ALTOS

Managing water resources within Mediterranean agrosystems by accounting for spatial structures and connectivities.

WP2: Monitoring fluxes and storages

Task 2.1: water and chemical fluxes (leader: CERTE)

Task 2.1: water and chemical fluxes (leader: CERTE)

- **2.1.1.Evapotranspiration, soil moisture and crop growth.**
- **2.1.2.Dam - aquifer transfers and upstream - downstream surface / subsurface transfers.**
- **2.1.3.Chemical pollutants: hydrological fluxes and retention processes.**

2.1.1.Evapotranspiration, soil moisture and crop growth.

- Targets: vegetation water status across growth cycle, yield, water use efficiency.
- Methodological innovations: joint use of eddy covariance / sap flow / isotopic measurements and optical / radar / thermal infrared remote sensing data, joint use of times series from in-situ and remote sensing data.
- Partners: INRGREF, SUPCOM, CESBIO, LISAH, UCAM, UNICA, IRTA.
- Study areas: Cap Bon, Merguellil, Tensift, Segre, Orroli.

LISAH Contribution

Monitoring ETR and water fluxes / LISAH

Objectives: monitoring ETR, soil moisture and crop growth

Method: joint use of different EC devices, SM moisture measurements, agricultural statistics

Means

- relying on former and ongoing experiments within OMERE observatory
- 1 ongoing PhD (MESRS / IRD) is gathering data.

Nomenclature	M	mesure								mettre en priorité 1 l'identification des périodes où les données sont disponibles
	C	carte								faire un diagramme de Gannt dans une 2nde feuille
	BV	bassin versant								détailler chaque type de variable dans d'autres feuilles
	Par	parcelle								
	Versant	versant (tour à flux)								
	Bi-hor	bi-horaire								

	Variables		Type de données (carte/mesures)	Echelle spatiale	Echelle temporelle	Années de mesures	Ordre de priorité	rçage / calage-validati	Personne à contacter	Remarques
Climat	actuel	Pluie	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		Tmin, Tmax	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		Humidité de l'air	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		vitesse du vent	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		rayonnement global	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		ET0	M	BV	journalière + Bi-hor	à partir de 2004	1		Rim	
		Flux (dont ETR)	M	Par / BV	Bi-hor	à partir de 2004	1		Rim et Laurent (2013)	sur quelques parcelles
	futur	Pluie	M				1		Insaf et Damien	préciser scénarios + périodes
		Tmin, Tmax	M				1		Insaf et Damien	
		Humidité de l'air	M				1		Insaf et Damien	
		vitesse du vent	M				1		Insaf et Damien	
		rayonnement global	M				1		Insaf et Damien	
		ET0	M				1		Insaf et Damien	
Sol	Propriétés permanentes	classes	C	Par	Invariante		2		Insaf et Damien	3 classes : vertisols ; sols calcimagnésiques ; sols minéraux
		texture	C	Par	Invariante		2		Insaf et Damien	
		profondeur	C	Par	Invariante		2		Insaf et Damien	
		taux de cailloux		Par	Invariante		2		Insaf et Damien	
		densité	M	Par	Invariante		2		Insaf et Damien	
		RU	M	Par	Invariante		2		Insaf et Damien	
	Propriétés variables	humidité du sol	M	Par	bihebdomadaire + bimensuelle		1		Insaf et Damien	pour choisir les périodes
		albédo	M	Par			2		Insaf et Damien	
		conductivité hydraulique	M	Par			2		Insaf et Damien	
		infiltrabilité							Damien	
Hydrologie		Runoff	M	Par	mensuelle + journalière	à partir de 2000	3		Insaf et Jérôme	
		Piezometrie	M	Par	mensuelle + journalière	à partir de 2001	3		Jérôme	
Végétation		Type de culture		BV			1			
		végétation naturelle	C	Par		à partir de 2004	1		Insaf - ALMIRA	
		Hauteur	M	Par			2		Rim et Insaf	
		Biomasse fraiche	M				2		Rim et Insaf	
		Biomasse séche	M	Par			2		Rim et Insaf	
		LAI	M	Par			2		Rim et Laurent (2013)	- mesurés sur quelques parcelles
		phénologie				à partir de 2015	2		Rim et Insaf	
		rendement potentiel					3			Collecte des données en cours
Management		calendrier cultural					2		Damien	
		labour (date et					2		Damien	
MNT							2		Insaf et Damien -	
Parcellaire							1		Insaf	faire une nomenclature des parcelles
Occupation de							1		Insaf	
occupation de						2015-2040	1		Fabrice	spatialisation
données télédétection	Images	domaine solaire (vis,					3			faire recensement des images disponibles
		domaine IR thermique					3			
	produits dérivés des images	LAI	M				3			LP : mettre données TLD en priorité 3 ?
		Biomasse fraiche	M				3			
		état de surface	C				3			thèse christina/Cécile Gomez
		infiltrabilité	C				3			Cécile Gomez
		texture	C				3			thèse walid ouerghmi/ cécile Gomez : le

Monitoring ETR and water fluxes / LISAH

Partnership

- INRGREF

Roadmap

- On going data gathering by PhD student
- Next stage is database setup and metadata for ALTOS web site

Difficulties

Observations at Lebna watershed

- **Eddy covariance** :

Flux tour at Kamech watershed: subcatchment scale since 2010

- **Vegetation growth** an average of 6 to 8 fields have been followed since 2016:

hemispheric photos for LAI and crop cover, phenology, height, Biomass and yield

- **Soil moisture**: only 2 fields were monitored 2019-2020

ALTOS ACTIVITIES 2020-2021
Lebna watershed

- Monitoring of 8 fields (wheat, fababean, fodder) of vegetation growth and soil humidity, biomass, yield

- Remote sensing images sentinel 1 and sentinel 2, terraSARX

PHD Abdelghaffar and Altos Engineer

Observations at Citrus orchard

- Drip irrigated Citrus orchard
  - Eddy covariance since 2015 (H, LE, 4 components of Rn, G)
  - Compaigns of xylem water potential
  - Yield
  - Soil moisture (1/ 2 points)

Fluxmed and Sicmed: 2020

- Sap flow measurements
- Additional soil moisture sensors
- Remote sensing

What could be considered with Altos?

CESBIO Contribution

- Evapotranspiration, soil moisture and crop growth
  - Irrigated (Tensift) and rainfed (Taous, Tunis) olive trees: joint use of eddy covariance / sap flow / isotopic measurements and optical / radar / thermal infrared remote sensing data, joint use of times series from insitu and remote sensing data.
    - CNES MOCTAR (Tensift) and TRISHNA (Taous) projects

IRTA Contribution

Confirmed activities : Spatio-temporal variability of ET in a almond and apple orchard.

Activities	Period	Study areas	Team
Validation of ET estimates (TSEB S2+S3) of a almond orchard with different irrigation treatments -> eddy covariance	2019 and 2020	Almond (Maials, Lleida, Spain) & Apple (Mollerussa, Lleida, Spain)	C Jofre J Bellvert M Pàmies A Pelechá
Validation of ET estimates (TSEB S2+S3) of an apple orchard with two irrigation treatments -> weighying lysimeter	2020 and 2021		
Test different sharpening approaches, modifications in the algorithms and comparisons with other satellites and airborne TIR imagery -> to improve LST estimates when it is downscaled from coarse to high-resolution pixels.	2019, 2020 and 2021		
pyTSEB S2+S3 in other study sites?			

ALTOS KoF meeting

- Cadi Ayyad University UCA -

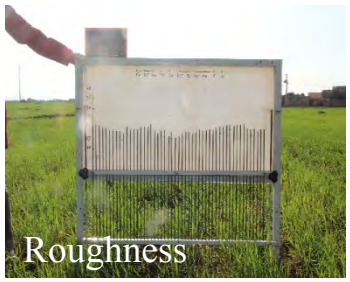
Tensift Site

WP2

April 20-21, 2020

Rainfed wheat functioning (2017-date)

Continuous measurements



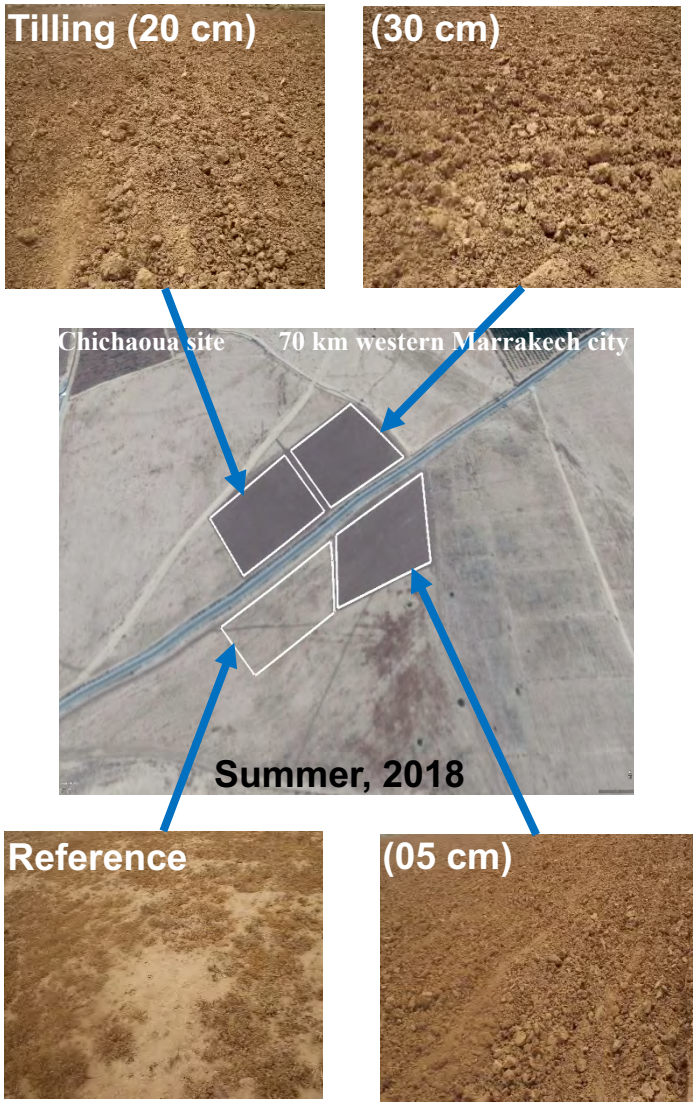
Field campaigns

Main objectives:

- Retrieving temporal variation of stress coefficient from fc, LST and SM observations,
- Validation of ET-TSEB constrained by 1 km resolution MODIS LST, f_c and disaggregated SM-SMOS,
- Calibration of sentinel-1 data using optical/thermal data (Landsat 7/8).

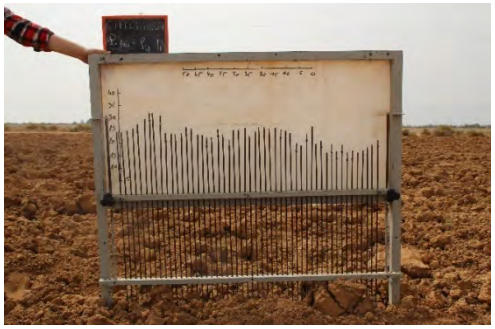
Thesis: Nadia Ouaadi

Roughness and SMC measurements on bare soil



Surface soil moisture

Soil roughness

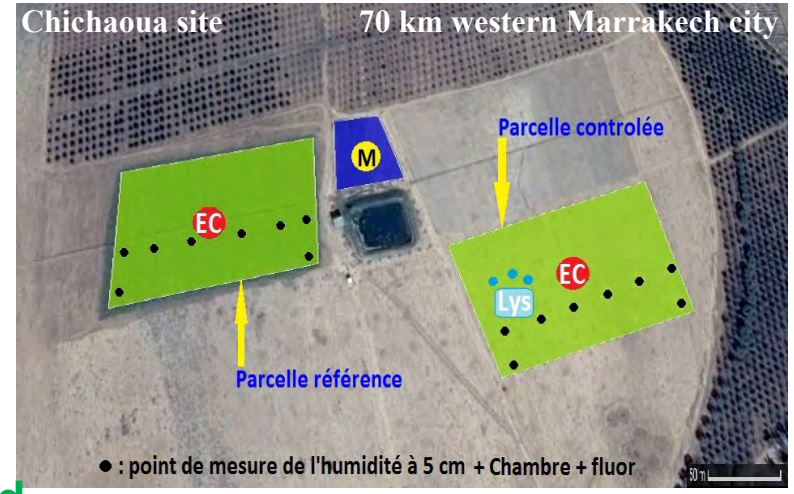


Main objectives:

- Investigation of the effect of surface roughness on the radar signal (C-band) over bare soils,
- Comparison of the backscattering coefficient derived from 3 radar models (IEM, Oh and Ulaby model),
- Retrieving surface soil moisture by using these models and Sentinel-1 data.

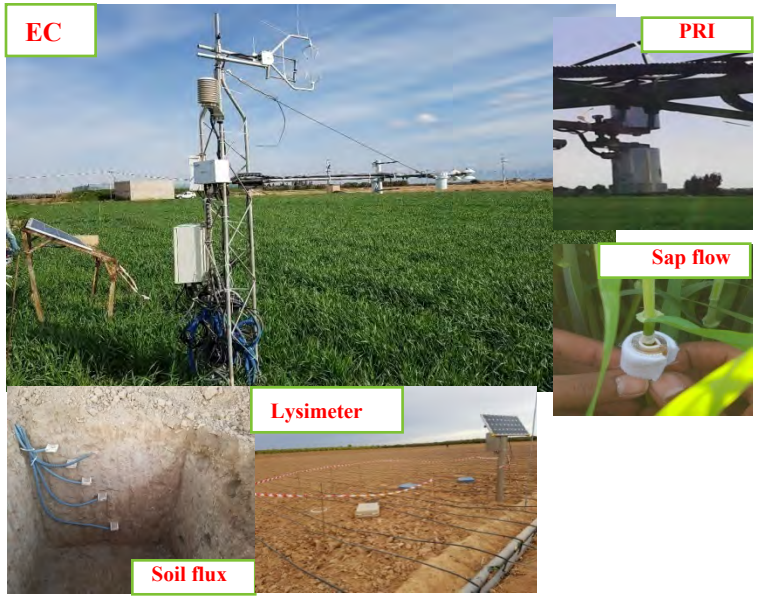
Partitioning E/T and Crop water stress

Partitioning E/T:
comparison/complementary between different sensors monitoring the surface water balance terms with various spatio-temporal resolutions,



➢ **Crop water stress**: measurement and characterization.

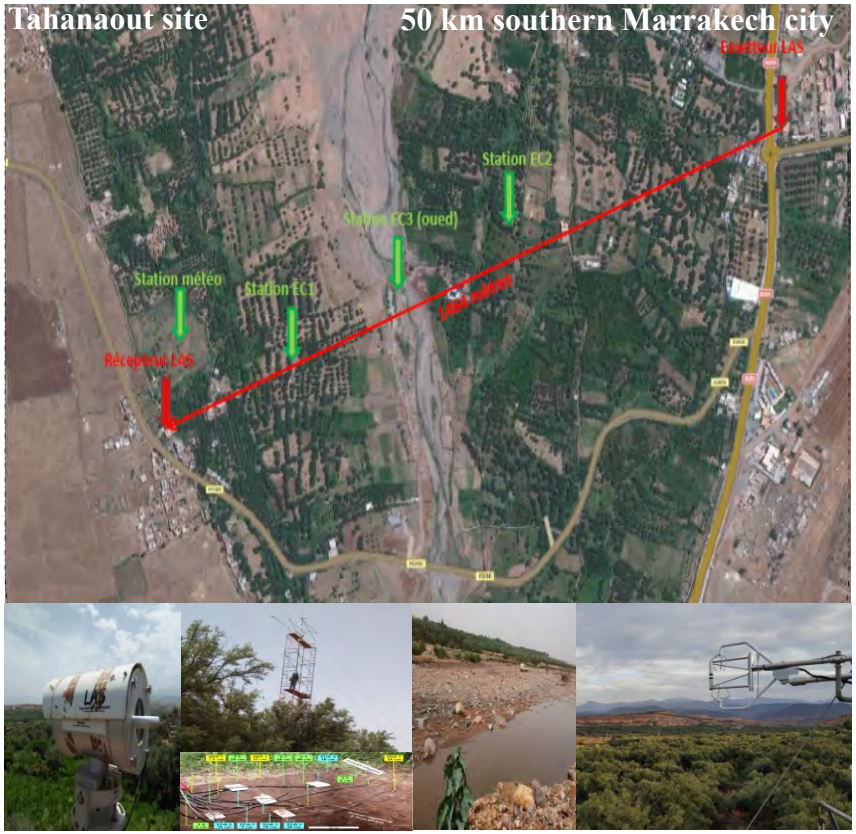
Measurement on stressed and non-stressed wheat :(2 EC, 3 smart lysimeters, sap flow systems, fluorimeter, PRI, gas chambers, porometer) + LAI, biomass, vegetation and soil water content ...



Thesis: Zoubair Rafi

Hydrological functioning of the foot-mountain zone (2017-date)

- Evaluation of the ETR over the practiced heterogeneous covers,
- Extension of SAMIR Software,
- Estimation of deep percolation with water balance (groundwater recharge).



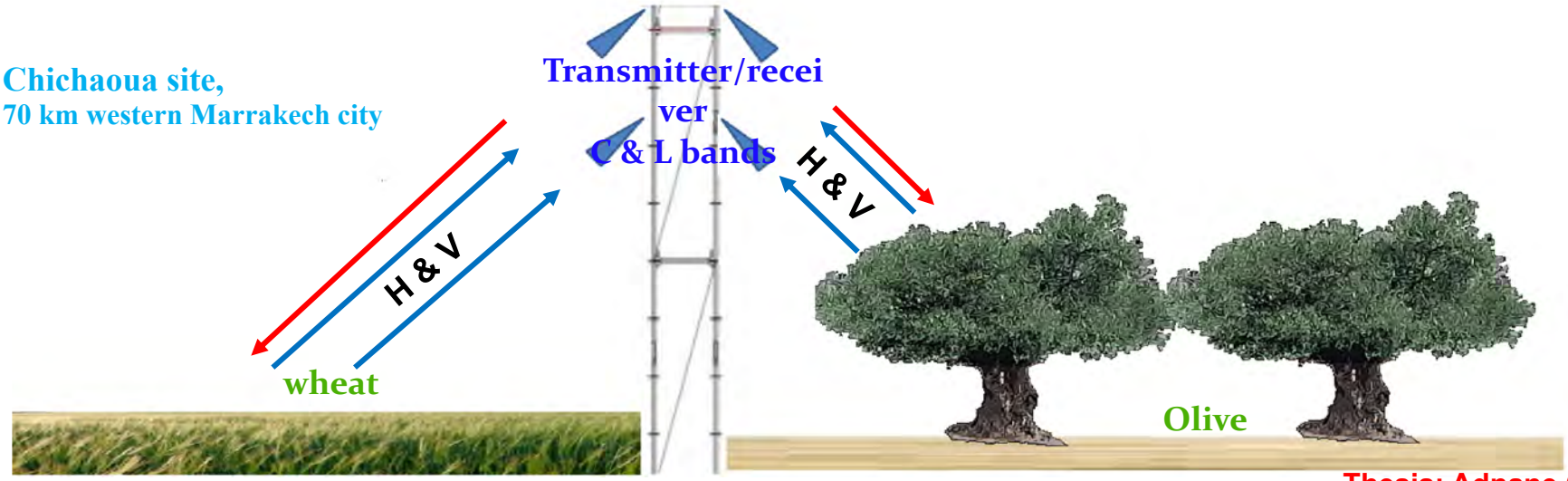
1 LAS (1.6km transect), 2 completes EC, 1 meteo station + OS, LAI

Thesis: Jamal Elfarekh

Observations des Cultures par Télédétection radAR

MOCTAR experiment (sentinel-1 mission): (2019-2022)

- Improve our understanding of the radar signal (C and L bands) on annual and perennial crops,
- Provide the key variables (biomass, soil moisture content) for monitoring evapotranspiration,
- Study the potential of Sentinel-1 data to monitor the crop water stress,
- Assessment of the complementary between the radar data (C and L bands) and optical data for piloting the crop models.



Thesis: Adnane Chakir

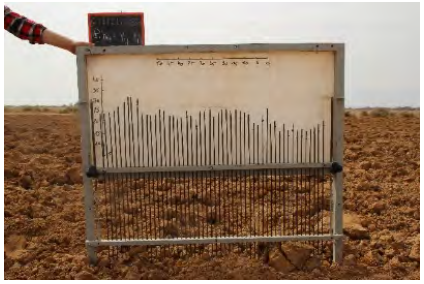
Surface soil moisture retreiving

By using the machine Learning, backscattering models and the interferometric coherence

Chichaoua Site: data from 2016-date

Wheat measurement

- Biomass
- LAI
- Height
- Canopy cover



Soil Measurement

- Surface soil moisture
- Surface roughness (needle-profilometer)

Meteorological data

- Rainfall
- Temperture

HDR: Jamal Ezzahar

Task 2.1. Water and chemical fluxes (leader CERTE)

UNICA Contribution

Dipartimento di Ingegneria Civile , Ambientale e Architettura

Università di Cagliari, Italy

PI: ***Nicola Montaldo***

Giulio Vignoli, Roberto Corona, Serena Sirigu, Alessandro Seoni, Antonio Mascia, Andrea Saba

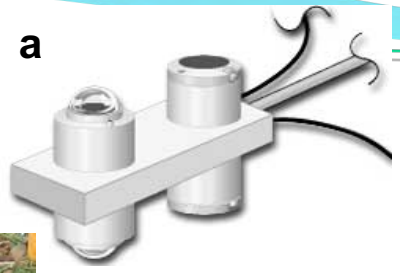
Orroli site (monitored from May 2003…)

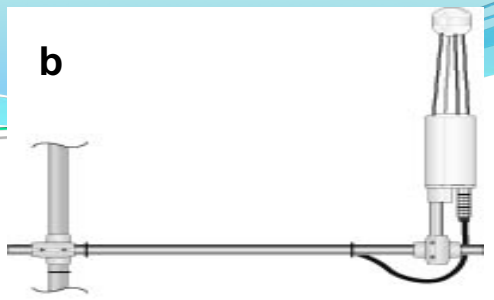
[Detto et al., WRR, 2006; Montaldo et al., HESS, 2008 – WRR, 2013]

Micro-metereological tower's instruments

a) CNR1 Radiometer

b) Li-7500 Gas Analizer





c) CSAT3 Sonic Anemometer

d) Soil h

Da al.
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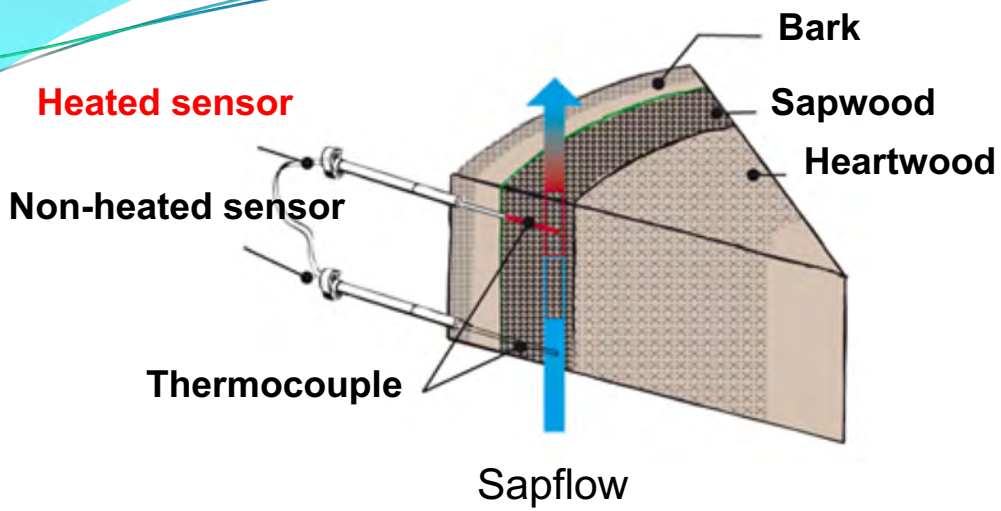
20

ET estimate: Sap flow sensor based method



Sapflow

Sap flow calculation (***Granier, 19***)

$$J_s = 0.714 \times \left(\frac{\Delta T_{\max}}{\Delta T} - 1 \right)^{1.231}$$

ΔT_{max}: maximum temperature difference measured at night time

ΔT : temperature difference

Sapwood area

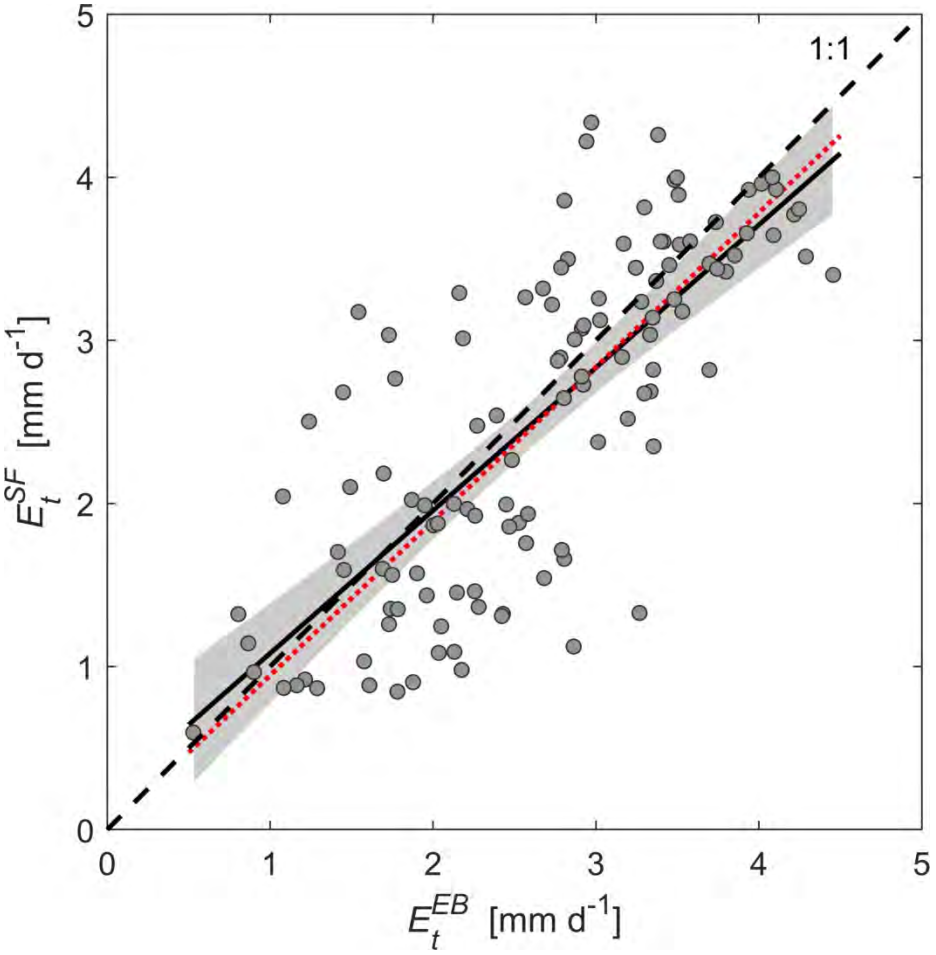
Transpiration at tree scal

$$T = J_s \left[\frac{mm}{\min} \right] \times \frac{A_{sw} \left[m^2 \right]}{A_g \left[m^2 \right]}$$

A_{sw} sapwood area

A_g: ground area

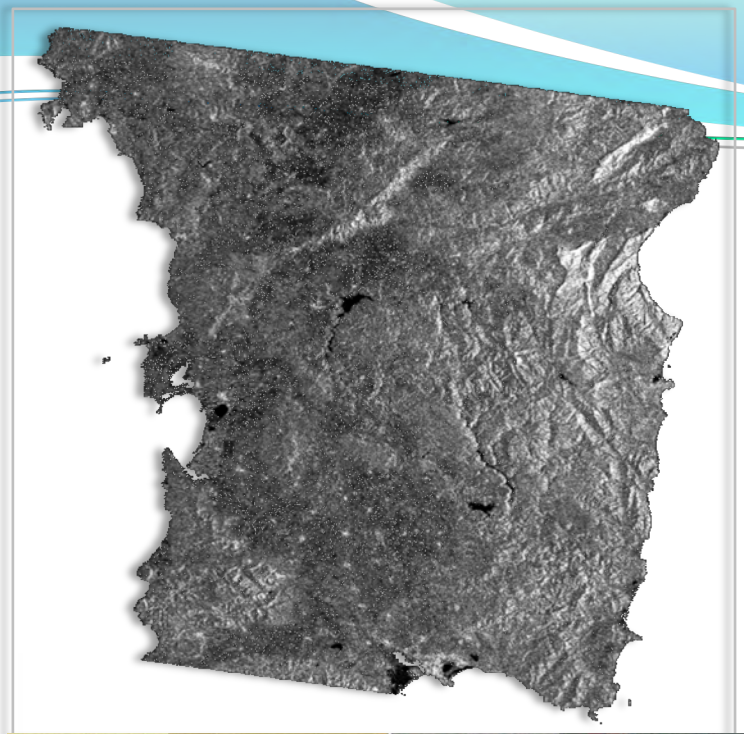
Comparison between transpiration from sapflow sensors and transpiration from energy balance using the thermal infrared sensors

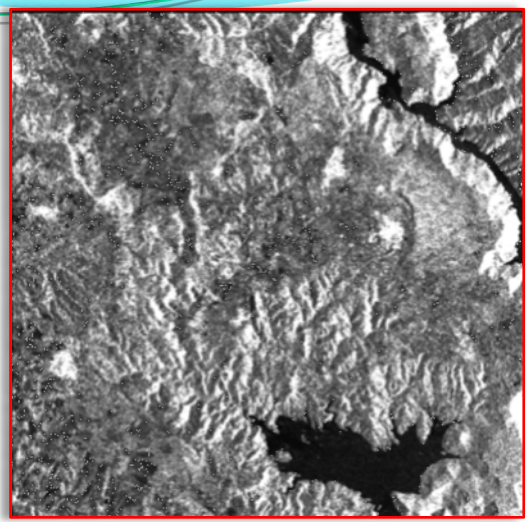


Montaldo et al. (Agricultural and Forest meteorology, 2020)

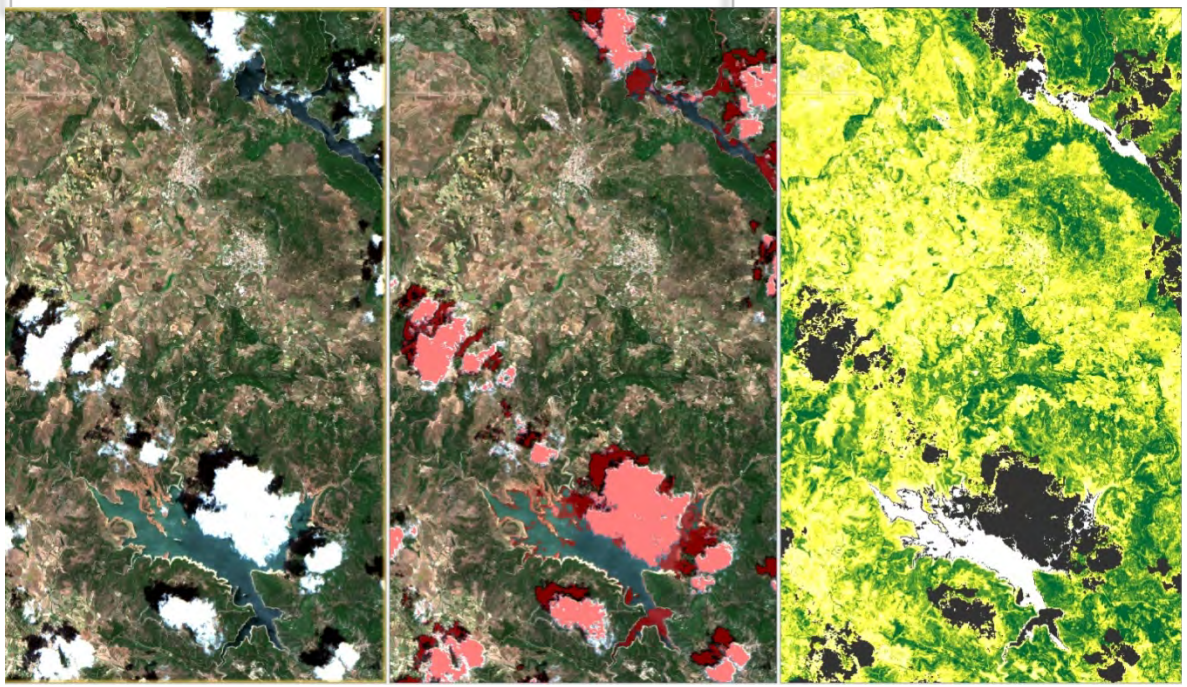
Remote sensing

Radar
Sentinel 1



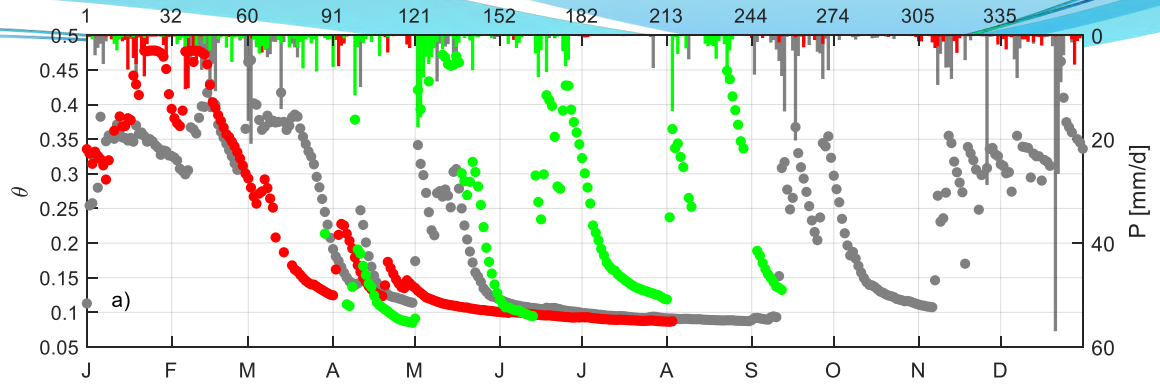


Sentinel 2



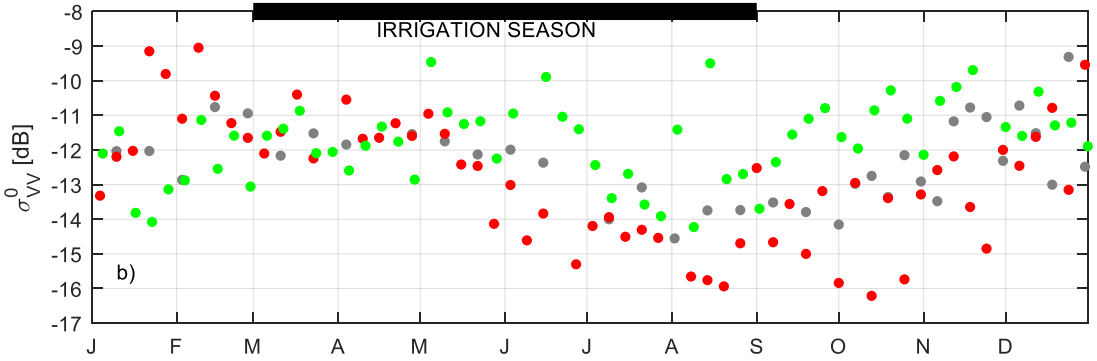
Orroli site
Remote sensing

Observed Soil moisture

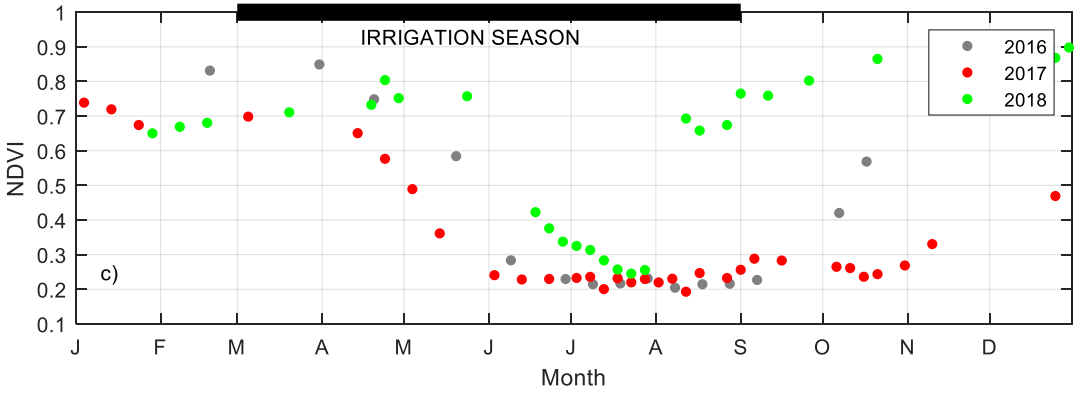


From Sentinel 1

Radar backscatter signal in VV pol.

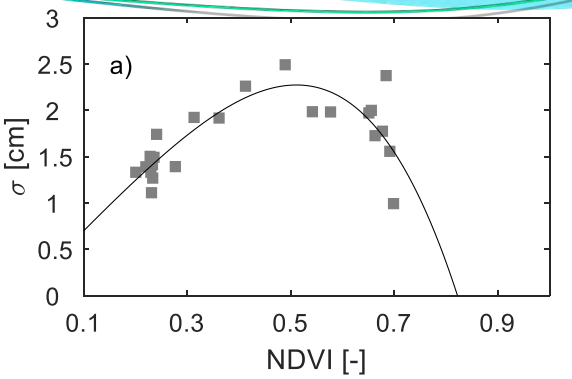


From Sentinel 2

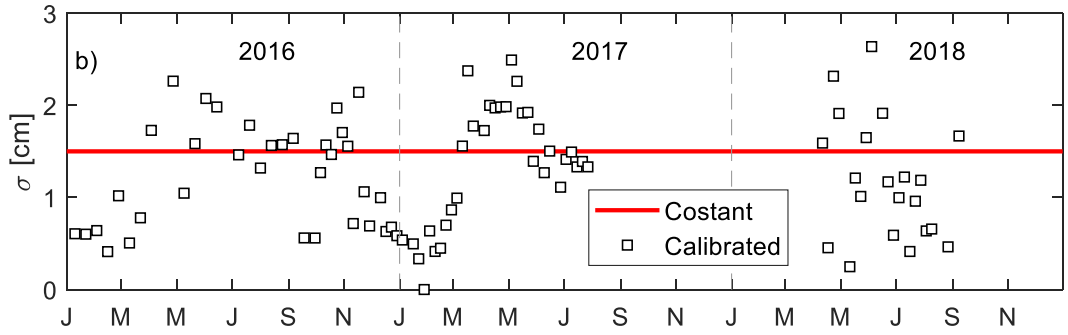


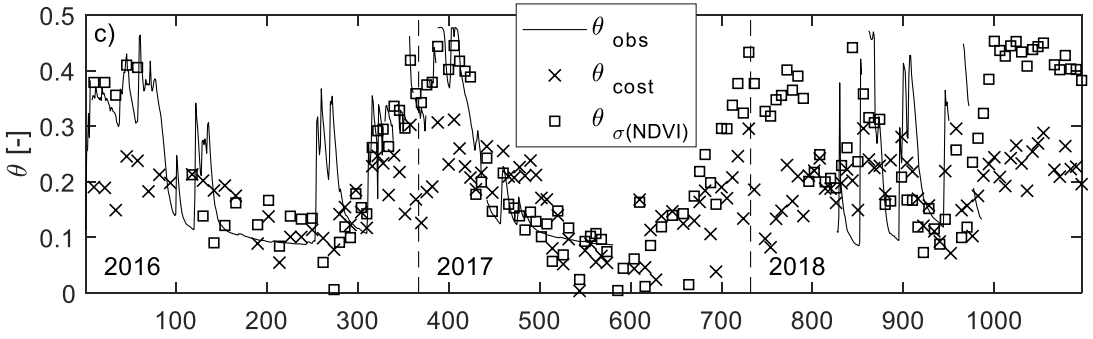
Orroli site

Surface roughness



A revised Dubois et al. (1995) method for soil moisture estimate using multi-temporal Sentinel 1 images





2.1.2.Dam - aquifer transfers and upstream - downstream surface / subsurface transfers

Targets: dam water budget and underlying leaks towards aquifer; subsurface flows and soil hydrodynamics for slopping terrains that link mountains to lowlands.

- Methodological innovations: joint use of:

(1) water budget calculation from hydrometric measurements (surface and subsurface inputs, water uses) and climate forcing data (rain, evaporation),

(2) piezometric network data,

(3) isotopic (stable δ18O and δ 2H) and geochemical tracing, and

(4) geophysical measurements from WP1.

Partners: CERTE, LISAH, CNRS-L, UCAM, CESBIO, UNICA.

Study areas: Cap Bon, Tensift, Litani.

CESBIO Contribution

- Dam - aquifer transfers and upstream - downstream surface / subsurface transfers.
  - –Tensift: water budget calculation from hydrometric measurements (surface and subsurface inputs, water uses) and climate forcing data (rain, evaporation), piezometric network data
    - ➢VI contract

LISAH, Contribution

Monitoring lake - aquifer water fluxes / LISAH

Objectives: monitoring lake - aquifer exchanges.

Method: joint use of hydrometeorological data, piezometric data, isotopic measurements

Means

- ongoing protocol within OMERE observatory

Monitoring lake - aquifer water fluxes / LISAH

Partnership

- INRGREF (OMERE observatory)

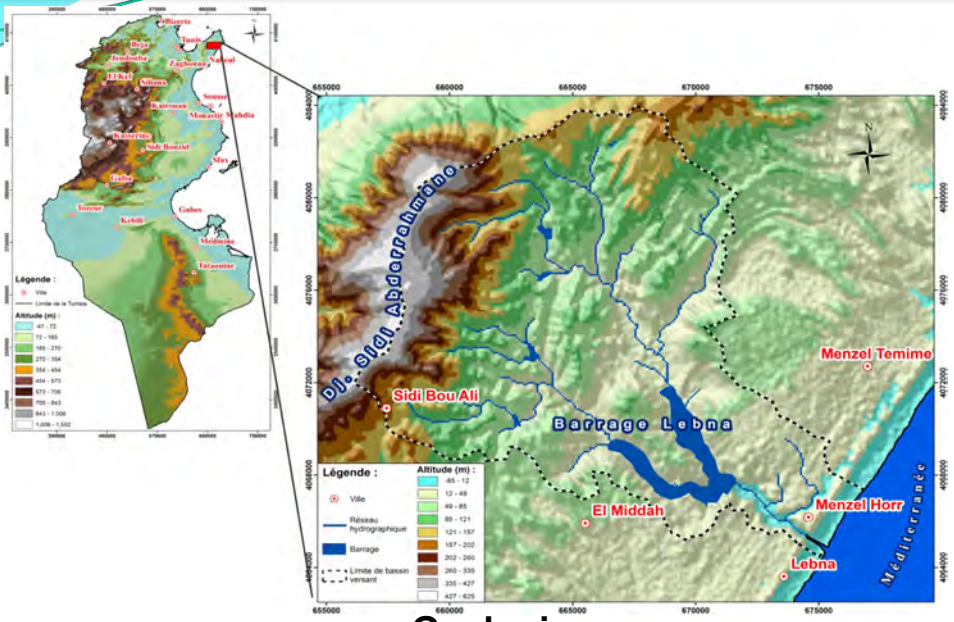
Roadmap

- Most data are automatically collected, processed, and quality checked. To be discussed with OMERE people

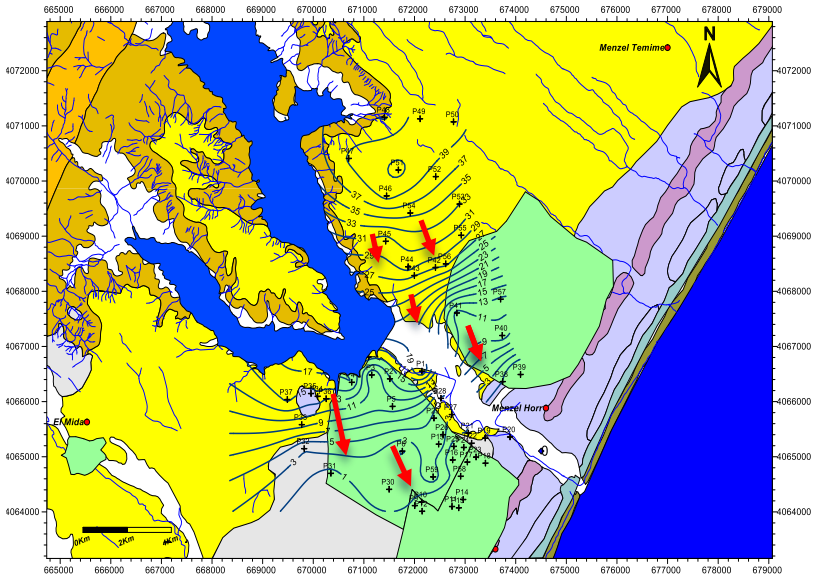
Difficulties

See also works on dam - aquifer with CERTE

CERTE, Contribution: Lebna dam - aquifer transfers and upstream



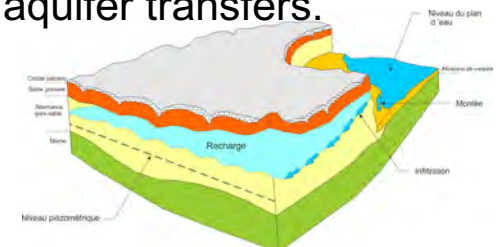
Geologique map



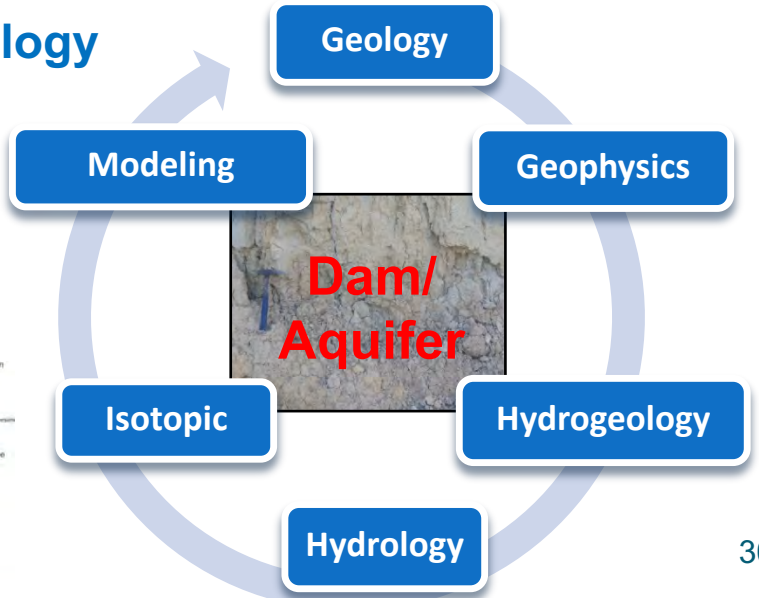
Piezometric map, Lebna (February 2019)

Goals

- Is the dam participate in the aquifer recharge?
- Characterize the dam leakage
- study the relationships: surface water / groundwater and Dam / Aquifer.
- odeling the Lebna Dam - aquifer transfers.



Methodology



Aquifer piezometric monitoring

Goals: piezometric evolution in relation with dam reservoir

Team: **PhD** (N Ouhichi), F Lachaal, O Grünberger, R Hamdi, and C Leduc,

Period: 2019-2021

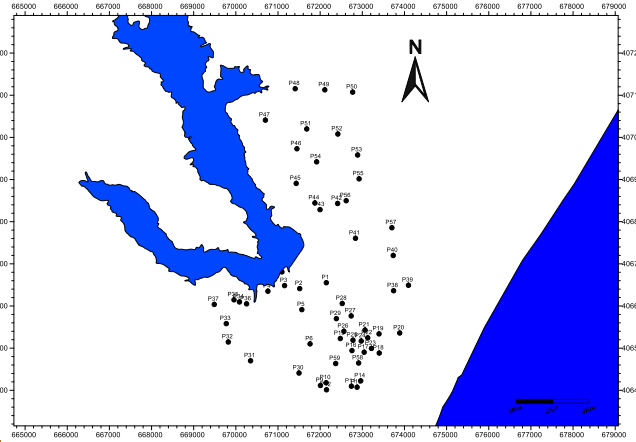
Methodology

1. Piezometric monitoring (59 wells);
2. Installation of 13 CTD-Divers;
3. Installation of the three piezometers;
4. Topographic leveling;
5. Isotope sampling and analysis (68 samples).

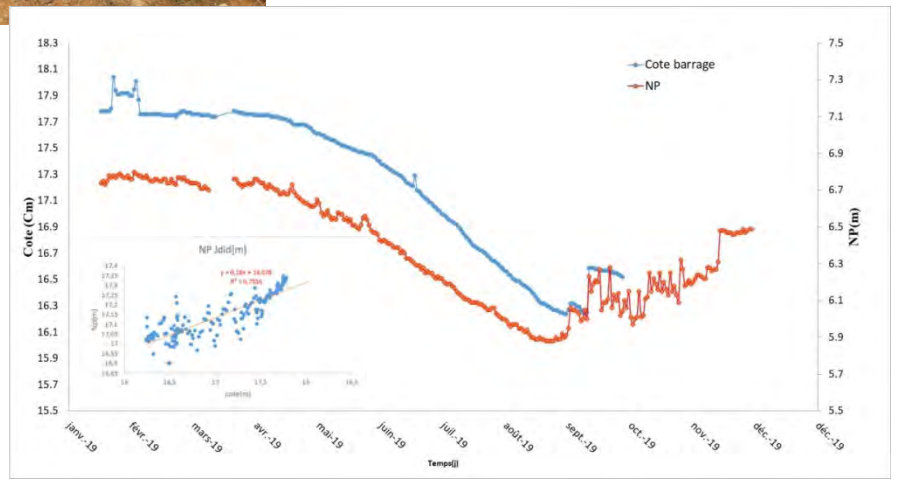
Partnership: LISAH

Project: LMI-NAILA

Aquifer recharge, LGR, CERTE

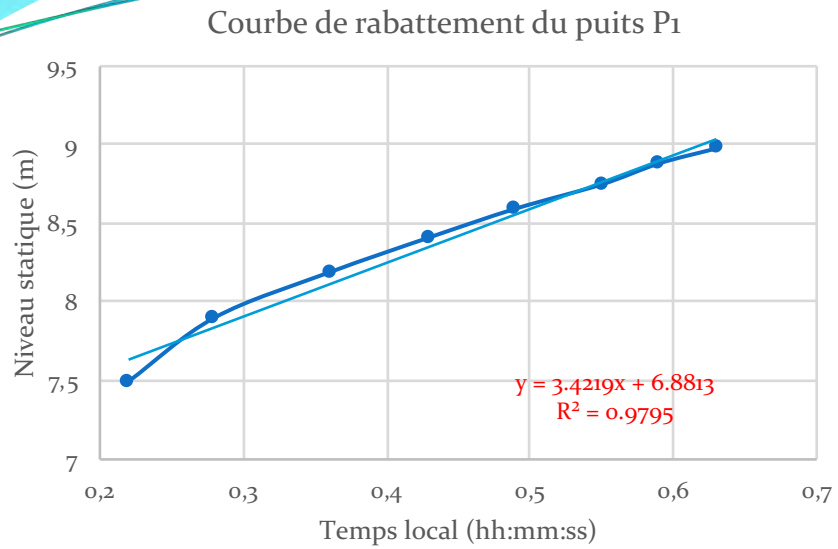


Piezometric monitoring well positions: 59 wells

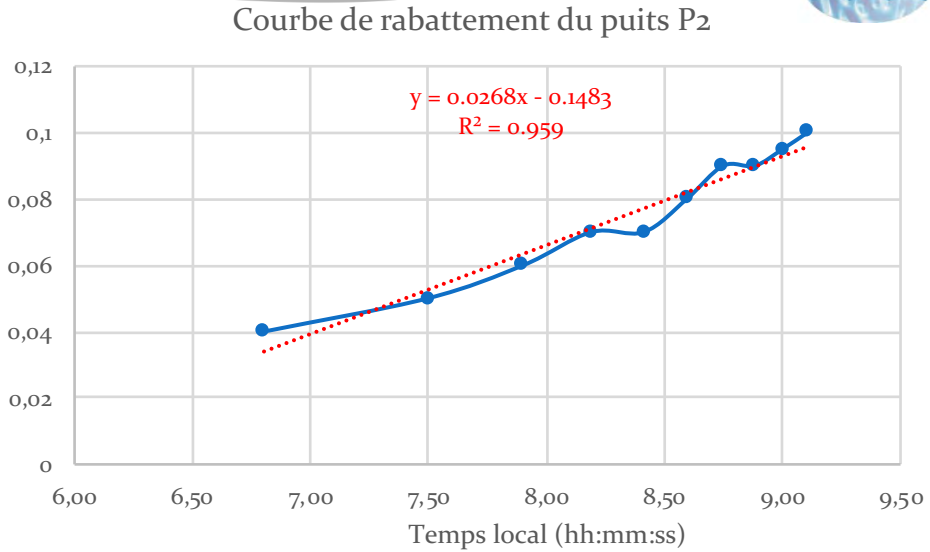


Correlation (NP well 1, water in the bam)

14 Pumping tests: downstream of Lebna dam: 10 wells and 6 piezometers



T(m2/S)	T(m2/J)	
5.21265E-05	4.50372738	Low



T(m2/s)	T(m2/j)	
0.00665566	575.048683	High transmissivity

Isotopic method

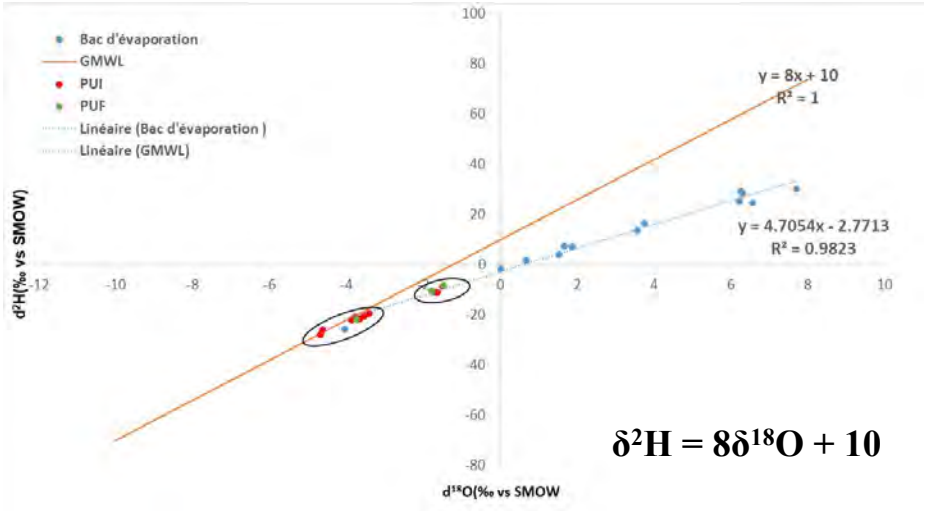
Goals: study the relationships: surface water / groundwater and Dam / Aquifer

Team: **PhD** (N Ouhichi), F Lachaal, O Grünberger, R Hamdi, and C Leduc,

Period: 2019-2021

Methodology

isotopic (stable $\delta^{18}O$ and $\delta\ ^{2}H$) and geochemical tracing (EC, Salinity)
sampling: River, Dam and Aquifer



$d^{18}O/d^{2}H$ diagram of samples investigated in Lebna region as compared to the global meteoric water line (GMWL) and Local meteoric water line (LMWL).

Partnership: LISAH

Project: LMI-NAILA

Aquifer recharge, LGR, CERTE

- Evaporation ligne: **$\delta^{2}H = 4{,}705\delta^{18}O + 2{,}7723$**

Group 1: presents a significant correlation with the GMWL,
Group 2: is placed below the GMWL.

Geophysical measurements From WP 1

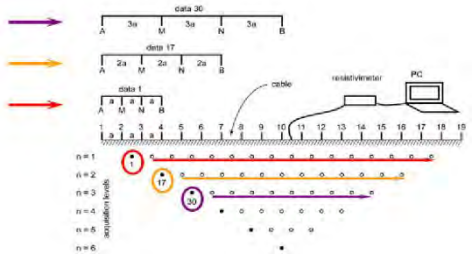
Goals: Aquifer Geometry + localisation of dam leakage

Methodology

69 SEV and 14 TRE profiles;

Team: **PhD** (N Ouhichi), F Lachaal, O Grünberger, R Hamdi, and C Leduc,

Period: 2019-2021



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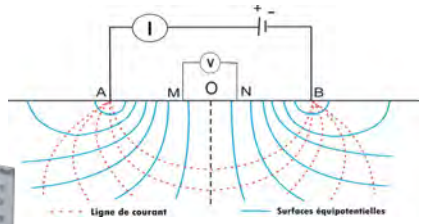
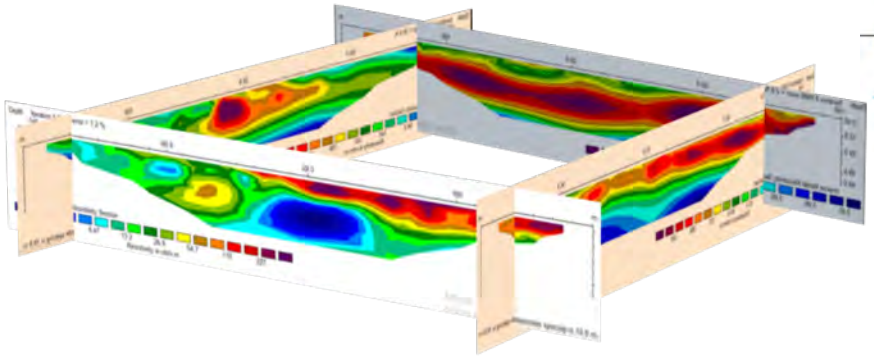
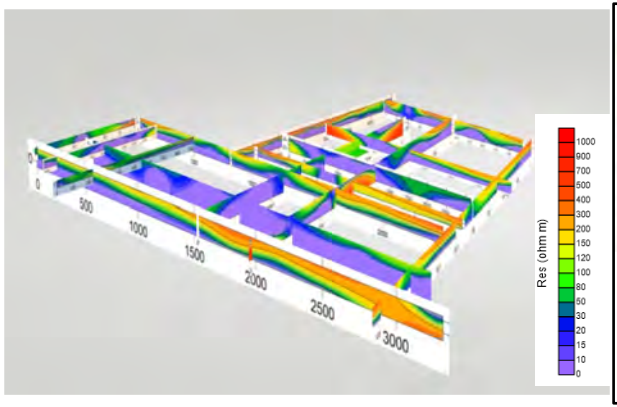
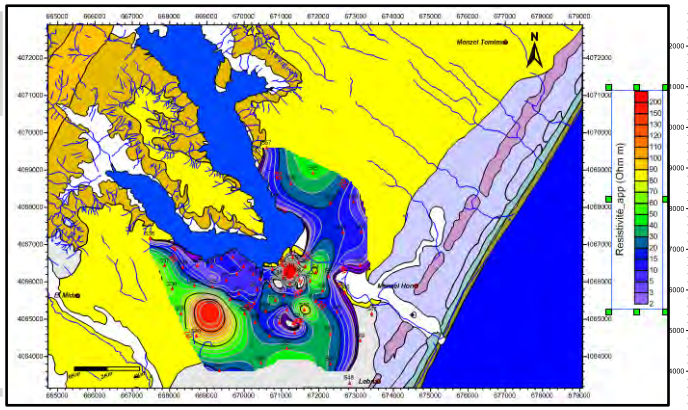


Dispositif : Schlumberger







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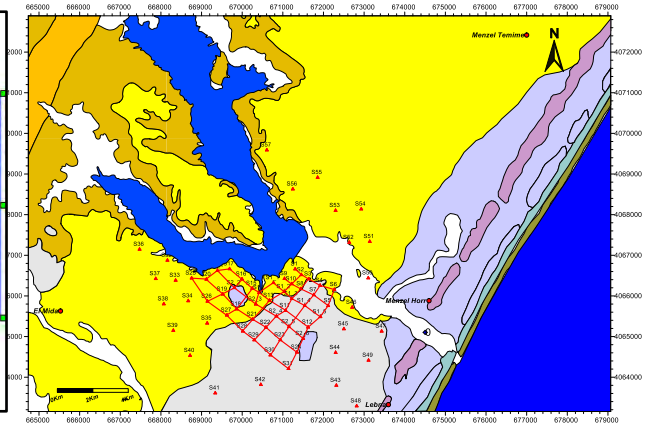


Positions of the 69 vertical electrical soundin

ALTOS KoF meeting

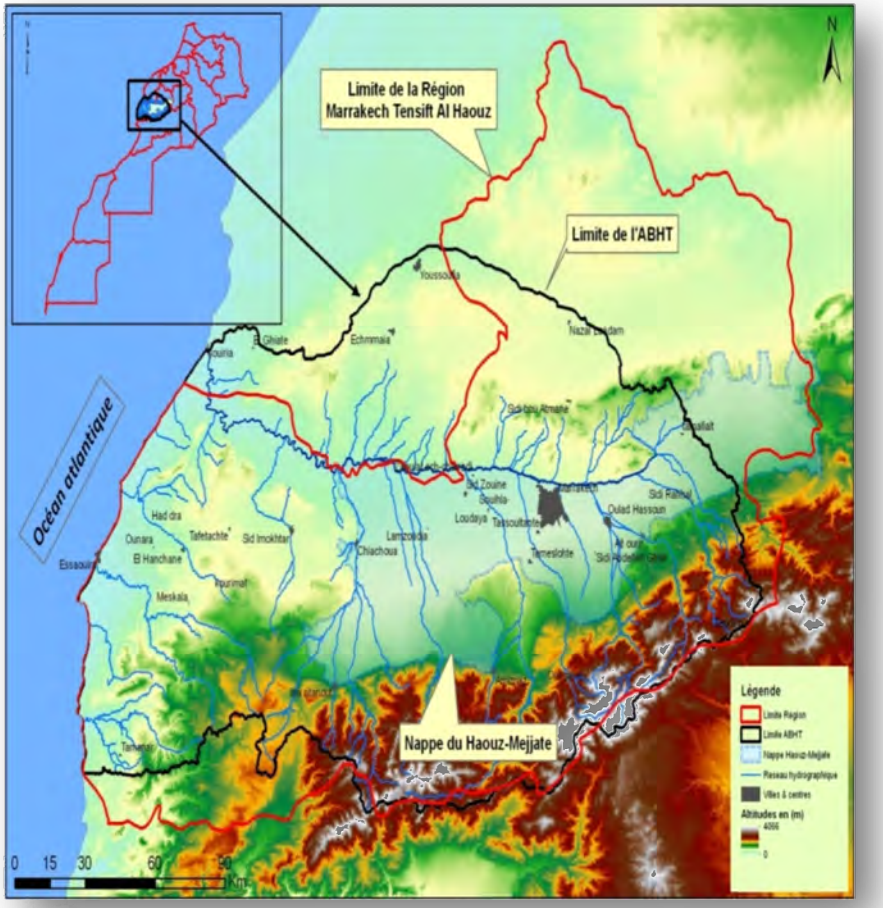
- Cadi Ayyad University UCA -

Tensift Site

WP2

April 20-21, 2020

GROUNDWATER RECHARGE IN THE HAOUZ-TENSIFT BASIN



Objectives:

- Identification and characterization of groundwater recharge sources.
- Quantification of exchanged fluxes between surface water and groundwater.

Tools :

- Hydrochemistry, isotopes and modeling

PHD: XXXXXX

Snowmelt contribution to surface water and groundwater recharge resources

Methodology:

Isotope studies of the Atlas mountain snow.

The main goals:

- This project seeks to test the main hypothesis that determines the isotopic signal of rainfall, snowmelt, surface and groundwater at the watershed scale and develops an improved methodology to quantify the contribution of snow cover on water cycle at the basin scale,
- Integrating the north and south sides of the atlas series (both high and middle atlas), and sampling on many seasons.
- Integrating hydro-isotopic modelisation to quantify the recharge and having a clear idea of underground water resources,
- The velocity water transfer from upstream to downstream ought to be evaluated through two physico-chemical dating tools (Tritium measurements and Anthropic gases (Ccs, HCFCs, SF6))

PHD: XXXXXX

Snow sublimation and soil evaporation on the High Atlas mountain

The main goals:

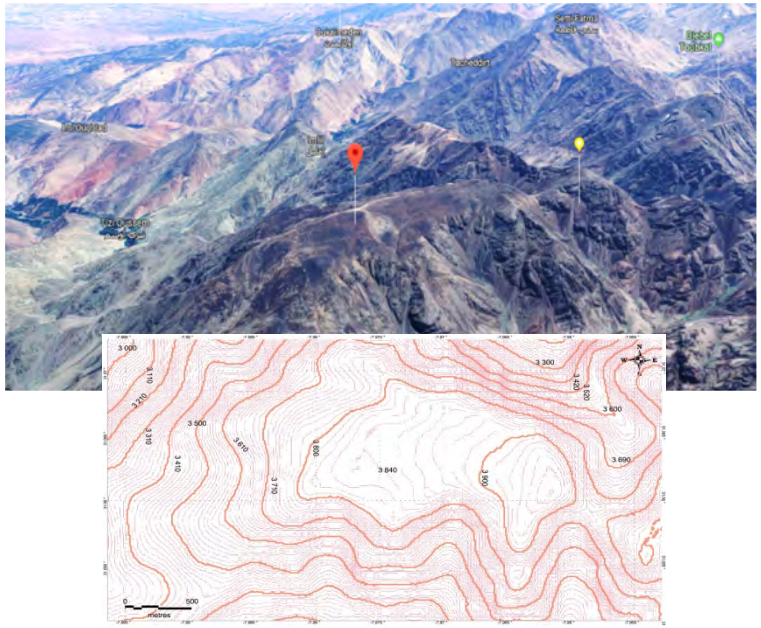
to better control the **water balance of mountain watersheds** and therefore the water resources supplying the Haouz plain.

Snow evaporation=?

Mountain soil evaporation=?

Methodology:

The experimental protocol consists of the installation of an **Eddy covariance system** and a device based on radio modems for data transmission on the **summit of Jbel Tazaghart (3850 m)** located in Toubkal park (*since summer 2020*).



PHD: XXXXXX

2.1.3. Chemical pollutants: hydrological fluxes and retention processes.

Targets: chemical flows within surface water flows, reservoirs, soils, aquifers.

Methodological innovations: sampling protocols designed according to agricultural practices (WP1) and during hydrological events, joint use of in-situ soil passive samplers and laboratory soil column experiments.

Partners: INAT, LISAH, CNRS-L.

Study areas: Cap Bon, Litani.

LISAH Contribution

Monitoring chemical pollutants / LISAH

Objectives: observing chemical content within surface and subsurface water fluxes, surface reservoirs and soils

Method: (1) in-situ experiments with passive samplers within soils, (2) laboratory experiment with soil column devices to determine adsorption characteristics.

Monitoring chemical pollutants / LISAH

Means

- 1 ongoing PhD (CHAAMS).
- 1 forthcoming PhD (ALTOS granted)
- Former and ongoing experiments (1) within OMERE observatory / Lebna watershed and Korba irrigated perimeters and (2) within LISAH / ENIT based laboratory (LHYGES contribution)
- Soil hydrodynamic parameters from former experiments

Partnership

- INAT

Roadmap

- Ongoing data collection within upstream rainfed area
- Forthcoming data collection on downstream Korba irrigated perimeters
- Forthcoming soil column experiments on irrigated soils (salinity constraint)
- Forthcoming stage is data processing including quality check.
- Further stage is database setup and metadata for ALTOS web site (PM)

Difficulties

- Cost of chemical analysis