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

Template for Research Progress Report

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JECAM Test Site Name: **TENSIFT, Morocco**

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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? Y/N
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, either off the shelf algorithm for supervised classifications.

- Crop Condition/Stress
  Methodological developments for the estimation and monitoring of surface parameters with multi-sensor, multi-spectral remote sensing of surfaces. Evapotranspiration from thermal infrared (energy budget approach) and visible data (FAO-56 coupled with NDVI time series).

- Soil Moisture
  High resolution soil moisture, by disaggregation of SMOS satellite measurements based on thermal and visible data (Merlin et al., 2009, 2012, 2013) and 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 an 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 functionning.

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

2 Site Description

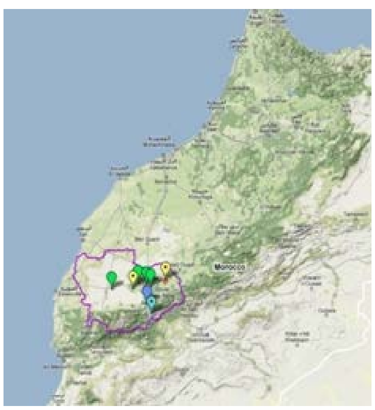

Figure 1 : location of the Tensift Watershed in Morocco

The watershed is located in the Tensift region of Marrakech in Morocco (Figure 1). Covering an area of about 20,000 km ^{2}, it is composed of 3 hydrological parts. South of the basin, the northern slopes of the Atlas is well-watered and snow (up to 600 mm / year). Peaking at over 4,000 m, those mountains are the water tower of the Haouz plain. In the center, a vast plain, characterized by a semi-arid climate (rainfall 250 mm / year), and where the water flows are predominantly vertical except for wadis and water infrastructures. The main irrigated areas are located in the central and eastern part (2000 km ^{2}) and rainfed cereals is practiced on the rest of the plain. The cultivation of wheat is majority with over 80% of acreage covered 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. 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.

Two observation 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. The other crops represent less than 20% of the cultivated area being Sugar Beet, Olive trees, etc. Soil texture is mainly Clay Loam. The growing season of winter wheat is December-June, sugar beet is from November to june, 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.

- Tha 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.

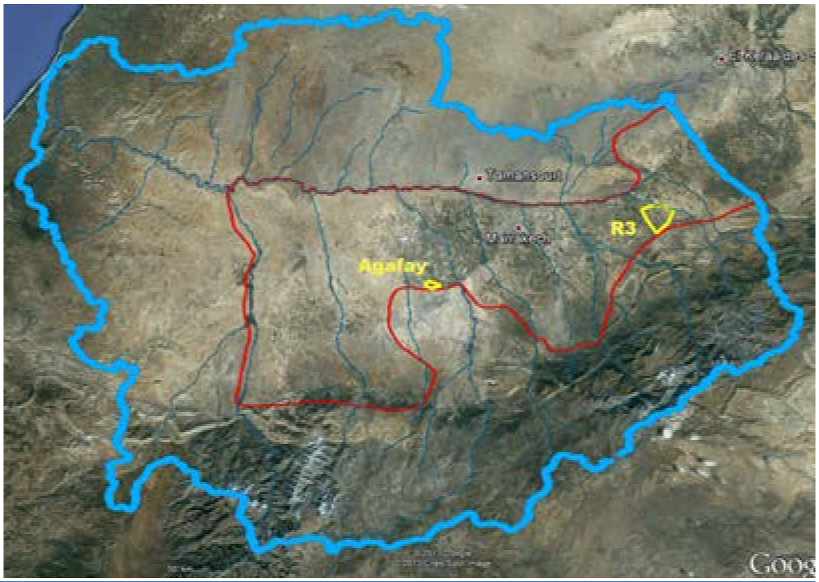

Figure 2 : location of the Haouz plain (red) and the two sites (yellow) in the Tensift Watershed (blue)

Figure 3 : 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 used during 2015 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
Sentinel-1	ESA	SAR	>100	2014 onwards	L1B	none	Soil moisture retrieval
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)
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)
SPOT 5-Take5 experiment	CNES	VIS-NIR	53	April-sept 2015	TOC reflectance	Call for submission	Not yet

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). Fir the 201(-2016 season, and experiment comparing drip and traditional gravity irrigated wheat was installed including a lysimeter to monitor soil percolation.

Fig.3 - The experiment on winter wheat for the 2015-2016 season, including eddy correlation (above pictures) and lysimeter (below pictures).

5 Collaboration

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

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). 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.

We have also been approached to work on the neighbouring Tadla area (by the National Center for Remote Sensing) and in the Bahira plain (another lab from Marrakech University).

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 2015 focused on the 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 (Advanced Microwave Scanning Radiometer-EOS; Njoku et al. 2003) and L-band SMOS (Soil Moisture and Ocean Salinity, Kerr et al., 2010) data have a spatial resolution of about 60 km and 40 km, respectively. The recent SMAP (Soil Moisture Active and Passive, Entekhabi et al. 2010) 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. 2012b; 2013a) estimates the soil moisture variability within a 40 km resolution SMOS (or 10 km resolution SMAP) pixel at the target 1 km resolution using MODIS data and the target 100 m resolution using Landsat data (Merlin et al. 2005; 2006b; 2008a,b; 2009; 2010a). The DISPATCH method relies on a self-calibrated evaporation model.

In the microwave domain, active sensors (radars) achieve a spatial resolution much finer than that of radiometers. Successfully launched on 3 April 2014, Sentinel-1 (Torres et al., 2012) provides C-band SAR (Synthetic Aperture Radar) data at a spatial resolution of about 20 m with an unprecedented repeat cycle of 6 days by combining both ascending and descending overpasses (3 days by combining the two satellites available from 2015). Although backscatter data have potential to monitor surface soil moisture (e.g. Balenzano et al., 2011), there is currently no operational product at such fine resolution. This is notably due to the difficulty to model in time and over extended areas the impact of vegetation cover/structure and surface roughness on the backscatter signal (e.g. Satalino et al., 2014), and thus the need for site-specific calibration (e.g. Zribi et al. 2011).

Within the H2020 REC framework (See section 7) we are proposing to combine Sentinel-1 SAR data with DISPATCH-disaggregated SMOS/SMAP soil moisture to derive a soil moisture product at both high-spatial and high-temporal resolutions (see Fig. below).

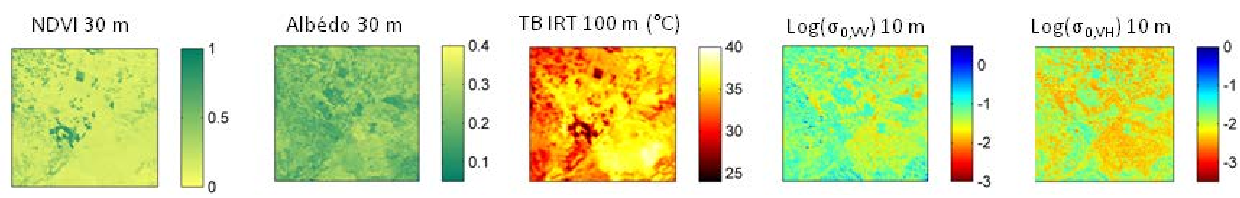

Fig.4 - Investigating a synergy between Landsat-8 NDVI, surface albedo and TIR brightness temperature data and Sentinel-1 backscatter coefficients for soil moisture retrieval over an irrigated area near Marrakech (A. Amazirh PhD thesis).

As an original application of the above soil moisture products available over agricultural areas we are investigating a remote sensing-based method to estimate irrigation. The proposed approach consists in combining the 1 km resolution DISPATCH data (disaggregated from SMOS and using MODIS data) and the modeling of the water budget in the soil surface (Malbéteau PhD thesis). In practice the remotely sensed soil moisture is assimilated into a force-restore type model that is forced by available meteorological including precipitation data. The approach has been tested already over a rainfed wheat area where no irrigation occurs (see Fig. below). As a step forward, we are extending it to an irrigated area in the Haouz plain where irrigation dates and volumes are precisely recorded using onground sensors for validation (see the REC campaign described in Section 7).

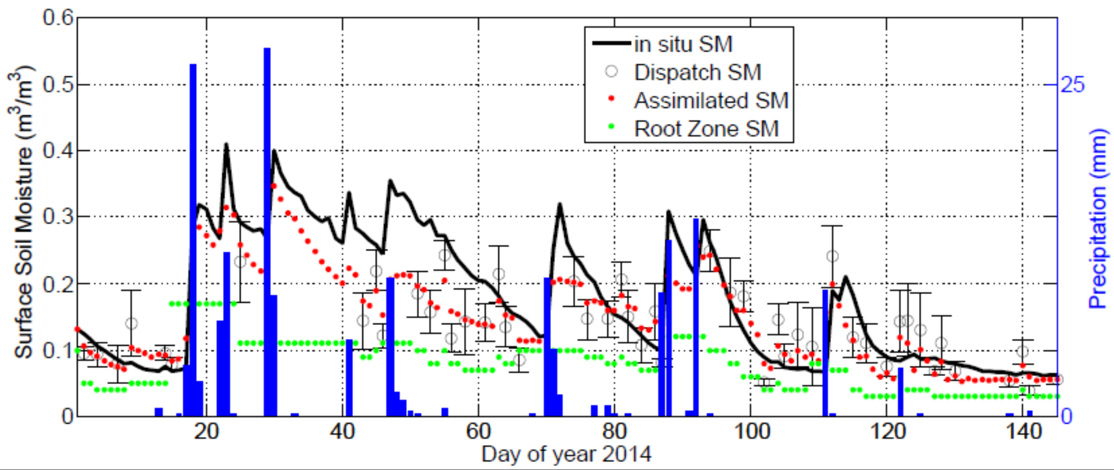

Fig.5 - Assimilation of DISPATCH soil moisture data into a dynamic model for mapping irrigated areas and retrieving irrigation dates (Y. Malbéteau PhD thesis).

Among the considerable variety of existing approaches to estimate ET from remote sensing data, the most widely used approach is to force the FAO-56 method (Allen et al., 1998, 2005) with NDVI data (Bausch and Neale, 1989). However, the FAO-NDVI method is not sufficient to accurately estimate water consumption, especially when soil evaporation and stress under full vegetation cover conditions occur as highlighted by Er-Raki et al. (2007). Within this context, Chirouze et al. (2014) compared several approaches based on thermal imagery that should be better suited for evapotranspiration estimate under stressed conditions. Those approaches, either solving the surface energy budget at the pixel scale or assuming that complete stress conditions (from unstressed to fully stressed) are present in a remote sensing image, provide snapshot estimates of evapotranspiration at the time of the satellite overpass. This work highlights the good performance of the TSEB model for evapotranspiration estimate. TSEB has been further evaluated in different crop conditions by Bigeard et al. (2015, submitted to HESS) and Diarra et al. (2013). At the same time, a consistent and unifying interpretation of the image-based approaches in Moran et al. (1994) and in Roerink et al. (2000) was proposed. The monosource surface energy balance model (SEB-1S) estimates the evaporative fraction (defined as the ratio of evapotranspiration to the available energy) from satellite data composed of surface temperature, a vegetation index (e.g. NDVI) and surface albedo, resulting in accurate evapotranspiration estimates at 100 m resolution (Merlin 2013). Recently, Stefan et al. 2015 have integrated a soil energy balance model in the image-based approach to improve the robustness of SEB-1S when applied to low resolution (MODIS like) data. As a step further, the SEB-1S approach was extended to a multi-source representation of agricultural fields (Merlin et al. 2014). The main originality of SEB-4S (four source surface energy balance model) is to explicitly separate the energy and water fluxes of unstressed green (photosynthetically active) vegetation, non-transpiring green vegetation, senescent vegetation and bare soil. SEB-4S has hence potential to better characterize the portion of evapotranspiration unusable for crop productivity (soil evaporation) and the crop water need (via the plant transpiration) from satellite images solely. Its modeling structure is also well adapted for integrating in the future the near-surface soil moisture retrieved from microwave data, as a further constraint on the evaporation/transpiration partitioning.

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. In the project, partition between T and E is measured on the ground using isotopic techniques or sap flux measurements. We also test models based on this criteria. The ISBA (Interactions Soil-Biosphere-Atmosphere) model was used for estimating ET and its partition over an olive orchard and a wheat field located near to the Marrakech City (Centre of Morocco). Two versions were evaluated: (1) a version which simulates a single energy balance for the soil and vegetation and (2) the recently developed multiple energy balance (MEB) version which solves a separate energy balance for each of the two sources. The test was done using previous eddy covariance measurements operated during years 2003-2004 for the Olive Orchard and during years 2013 for wheat. The transpiration component was measured using a Sap flow system during summer over the wheat crop and stable isotope samples were gathered over wheat. The comparison between ET estimated by ISBA model and that measured by the Eddy covariance system showed that MEB version yielded a remarkable improvement compared to the standard version. The result also showed that MEB version simulates more accurately the crop transpiration compared to the standard version. (EGU communication in 2016)

6.3 SPOT5-TAKE5 experiment

A time series of 53 SPOT 5 images was acquired on our site from 9 april to 11 sept 2015. The processing of this data has not been achieved yet. The objectives are to use it to force a model for evapotranspiration estimates using the FAO56 method coupled with Kcb obtained from the NDVI from these images (SAMIR tool developed by the team).

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.

The daily management of irrigation requires knowledge about the right amount of water that is needed by crops. The Spanish ASG (Aigües del Segarra Garrigues) and the Moroccan ORMVAH (l'Office Régional de Mise en Valeur Agricole du Haouz) have stressed the importance of a spatialized information on the soil water content in the root zone to optimize irrigation water turns. The specifications mentioned by both ASG and ORMVAH regarding a potential soil moisture product are : a spatial resolution finer than 100 m with a temporal frequency of 1 per day. Note that the frequency of 1 per week remains satisfying given the constraints imposed by the current water distribution systems. The scientific approach of the H2020 RISE REC (2015-2019) project aims to achieve those specifications by combining readily available multi-sensor remote sensing including Sentinel-1, Sentinel-2, Landsat-8, MODIS and SMOS data with adequate land surface modelling. REC partners UPS-CESBIO, IRD-CESBIO, UCAM and two Spanish SME isardSAT (PI) and LabFerrer, in collaboration with irrigation agencies. To meet the REC objectives, an original experiment is being conducted in two wheat crops located 40 km east of Marrakech. It combines advanced instrumentation (eddy covariance, tension controlled field lysimeters, sap flow and Photochemical Reflectance Index sensors) dedicated to a close monitoring of all the water fluxes in soil and at the surface-atmosphere interface. Moreover, the remote sensing variables (surface soil moisture, radiometric temperature, surface albedo, vegetation and water stress indices) are being measured continuously in both wheat crops, as well as in the surrounding area. Such data will allow the REC approaches to be tested for flood and drip irrigated wheat crops.

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

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

1. Publications

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

Articles 2015

1. Aouade G., Ezzahar J., Amenzou N., Er-Raki S., Benkaddour A., Khabba S., Jarlan L., 2016, Combining stable isotopes and micrometeorological measurements for partitioning evapotranspiration of winter wheat into soil evaporation and plant transpiration in a semi-arid region, submitted to Agricultural Water Management.
2. Ayyoub A., Khabba S., Er-Raki S., Merlin O., Bahlaoui A. 2016. Calibration and validation of the Penman-Monteith Model for estimating evapotranspiration of an orange orchard in semi-arid region. Acta Horticulturae, accepté.
3. Jarlan, L., Khabba, S., Er-Raki, S., Le Page, M., Hanich, L., Fakir, Y., Merlin, O., Mangiarotti, S., Gascoin, S., Ezzahar, J., Kharrou, M.H., Berjamy, B., Saaïdi, A., Boudhar, A., Benkaddour, A., Laftouhi, N., Abaoui, J., Tavernier, A., Boulet, G., Simonneaux, V., Driouech, F., El Adnani, M., El Fazziki, A., Amenzou, N., Raibi, F., El Mandour, A., Ibouh, H., Le Dantec, V., Habets, F., Tramblay, Y., Mougenot, B., Leblanc, M., El Faïz, M., Drapeau, L., Coudert, B., Hagolle, O., Filali, N., Belaqziz, S., Marchane, A., Szczypta, C., Toumi, J., Diarra, A., Aouade, G., Hajhouji, Y., Nassah, H., Bigeard, G., Chirouze, J., Boukhari, K., Abourida, A., Richard, B., Fanise, P., Kasbani, M., Chakir, A., Zribi, M., Marah, H., Naimi, A., Mokssit, A., Kerr, Y., Escadafal, R., 2015. Remote Sensing of Water Resources in Semi-Arid Mediterranean Areas: the joint international laboratory TREMA. Int. J. Remote Sens. 36, 4879–4917.
4. Merlin O., Malbéteau Y., Notfi Y., Bacon S., Er-Raki S., Khabba S., Jarlan L. 2015. Performance metrics for soil moisture downscaling methods: Application to DISPATCH data in central Morocco. Remote sensing, 7: 3783-3807.(doi:10.3390/rs70403783)
5. Nassah H., Er-Raki S., Khabba S., Fakir Y., Ezzahar J., Hanich L., Merlin O. 2016. Evaluation of deep percolation in irrigated cirtus orchards in the semi arid region of Tensift al Haouz, Morocco. Acta Horticulturae, accepté.
6. Stefan V., Merlin O., Er-Raki S., Escorihuela M.J., Khabba S. 2015. Consistency between in situ, model-derived and image-based soil temperature endmembers: towards a robust data-based model for

multi-resolution monitoring of crop evapotranspiration. Remote sensing, 7(8): 10444-10479. doi:10.3390/rs70810444.

7. Toumi, J., Er-Raki, S., Ezzahar, J., Khabba, S., Jarlan, L., Chehbouni, A., 2016. Calibration and Validation of the Aquacrop model for estimating evapotranspiration and grain yields of winter wheat in semi-arid region of Tensift Al-Haouz (Marrakech, Morocco): application to manage water irrigation. Agric. Water Manag., 163, 219-235.

8. Malbéteau Y., O. Merlin, B. Molero, C. Rüdiger, S. Bacon (2016) DisPATCh as a tool to evaluate coarse-scale remotely sensed soil moisture using localized in situ measurements: Application to SMOS and AMSR-E data in Southeastern Australia. International Journal of Applied Earth Observations and Geoinformation, pp. 221-234. doi:10.1016/j.jag.2015.10.002

9. Merlin O., V. G. Stefan, A. Amazirh, A. Chanzy, E. Ceschia, T. Tallec, J. Beringer, P. Gentine, S. Er-Raki, S. Bircher, and S. Khabba, Modeling soil evaporation efficiency in a range of soil and atmospheric conditions: A downward approach based on multi-site data, Water Resources Research, under review, 2015.