GEO Joint Experiment for Crop Assessment and Monitoring (JECAM):

Template for Research Progress Report

Date: 06/02/2017

JECAM Test Site Name: **Tensift**

Team Leader and Members: Co-leaders Vincent Simonneaux and Said Khabba

Other members Salah Er-Raki, Lionel Jarlan, Jamal Ezzahar, Younes Fakir, Olivier Merlin

Use of Information

In addition to the report we would also like to use the information and images you provide to update the jecam.org website. Do you agree to this use of your information?

Yes

1 Project Objectives

Have the original objectives for your site changed?
No

Please briefly describe the areas that you are working on from the list below (i.e. topic, general methods, intended operational outcome, if any):

- Crop identification and Crop Area Estimation

Landcover maps at medium scale resolution from NDVI time series using either a thresholding algorithm, or off the shelf algorithm for supervised classifications.

- Crop Condition/Stress

Methodological developments for the estimation and monitoring of crop parameters with multi-sensor, multi-spectral remote sensing of surfaces. Evapotranspiration from thermal infrared (energy budget approach), microwave (complementary to energy budget approach) and visible/shortwave data (FAO-56 coupled with NDVI time series). A PhD is actually working on remote sensing water stress detection.

- Soil Moisture

High resolution surface (0-5 cm) soil moisture, by disaggregation of SMOS satellite measurements based on thermal and visible MODIS/Landsat data (Merlin et al. 2013; Malbéteau et al. 2017b; Stefan et al. 2017) and/or Sentinel-1 radar data.

- Yield Prediction and Forecasting

A PhD thesis is working on the Forecasting of Wheat Yield at the plot level using empirical relations linking yield with remote sensing data, or using efficiency models (Monteith like).

- Crop Residue, Tillage and Crop Cover Mapping

No

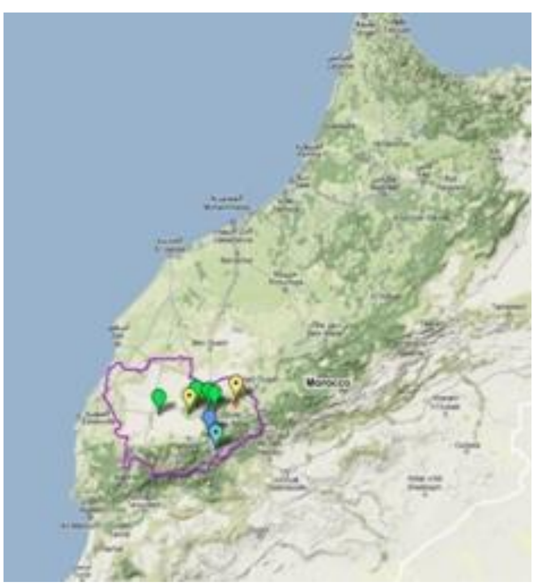
- Others?

The team has also as main objective the hydrological modelling of the whole Tensift watershed, including the mountainous part providing most of the water (with a significant fraction as snow) and the irrigated agricultural plain. In this frame, we are developing a modelling plateform by satellite and ground observations to predict the evolution of resources under human pressure and climate changes. We especially compare various approaches of evapotranspiration estimate with contrasted level of complexity and their application for irrigation management, and intend to assimilate various satellite products (VIS, SAR, TIR) to improve model functioning.

Another objective is the production of bio-physical indicators at regional level using remote sensing data (drought, soil moisture, yield, etc.). This axis includes the study of inter-annual variability and the predictability of parameters.

2 Site Description

- Location



The watershed is located in the Tensift region of Marrakech in Morocco (Figure 1). Covering an area of about 20,000 km ².

- Topography

It is composed of two main hydrological parts. South of the basin, the high Atlas peaks at over 4,000 m.a.s.l., those mountains are the water tower of the Haouz plain. In the center, a vast plain (450 m.a.s.l.) is occupied by rainfed and irrigated agriculture. In the north, the small chain of arid mountains "Jbilets" has, in the present state of knowledge, little influence on the hydrological cycle in the region.

- Soils

Loam to Clay Loam soils

- Drainage class/irrigation

Drainage is correct, non hydromorphy reported.

Traditionnal irrigation is mainly gravity, but drip is rapidly spreading

- Crop calendar

Winter wheat (between december and may) occupies 80% of the acreage followed by olive trees occupy about 13% of the plain, the remaining area being occupied by citrus, apricot, market gardens, vineyards, fodder. These proportions change significantly in the irrigated area where tree crops dominate. Market gardening is developing and is mainly encountered between april and October

- Field size

High variability, depending on history of the sites. Tradionnal areas with small plots (0,25 ha), modern one 4 ha plots

- Climate and weather

Plain is characterized by a semi-arid climate (rainfall 250 mm / year, ET0 is about 1600 mm/year). The mountains receive between 300 and 700 mm precipitation, ET0 is about 1000 mm/year.

- Agricultural methods used

The main irrigated areas (2000 km ^{2}) are located in the central and eastern part of the Haouz plain and rainfed cereals is practiced on the rest of the plain.

Two observation sub-sites are considered for JECAM:

- The R3 sector is a 3000 ha area with flood irrigation on demand located 40 km east of Marrakech. The main crop is Winter Wheat. Olive trees represent less than 20% of the cultivated area. Soil texture is mainly Clay Loam. The growing season of winter wheat is December-May, and Olive grove is evergreen with latency during the summer. The whole site have been under study since 2002 and benefited from several remote sensing campaigns with optical (SPOT, Landsat, Formosat), thermal (Aster, Landsat), and radar (ASAR) satellite time series.

- The Agafay plantation is a mandarin orchard located 20 km east of Marrakech which extends on 500 ha. The plantation benefits from drip irrigation. Soil texture is loam, mandarins trees are evergreen with latency during the summer. The site is monitored since 2006 with an eddy covariance system, soil temperature and humidity sensors, fluxmeters. Sapflow measurements for separation of evaporation and transpiration have been carried on.

A picture of a wheat field in the Haouz plain of Marrakech, with the High Atlas Mountain in the back.

3 Earth Observation (EO) Data Received/Used

For each Mission/sensor:

- *Space agency or Supplier*
- *Optical/SAR*
- *Number of scenes*
- *Range of dates*
- *Beam modes/ incidence angles/ spatial resolutions*
- *Processing level*
- *Challenges, if any, in ordering and acquiring the data*
- *Challenges, if any, in processing and using the data*
- *Please provide sample pictures of the imagery provided*

We have not received any EO through JECAM. The EO images since 2002 are:

	Supplier	Optical/SAR	Number of scenes	Range of dates	Processing level	Challenge ordering	Challenge Using
SMOS	CATDS	Passive Microwave (L-band)	>100	2002 onwards	L3	none	Spatial resolution
MODIS	LPDAAC	Optical	>100	2002 onwards	L2-L3	none	none
Landsat 7	USGS	Optical (shortwave infrared reflectances and TIR brightness temperature)	> 100	Since launch onwards	Surface reflectances and brightness temperatures	none	TIR data require atmospheric corrections (depending on applications)
Landsat 8	USGS	Optical (shortwave infrared reflectances and TIR brightness temperature)	> 100	Since launch onwards	Surface reflectances and brightness temperatures	none	TIR data require atmospheric corrections (depending on applications)
SPOT 5-Take5	CNES	VIS-NIR	53	April-sept 2015	TOC reflectance	Call for submission	Not yet

experiment							
Sentinel-1	ESA	SAR	>100	2014 onwards	L1B	none	Soil moisture retrieval
Sentinel-2	ESA	VIS-NIR	10	Since dec 2015	ESA download, => no atmospher corrections	We are waiting for processed images from THEIA	

4 In situ Data

Describe the in situ data collected, with methods and challenges, if any. For communication purposes, please provide photographs of site work if available.

The team has installed an observatory running since 2002 (http://www.cesbio.ups-tlse.fr/fr/sudmed/sites_ateliers_maroc.html) which is collecting basically meteorological data (rainfall, wind speed, T, Rg) for about ten permanent stations, and additionally some fluxes experiments measuring especially ET using eddy correlation, soil moisture). These flux measurements are done each year on some annual crops (wheat) or during several years on permanent land cover (trees, rainfed wheat).

Chichaoua'17 experiment

For the 2016-2017 season, and experiment comparing drip and traditional gravity irrigated wheat was installed including a lysimeter to monitor soil percolation. The objective is to evaluate the water budget and associated (irrigation, evaporation, transpiration, drainage) fluxes of two 1.5 ha drip-irrigated wheat fields, one field being irrigated according to the water needs estimated by the FAO method and the other field being irrigated exactly the same way except during controlled stress periods when irrigation is cut. Station-based instrumentation includes eddy covariance towers, radiometers in various spectral bands, lysimeters and ground heat flux, sap flow and soil moisture/potential/temperature sensors. The response of wheat to various levels of water availability is also characterized by manual measurements of carbon and water fluxes using a canopy chamber, and at leaf scale the water potential, stomatal conductance, chlorophyll content and fluorescence.

Thanks to this dataset, we want to analyze the link between Photochemical Reflectance Index (PRI) and the Light Use Efficiency (LUE) at canopy scale on wheat grown under different water regimes (irrigated or rainfed). The Photochemical Reflectance Index (PRI) is based on the short term reversible xanthophylls pigment changes accompanying plant stress and therefore of the associated photosynthetic activities. Strong relationships between PRI and LUE were shown at leaf and canopy scales and over a wide range of species (Garbulsky et al., 2011). But very few previous works have explored the potential link with plant water status. In this context, we investigate the daily and seasonal dynamics of PRI; linking its variations to meteorological factors (global radiation and sun angle effects, soil water content, relative air humidity …) and plant processes. We explore relationships between PRI and sapflow measurements (i.e. transpiration rate) to evaluate the potential of this index to detect and monitor a moderate plant water stress.

The experiment on winter wheat for the 2016-2017 season, including eddy correlation (right) and lysimeter (left).

The Sidi Rahal monitoring station was set up in a rainfed wheat field in December 2013. Due to an unusual lack of precipitation late 2015, the winter wheat crop had not been planted during the 2015-2016 season. As a result, the crop field remained in bare soil conditions from January to September 2016. This unique “bare soil” data set is being used to test new radar-based retrieval approaches of surface soil moisture and new formulations of soil evaporation.

Tahanaout experiment

A 1.4 km scintillometer transect has been running for one year on traditional agriculture areas (including mainly olive trees and annual crops (wheat mainly) in the Haouz plain at the outlet of the high Atlas mountains. To complement this set-up and especially test aggregation of fluxes over heterogeneous surfaces, two eddy correlation towers are currently being installed under this transect.

5 Collaboration

Have you been approached to participate in a collaborative project with other sites?

Yes

If yes, please describe the nature of the collaboration (i.e. Who, objective, brief status).

The International Joint Laboratory TREMA associates several partners from the research and academic sector (University Cady Ayyad of Marrakech, Moroccan Center of Energy and Nuclear Sciences, Moroccan National Meteo Center, French Laboratory CESBIO) as well as decision makers (Basin Agency of the Tensift River, Regional Office of Agriculture). The LMI TREMA works in close collaboration with the “Merguellil team” in Tunisia, which is also a JECAM site (CESBIO and G-EAU labs, Tunisian Institute of Agronomy), and the Agues Segarra-Garrigues in Spain within a H2020 RISE project. The Tensift site is also part of the S2-AGRI project financed by the European Space Agency and will benefit from Sentinel-2 image surface reflectance processing in the frame of a THEIA project (CNES, French Space Center).

6 Results

Describe your key the results, positive and negative.

For communication purposes, please provide some graphic representation(s) of the results.

To what extent have the project objectives been met?

Can this approach be called ‘best practice’?

Have you modified the project objectives? If so, in what way?

Main research axes

Based on a lot of work done by the team since 2002 regarding crop hydrological functioning, the research in 2016 focused on the surface evapotranspiration and soil moisture retrieval (both surface and root zone) using microwave and thermal data, using disaggregation. This type of information is potentially used directly by irrigation managers, and also to feed land surface models.

Besides, work is done on the fractioning between vegetation transpiration and soil evaporation, as a key knowledge to assess crop water use efficiency and to suggest irrigation management improvement.

Also we are still working on yield assessment which is a key variable for decision makers.

6.1 Soil moisture retrieval

Currently, the soil moisture data sets available at global scale have a spatial resolution much coarser than the typical size (several ha) of fields. Especially, the soil moisture retrieved from passive microwave observations such as C-band AMSR-E and L-band SMOS data have a spatial resolution of about 60 km and 40 km, respectively. The recent SMAP mission, launched in 2015, ensures continuity of L-band derived soil moisture products with similar resolutions. In this context, downscaling methodologies have been developed to improve the spatial resolution of readily available passive microwave-derived soil moisture data. DISPATCH (DISaggregation based on Physical And Theoretical scale CHange, Merlin et al. 2013) estimates the soil moisture variability within a 40 km resolution SMOS/SMAP pixel at the target 1 km resolution using MODIS data and the target 100 m resolution using Landsat data.

V. Stefan (PhD UPS 2013-2016) improved DISPATCH by integrating a physically-based energy balance model forced by meteorological data available within irrigated perimeters. The approach was validated over the Agues Segarra-Garrigues site in Spain (Stefan et al. 2017).
B. Ait Hssaine (PhD thesis, UCAM/UPS, 201--2018) is working on the retrieval of surface soil moisture at multiple scales by developing synergies between Sentinel-1 radar and 1 km resolution DISPATCH (disaggregated from SMOS using MODIS) data.
Y. Malbéteau (PhD UPS 2013-2016) improved the temporal resolution of DISPATCH data by assimilating the disaggregated soil moisture in a dynamic surface soil water balance model. The approach was tested on a daily basis over the Haouz plain (Malbéteau et al. 2017b). Being based on global scale SMOS, MODIS and ECMWF reanalysis data, it is easily transferable to other semi-arid areas. Moreover, the method has potential for retrieving irrigation amounts at the perimeter scale.
A. Mohamed (PhD isardSAT 2015-2018, seconded to UCAM during 9 months) is developing synergies between 1 km resolution DISPATCH (SMOS disaggregated using MODIS) and Sentinel-1 radar data to derive an enhanced soil moisture product at multiple resolutions.
A. Amazirh (PhD thesis, UCAM/UPS 2016-2018) is developing synergies between Sentinel-1 radar and thermal/optical Landsat-7, 8 data to retrieve the surface soil moisture at high spatio-temporal resolution (crop field scale) without any prior knowledge of soil roughness parameters.

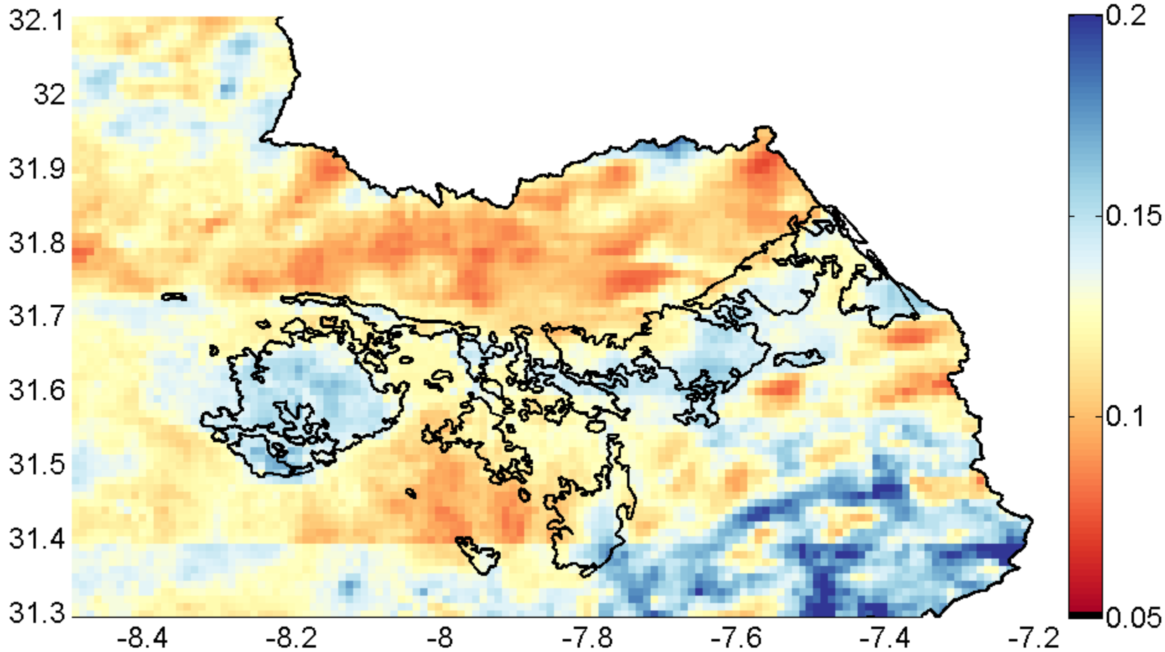


Fig. 8: Image of the mean volumetric soil moisture in 2014 over Tensift Haouz region. Black lines represent the irrigated areas (extracted from Malbéteau et al. 2017b).

6.2 Partition between evaporation and transpiration

The purpose is, beyond the estimates of evapotranspiration, to separate soil evaporation from plant transpiration. This would allow the assessment of irrigation efficiency, considering the objective is to minimize evaporation, and this a major stake in the area were water is scarce.

B. Aït Hssaine (PhD UCAM/UPS 2016-2018) is developing a calibration strategy to integrate both land surface temperature and near-surface soil moisture data in a two-source energy budget model. State-of-the-art evapotranspiration models are generally based on thermal/visible data only and rely on ad hoc assumptions to represent the evaporation/transpiration components. The new approach integrates microwave-derived surface soil moisture as additional constraint on soil evaporation, and subsequently on vegetation water status.

Y. Malbéteau (PhD UPS 2013-2016) developed a method for correcting the remotely sensed land surface temperature for topographic effects. Thermal-based evapotranspiration models could now be applied to hilly and mountainous agricultural areas (Malbéteau et al. 2017a).

L. Olivera (PhD UPS 2016-2019) is investigating different coupling schemes between the FAO-based water budget model and remote sensing data available in the shortwave, thermal infrared and microwave bands to estimate the root zone soil moisture and crop water needs at the daily/field scale.

G. Aouade is combining the isotopic approach (oxygen stable isotopes) and the physically-based modelling of water and energy exchange at the soil-vegetation-atmosphere interface to monitor and predict evapotranspiration partition. She has evaluated, in particular, the domain of validity and the performances of a double energy budget SVAT model recently developed by meteo-france on the main crops of the region based on the Tensift observatory database.

6.3 Stress detection

Z. Rafi (PhD UCAM 2017-2019) is testing the usefulness of (1) thermal, (2) "PRI" shortwaves reflectances (531 nm, 570 nm and between 680-690 nm) and (3) C-band microwave data to characterize the water status of crops. He is also evaluating the complementarity of those wavelengths to better represent the non-stomatal (evaporation) and stomatal (transpiration) fluxes in land surface models.

6.4 Remote sensing for irrigated crops water budget monitoring

A. Diarra evaluated the performance and the domain of validity of the two-source energy balance model (TSEB) for the monitoring of actual evapotranspiration (ET_a) as a first step towards its use for irrigation planning. Secondary objectives are to analyse the evapotranspiration partition between evaporation (E) and transpiration (T) and the ability to detect water stress over irrigated annual crops. Within this context, TSEB was compared to the calibrated FAO-56 dual approach, taken as a reference tool for the monitoring of plant water consumption. TSEB computes ET_a as the residual of a double component energy balance driven by the radiative surface temperature (T_s) used as a proxy of crop hydric conditions; the FAO-56 dual crop coefficient approach uses the Normalized Difference Vegetation Index (NDVI) as a proxy of Basal Crop Coefficient (K_{cb}) and assesses the hydric status directly by solving a two layer soil water budget. Both approaches are evaluated using in situ forcings measured over four plots of wheat and sugar beet located in the Haouz plain (Marrakech, Morocco) that were instrumented with eddy covariance systems during the 2012 and 2013 growing seasons. Both models offer fair performances compared to ET_a observations with Root Mean Square Error (RMSE) lower than 1 mm day^{-1} apart from the FAO-56 dual approach on the sugar beet plot because of uncertain irrigation inputs. This highlights a major weakness of this model when water inputs are uncertain; a very likely case at the plot scale. By contrast, the TSEB model offers smoother performances in all cases. Finally, the partition of ET_a between soil evaporation and plant transpiration is estimated indirectly by confrontation between simulated soil evaporation and surface (0–5 cm) soil moisture acquired spatially with ThetaProbe sensors and taken as a proxy of soil evaporation. TSEB evaporation is well correlated to surface soil moisture (r=0.82) for low Leaf Area Index (LAI) values (<1.5 m^2 m^{-2}). In addition, TSEB predicted partition compares well to snapshot measurements based on the stable isotope method. This in-depth comparison of two simple tools to monitor ET_a leads us to the conclusion that, if thermal images were available at high repetivity (as planned in future High spatial resolution thermal mission), the TSEB model could reasonably be used to map ET_a and possibly for the decision-making process of irrigation scheduling.

Besides the thermal approach, we develop a simple SVAT approach based on NDVI forcing to monitor the crop water budget. The Sat-Irr tool (http://osr-cesbio.ups-tlse.fr/Satirr/) is an on-line software based on the FAO-56 approach aiming to help irrigation scheduling at the plot scale. All the technical processing step (data downloading, image correction, data processing, etc...) are totally transparent to the users. An experiment designed to evaluate the tool in terms of both the quality of irrigation advise and of the way the farmers perceived this new information is actually carried out in the Tensift region. To this objective, about 8 farmers in different irrigated sectors have been trained to the use of Sat-Irr and receive their customized advises of irrigation schedule. Surveys are carried out in parallel to evaluate the difference between what has been scheduled by the tool and what was done by the farmers and also to understand the main reasons of the gaps. In addition, a network of low cost soil moisture sensor has been installed on the monitored fields with the objective of testing the assimilation of soil moisture data to improve the performance of the SatIrr tool.

7 Plans for Next Growing Season

Next growing season, will you maintain your current approach, or modify the approach? If you plan to modify, please describe your new approach.

Do you anticipate ordering the same type/quantity of EO data next year?

Yes, but actually as more imagery should be available through COPERNICUS / THEIA, there is less need to order other ones

If not, what type and quantity of EO data do you plan to acquire?

8 Publications

Please list any publications from your JECAM related research since last year's report (presentations, peer reviewed papers, technical reports, etc).

8.1 Articles

Malbéteau Y., O. Merlin, S. Gascoin, J.P. Gastellu, C. Mattar, L. Olivera-Guerra, S. Khabba, L. Jarlan, Normalizing land surface temperature data for elevation and illumination effects in *mountainous areas: A case study using ASTER data over a steep-sided valley in Morocco, Remote Sensing of Environment, Volume 189, February 2017, Pages 25-39, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2016.11.010.*

Malbéteau Y., O. Merlin, G. Balsamo, S. Er-Raki, S. Khabba, J.P. Walker, L. Jarlan, 2017. Towards a soil moisture product at high spatio-temporal resolution: temporally-interpolated spatially-disaggregated SMOS data based on precipitation. Journal of Hydrometeorology, accepted.

Merlin O., V. Stefan, A. Amazirh, A. Chanzy, E. Ceschia, S. Er-Raki, P. Gentine, T. Tallec, J. Ezzahar, S. Bircher, J. Beringer, S. Khabba: Modeling soil evaporation efficiency in a range of soil and atmospheric conditions using a meta-analysis approach. Water Resources Research, 52, May 2016, pp 3663–3684 2016, http://dx.doi.org/10.1002/2015WR018233.

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Ayyoub, A., Khabba, S., Er-Raki, S., Merlin, O. and Bahlaoui, A. (2017). Calibration and validation of the Penman-Monteith model for estimating evapotranspiration of an orange orchard in semi-arid region. Acta Hortic. 1150, 15-22. https://doi.org/10.17660/ActaHortic.2017.1150.3

Nassah, H., Er-Raki, S., Khabba, S., Fakir, Y., Ezzahar, J., Hanich, L. and Merlin, O. (2017). Evaluation of deep percolation in irrigated citrus orchards in the semi-arid region of Tensift Al Haouz, Morocco. Acta Hortic. 1150, 145-152. https://doi.org/10.17660/ActaHortic.2017.1150.21

Abdellatif Ayyoub, Salah Er-Raki, Saïd Khabba Khabba, Olivier Merlin, Julio Cesar Rodriguez, Jamal Ezzahar, Ahmed Bahlaoui, and Abdelghani Chehbouni. A simple and alternative approach based on reference evapotranspiration and leaf area index for estimating tree transpiration in semi-arid regions.. Agricultural Water Management, in press, 2017.

Luis Enrique Olivera-Guerra, Cristian Mattar, Olivier Merlin, Claudio Durán-Alarcón, Andrés Santamaría-Artigas and Rodrigo Fuster. An operational method for the disaggregation of land surface temperature to estimate actual evapotranspiration in the arid region of Chile. International Journal of Applied Earth Observation and Geoinformation, in press, 2017.

Stefan V., O. Merlin, B. Molero, B. Aït-Hssaine, M.-J. Escorihuela, P. Quintana-Seguí, S. Er-Raki, 2017. Improving the physics and robustness of an evaporation-based disaggregation method of SMOS soil moisture data. Submitted to Remote Sensing of Environment.

Jian Peng, Alexander Loew, Olivier Merlin, Niko E. C. Verhoest, 2017. Spatial downscaling of remotely sensed soil moisture. Reviews of Geophysics, under review.

Alhousseine Diarra, Lionel Jarlan, Salah Er-Raki; Michel Le Page, Ghizlane Aouade, Adrien Tavernier, Gilles Boulet, Jamal Ezzahar, Olivier Merlin, Said Khabba, 2017. Performance of the two-source energy budget (TSEB) model for the monitoring of evapotranspiration over irrigated annual crops in North Africa. Agricultural Water Management, in revision.

Andreas Colliander, Josh Fisher, Olivier Merlin et al. SMAP soil moisture disaggregation with MODIS during SMAPVEX15. In preparation for Remote Sensing of Environment.

8.2 Conferences

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Vivien Georgiana Stefan, Olivier Merlin, Maria José Escorihuela, Bouchra AïtHssaine, Beatriz Molero, Jamal Ezzahar, Salah Er-Raki, Ahmad Al Bitar, and Yann Kerr. Towards a robust evaporation-based disaggregation method of SMOS soil moisture by combining high-resolution shortwave/thermal and available meteorological data. European Geophysical Union 2016, Vienna, Austria.

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Maria Jose Escorihuela, Cyril Piou, Olivier Merlin, Mehrez Zribi, Omar Ali Eweys and Benjamin Koetz. Soil Moisture for dEsert Locust earLy Survey- SMELLS project. ESA Living Planet 2016, Praga, Tchec rep..

Al Bitar A., Merlin O., Malbeteau Y., Molero B., Zribi M., Sekhar M., Tomer S., Escorihuela M.J., Vivien S., Suere C., Mialon A., Kerr Y. On the use of L-band microwave and multi-mission EO data from optical and radar for high resolution soil moisture. European Geophysical Union 2017, Vienna, Austria.

Jamal Ezzahar, Abdelghani Chehbouni, Salah Er-Raki, Ghizlane Aouade, Said Khabba, Olivier Merlin, Gilles Boulet, and Lionel Jarlan. A Two-source Energy Balance Model for estimating evapotranspiration over an olive orchard in a semi-arid region of Morocco. European Geophysical Union 2016, Vienna, Austria.

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8.3 Movie

"De l'eau, du blé et des hommes", 2016 - 12 min - A film shot by M.-C. Burg, B. Mantaux and T. Chevallier in the frame of the undergraduate interdisciplinary exchange program of IRD Body/Sorbonne-Universités. With the participation of M. H. Kharrou (ORMVAH), O. Merlin (IRD), S. Khabba (UCAM), A. Chakir (IRD), A. Amazirh (PhD student), B. Aït Hssaine (PhD student), Z. Rafi (Master student) and Jamal El-Fakh (Master Student).