resonance Sounding for aquifer parameterization









For saprolite validation

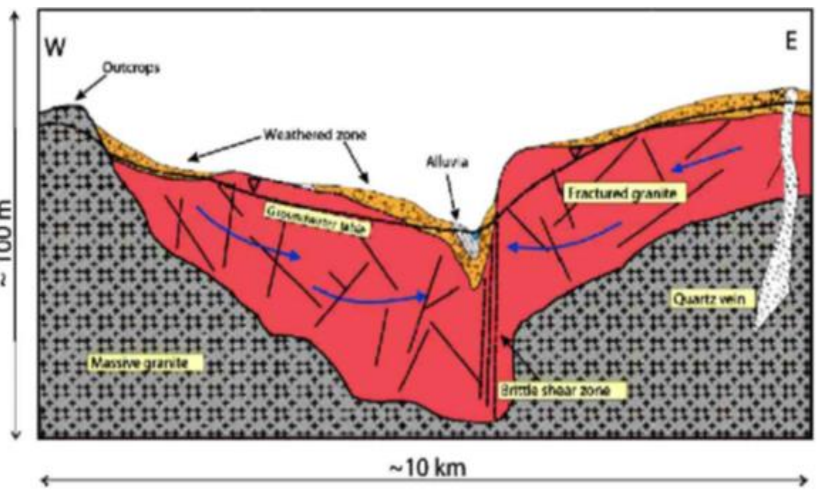
For fractured granite validation

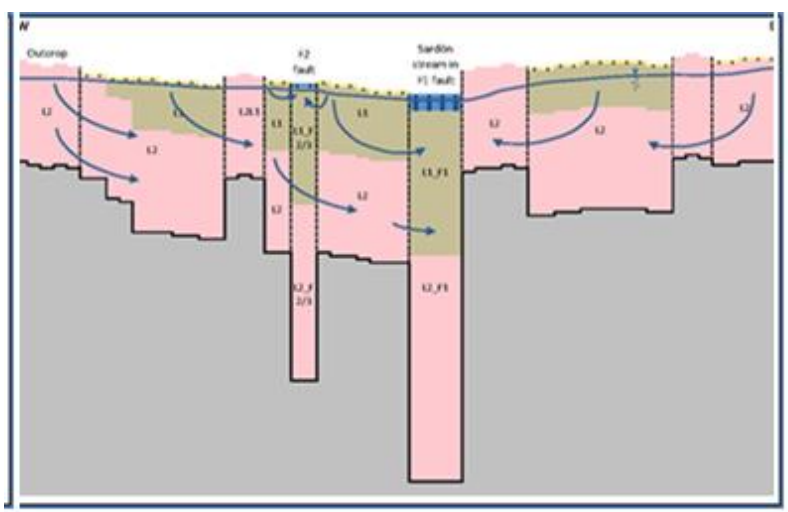
DRILLING SUMMARY									W1_Pcl7
Drilling Technique	Cable tool (P)	Auger	Down-hole hammer (R)	Other (specify)	**Final depth of the bore (m)**	38	**Deviation from vertical (º)**	0	**Geological settings:** highly weathered granite in fault zone
	Roraty mud (R)	Rotary air (R)			**Final depth of the well (m)**	35	**Azimuth of deviated bore (º)**	0	**Remarks:** Air flow developement 15mn from 32m to 35m (column inserted at 28m up to 32m)

DRILLER'S LOG

Depth (m)	Log	Rock Type	Bore diameter (mm)	Samples	Drilling rate	Surficial isolation casing	Casing: Inside diam (mm)	Casing: Ext. diam (mm)	Casing: Material	Screen: Inlet type*	Screen: Number/m & size/diam. (mm)	Cuttings (DHH): Dry	Damp	Slurry	Black	Grey	Red	Brown	Remarks
-1																			
0												x							
1		Soil (loam sandy)				-0,1 to 5,2: iron casing inside O 230mm, outside O 238+2 (spiral)													ligth brown
2		Soil + Quarztitic clasts											x						
3			250																
6				yes															
9							138 (start at 1,1m below ground)	160 (start at 1,1m below ground)	PVC 12,5 atm (ligth blue) (start at 1,1m below ground)										
10				yes															
15				yes															
20		weathered clayey granite, very plastic, sometimes reddish; alternance with coarser, grey, less plastic; quarz clasts (1-2mm)																	
22			220	yes															
27							138	160	PVC 12,5 atm (ligth blue)	Slotted (hand made)	Longitudinal, every 40/50 cm, size 3mm*120								

Conceptual models developed





Lubczynski, M.W. and Gurwin, J. (**2005**) Integration of various data sources for transient groundwater modeling with spatio - temporally variable fluxes : Sardon study case, Spain. In*: Journal of hydrology*, 306 (2005)1-4 pp. 71-96.

Tanvir Hassan, S.M., Lubczynski, M.W., Niswonger, R.G. and Su, Z. (**2014**) Surface - groundwater interactions in hard rocks in Sardon Catchment of western Spain : an integrated modeling approach. In: Journal of hydrology, 517, pp. 390-410.

Francés, A.P., Lubczynski, M.W., Roy, J., Monteiro Santos, F.A. and Mahmoudzadeh, M.R. (**2014**) Hydrogeophysics and remote sensing for the design of hydrogeological conceptual models in hard rocks - Sardón catchment, Spain. In: Journal of applied geophysics, 110, pp. 63-81.

Weldemichael, M.Y. (**2016**) Integrated numerical modeling applying stratiform hydrogeological conceptual model : Sardon catchment study case, Spain. Enschede, University of Twente Faculty of Geo-Information and Earth Observation (ITC).

CONCLUSIONS

- Remote sending is suitable for surface, spatial and some spatio-temporal contributions to conceptual models in hard rocks;
- Different non-invasive hydrogeophysical methods contribute differently to conceptual models in hard rocks:
  - GPR could detect water table but only in <3m depth and only when referenced to piezometers;
  - ERT was supportive in subsurface layering but not time efficient
  - Among EM methods the most successful was FDEM, providing similar quality info as ERT but in more time efficient way
  - MRS is the only method that can parameterize system, but its application was limited to sites with sufficiently strong signal (due to sufficient amount of water) that were not common
- The stratiform concept of Lachassgne et al. was implemented successfully although it was not possible to calibrate model with larger K of fissured rocks than saprolite

THANK YOU FOR COMING ☺