EVAPOTRANSPIRATION MONITORING IN SEMI-ARID AREAS USING MSG/SEVIRI DERIVED DATA: IMPROVEMENTS FROM THE USE OF LEAF AREA INDEX AND LAND SURFACE TEMPERATURE

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Abstract

Water resource is a major concern for sustainable development in many semi-arid areas. Early detection of drought and monitoring water consumption by agriculture are highly important for adaptation in water use regional policy. As a crucial component of the water cycle, land evapotranspiration is a primary source of information for such water resources assessments, and remote sensing from geostationary satellites offers the possibility to monitor it over large areas at relatively high temporal and spatial resolutions. The Satellite Application Facility on Land Surface Analysis (LSA-SAF) of EUMETSAT proposes an operational evapotranspiration product based on radiation components (surface short and longwave incoming radiation and albedo) derived from the SEVIRI instrument of the Meteosat Second Generation (MSG). Previous validation studies had shown its success for temperate and moist regions, while semi-arid and arid areas of Africa had been shown to be more prone to model errors. In this contribution, we show that the use of the land surface temperature and leaf area index derived from MSG/SEVIRI improves the evapotranspiration monitoring over semi-arid areas of Europe and Africa. The vegetation dynamics and status of the soil water content available for the process are better represented in the model leading to more accurate results. Statistical comparisons between the current operational LSA-SAF evapotranspiration product from EUMETSAT and in-situ measurements are given to demonstrate the benefits from using new input data derived from the satellite. An updated algorithm incorporating those improvements should be integrated soon into the LSA-SAF operational production.

THE LSA-SAF EVAPOTRANSPIRATION PRODUCT: SUCCESS AND DEFFICIENCIES

Drought is a major disaster affecting regions relying on natural occurrence of rain for food production. It causes a serious decrease in crop productivity, leading to lack of food, in livestock and in direct accessibility to water for local communities. National and international actions can only be taken if warned in due time, especially if early warnings are issued. In setting up such service, experts must know very accurately the different water gains and losses. An important loss of water from land is the water vapour released into the atmosphere, by plant transpiration and evaporation from the soil.

While wide networks of towers have been installed to observe evapotranspiration from the ground, no real-time quality controlled monitoring can be achieved with a good spatial coverage. Instead, models, like global circulation models, can estimate it, but are prone to fail in regions with no or sparse observations because of parameterization deficiencies. Remote sensing from spaceborn sensors is one valuable option, especially aboard geostationary satellites, because of its wide sensing view (several continents) in a short time (5 to 15 minutes), with a spatial resolution of 3 to 5 km.

An evapotranspiration algorithm has been implemented in the operational framework of EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA-SAF, Trigo et al., 2011), which produces variables related to land surface from the SEVIRI sensor aboard the Meteosat Second Generation satellites (view figure 1 for a sketch of the different variables derived). The implemented evapotranspiration algorithm is largely based on the ECMWF land surface scheme (van den Hurk et al., 2000), without any derivation of the soil variables evolution. Specific parameterizations have been added to work at the resolution of SEVIRI sensor, and several modifications have been applied to the original scheme (Ghilain et al., 2011). The model is forced by radiation components produced by LSA-

SAF, vegetation state provided by a customized database based on ECOCLIMAP (Masson et al., 2003), meteorological fields (surface air temperature, air humidity, wind speed) and soil moisture provided by the short-term forecasts of the ECMWF global atmospheric model.

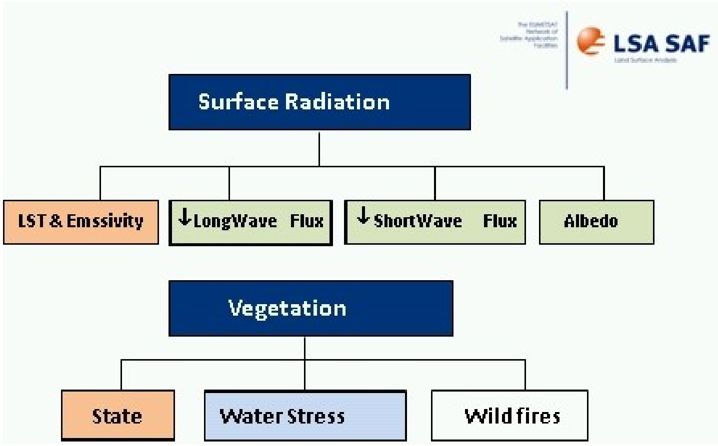

***Figure 1:* The evapotranspiration is one of the variables derived from SEVIRI aboard MSG satellites in the context of the EUMETSAT's LSA-SAF service. In this schematic view, evapotranspiration is part of the vegetation/water stress component. The operational algorithm makes use of three radiation components, the albedo, the short/long- wave downward radiations. In this study, we have added the vegetation state, leaf area index, and the land surface temperature.**

The operational LSA-SAF system produces in near-real time every half-hour evapotranspiration estimates at continental scale over the field of view of SEVIRI sensor. This product and its derivative, the daily cumulated product, have been in operation for 4 years, disseminating the information among the user community, targeted mainly as drought warning services.

However, while its accuracy has been demonstrated over temperate regions of Europe (Ghilain et al., 2011) and could be used for an early application of drought monitoring over Europe (Sepulcre-Canto et al., 2013), the product obviously suffers from deficiencies, particularly in semi-arid areas with lower correlation scores with ground observations and an underestimated annual variability (results presented in a Taylor diagram (Taylor, 2001) in Figure 2). Those deficiencies have been attributed to inadequate forcing, related to vegetation, the main medium through which the transpiration process occurs, and soil water availability. Correcting those drawbacks could help a better drought monitoring in view to issue early warnings and prevent as much as possible damages.

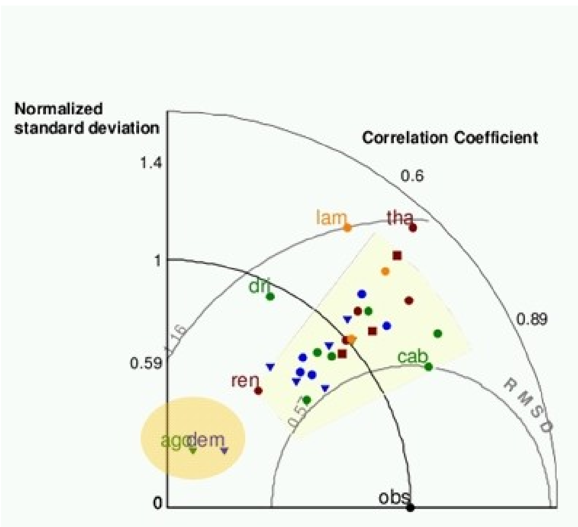

Figure 2: **The LSA-SAF evapotranspiration product is in good agreement with ground observations for temperate regions of Europe, especially over grasslands. However, it disagrees at semi-arid sites, especially in Africa (elliptical shaded area), uncovering some model deficiencies linked to vegetation or/and soil moisture in those regions.**

In this contribution, we briefly show the improvements of the results in ingesting leaf area index and land surface temperature into the evapotranspiration model of the LSA-SAF. We have proceeded step-by-step, ingesting first the vegetation component, then adding the information derived daily from land surface temperature.

IMPROVEMENTS FROM LEAF AREA INDEX

Leaf Area Index is a variable characterizing the vegetation vertical abundance of leaves, quantifying the vertically integrated area of green material per surface unit on the ground. The leaf area index used in this context is produced daily by LSA-SAF at a spatial resolution of a few kilometres in the SEVIRI projection. Using that product presents several advantages resulting from an up-to-date follow-up of the vegetation state pixelwise: it allows the detection of short-term local fluctuations to inter-annual variability of the vegetation health and productivity. Those are expected to bring a clear improvement to the evapotranspiration model, as its vegetation information was monthly varying, based on past data and not varying from year to year.

After having implemented the change from ECOCLIMAP customized database to the LSA-SAF LAI for use in the evapotranspiration algorithm (Ghilain et al., 2012), we have reprocessed archives for the year 2007 over Europe and Africa. The result of the comparison between the new version and ground observations shows a clear improvement over semi-arid areas especially in Europe: correlation scores have been improved, and variability is comparable to the observations (figure 3). However, the scores at sahelian sites have been found to be still very low, showing that the model is quite more sensitive to soil water availability than vegetation input and that the current soil moisture information was not adequate for those regions.

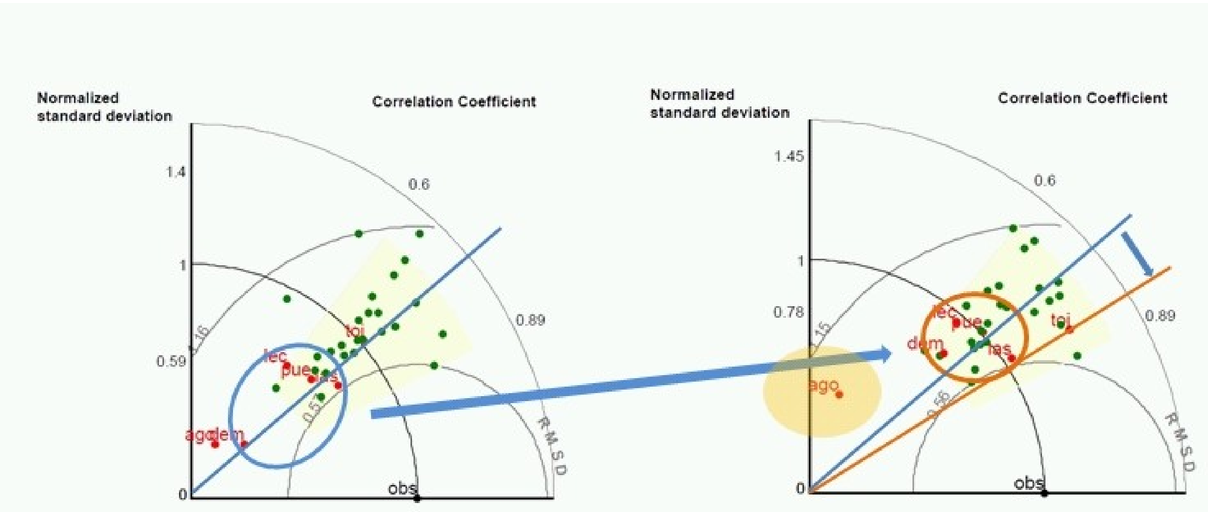

Figure 3: **The evapotranspiration is better estimated at sites experiencing strong water stress (red points) when using LSA-SAF vegetation v**

ADDITIONNAL IMPROVEMENT FROM LAND SURFACE TEMPERATURE

LSA-SAF does not produce a soil moisture index that could be used by the evapotranspiration model. However, the international community has recognized land surface temperature as being a proxy for soil moisture, with some limitations. Land surface temperature is one of the key variables from LSA-SAF: it is produced every 15 minutes at SEVIRI spatial resolution, and is carefully being validated in several locations of Europe and Africa (Göttsche et al., 2013).

In a previous study (Ghilain et al., 2013), we have used the morning heating rates from the land surface temperature pixelwise to infer a surface soil moisture index applicable at continental scale, using a simple empirical function, only for clear sky days. This daily soil moisture estimation over a period between 2007 and 2011 has been validated extensively with the help of ground measurements from FLUXNET and ISMN networks, showing very good performances over Sahelian landscapes and semi-arid regions of Europe, and outperforming the current model input (figure 4). In addition, the newly derived soil moisture presents the advantage of detecting rapid changes in soil moisture, but also irrigation and wetland extends. Limitations have been shown in rocky mountainous areas, as well as over very dense vegetation for which the signal is very weak, and dust storms that are not systematically screened out during the land surface temperature production.

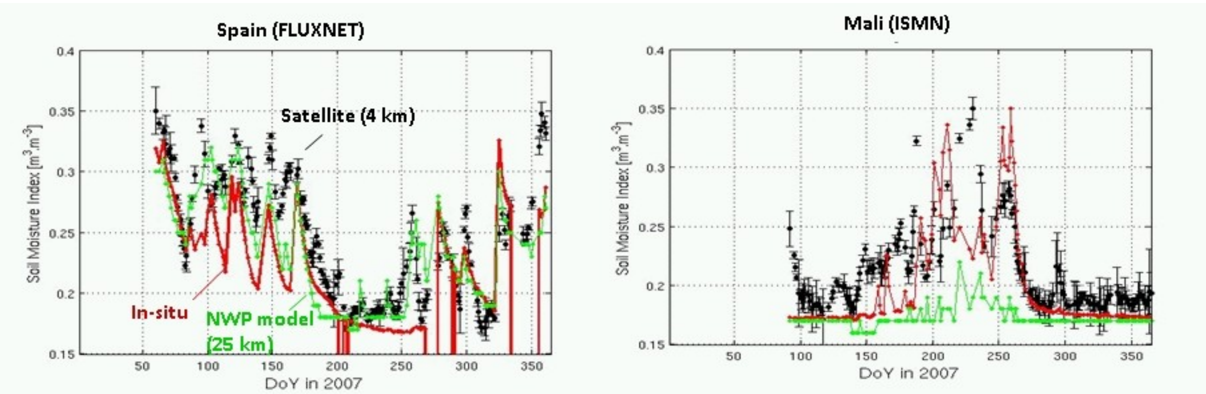

Figure 4: **The new soil moisture estimates derived from land surface temperature data from SEVIRI (black dots) show a good performance when compared to ground observation (red). It even outperforms the NWP soil moisture forecast used in the current operational LSA-SAF evapotranspiration product at the station in Mali.**

We have reprocessed the year 2007 with the evapotranspiration model over validation sites across Europe and Africa using LSA-SAF LAI as input and the estimated soil moisture. For this reprocessing, we have assumed a single soil layer to which the surface soil moisture has been attributed. The estimated evapotranspiration has been largely improved compared to the first version, especially for the site in Mali, with a better correlation to the observations and a better match with the observed variability (figure 5).

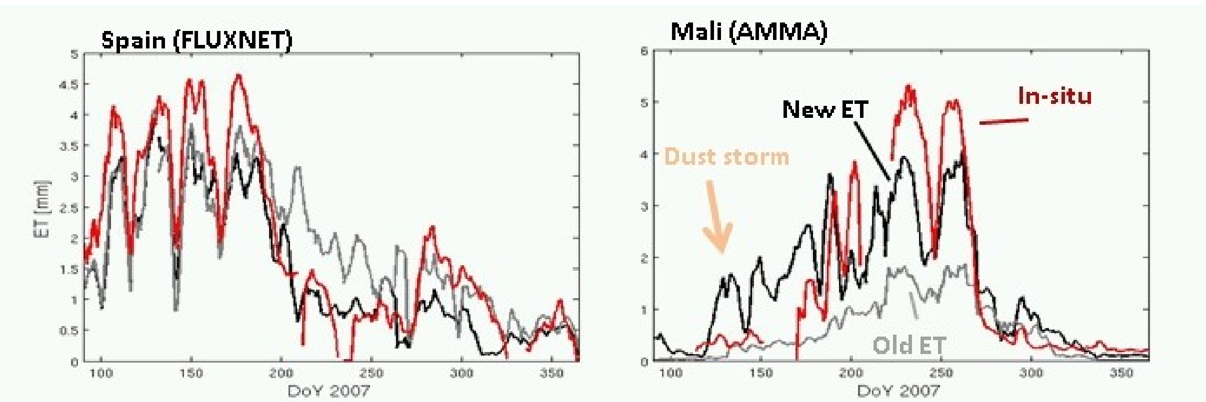

Figure 5: **Evapotranspiration monitoring is largely improved by the combined used of LSA-SAF vegetation variable and land surface temperature at semi-arid sites. The temporal variability of the observations is well reproduced, the order of magnitude is correct during the drying periods. Some corrections still need to be done, like dust storm screening in the land surface temperature retrievals that would imply a better tracking of evapotranspiration during the dry period over the Sahel.**

CONCLUSION AND PERSPECTIVES

In this study, we have shown the interest of ingesting new surface variables derived from MSG/SEVIRI in the evapotranspiration model of EUMETSAT's LSA-SAF for a more accurate monitoring over semi-arid areas. Leaf area index, which describes quantitatively the vertically integrated vegetation green material, cannot alone correct the observed model deficiencies. Land surface temperature, converted into soil moisture, can further improve the results, especially over sahelian Africa, and provide a realistic evapotranspiration evolution compared to ground observations. The natural follow-up of this study is the adaptation of the operational evapotranspiration algorithm of LSA-SAF to conform with the proposed changes. The resulting product will be more reliable over semi-arid areas, making use of LSA-SAF full potential. We expect this will offer new opportunities to an improved drought monitoring in those regions.

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