Operational evapotranspiration based on Earth observation satellites

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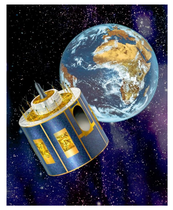
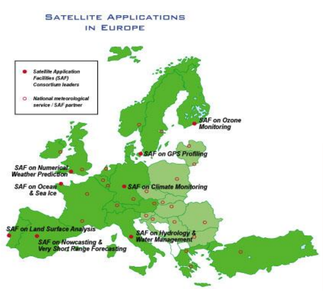


SAF network:

The EUMETSAT Network of Satellite Application Facilities

LSA SAF Land Surface Analysis



LSA-SAF objective: to increase the benefits from MSG and METOP data related to **land**, **land-atmosphere interactions** and **biophysical applications**

LSA-SAF products:

- Surface Albedo (AL), Land Surface Temperature (LST)
- Radiative surface fluxes (DSSF, DSLF)
- Snow cover (SC)
- Vegetation indices (FVC, LAI, fAPAR)
- Evapotranspiration (ET)
- Fires (FD&M, RFM)

  See Trigo et al. (2011)

ET methodology:

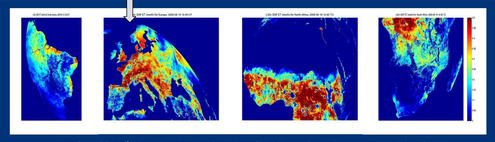
At surface level, the energy balance (Rn), computed from the different components of short- and long-wavelength radiation (SW and LW, respectively), is distributed in 3 different fluxes: soil heat flux (G), sensible heat flux (H) and latent heat flux (LE). The latter one is the flux of water vapour produced by both soil evaporation and canopy transpiration. LE is the energetic variable directly related to ET, which indicates the rate of water evaporating from the surface (soil + biosphere).

In the framework of LSA-SAF, RMI has developed a physical model of energy exchange between soil-biosphere and atmosphere driven by SAF products, in order to evaluate evapotranspiration over land, see Ghilain et al. (2011).

Key LSA input variables in the algorithm: SW↓, LW↓ , albedo (=SW↑/SW↓) [in current operational version], LAI (leaf area index), FVC (fraction of vegetation cover), LST (Land Surface Temperature), emissivity, snow cover, fires location [in next version of the algorithm]; ancillary data: weather data from ECMWF model and parameters from vegetation data base.

A. LSA ET: current operational products

The LSA-SAF ET algorithm produces in near real time ET estimates at SEVIRI spatial resolution each 30 minutes ('MET' product). Results are generated operationally since mid 2009 over four regions (Europe, North and South Africa and the Eastern part of South America) inside the MSG field of view. MET is integrated over time to provide daily results ('DMET' product). Since 2015, the 4 windows are merged in a single image of the MSG disk.



ET (mm/h) 19th August 2009 at 12.00 UT for S. America, Europe, N. and S. Africa.

Data accessibility:

- Registered users have free access to LSA-SAF ET results over full disk through LSA-SAF web site (see http://landsaf.meteo.pt/); near real time results are also accessible via EUMetCast); in case of problems/questions: please take contact with us;
- Registered beta-users can access earlier results (new model versions) through LSA-SAF ftp site;
- By giving us their feedback, users can contribute to improving the results.

- Validation performed against in-situ measurements demonstrate the good quality of LSA-SAF ET.
- Nevertheless, some deficiencies have been noticed in semi-arid environments.
- From both user's experience and own validation, we have worked towards improvements and adding more features (see 'B. LSA ET: preparation of next release').
- LSA-SAF ET V2 will rely on more satellite data and will additionally deliver the surface heat fluxes.

References:

From LSA-SAF team:

Ghilain, N., Arboleda, A. and Gellens-Meulenberghs F., 2011: Evapotranspiration modelling at large scale using near-real time MSG SEVIRI derived data. Hydrol. Earth Syst. Sci., doi:10.5194/hess-15-771-2011, 15, 771–786.

Trigo, I., DaCamara, C., Viterbo, P., Roujean, J.-L., Olesen, F., Barroso, C., Camacho-de-Coca, F., Carrer, D., Freitas, S., García-Haro, J., Geiger, B., Gellens-Meulenberghs, F., Ghilain, N., Meliá, J., Pessanha, L., Siljamo N., Arboleda., A., 2011: The Satellite Application Facility on Land Surface Analysis. Int. J. Rem. Sens., 32(10), 2725–2744.

From users (examples):

Hu, G., Jia, L., & Menenti, M. 2015: Comparison of MOD16 and LSA-SAF MSG evapotranspiration products over Europe for 2011, Remote Sens. Environ., 156, 510-526.

Petropoulos P., G., Ireland, G., Lamine, S., Griffiths, H., Ghilain, N., Anagnostopoulos, V., North, M., Srivastana, P., Georgopoulou, H. , 2016): Operational evapotranspiration estimates from SEVIRI in support of sustainable water management, International Journal of Applied Earth Observation and Geoinformation 49, 175-187.

Romaguera, M., Krol, M. S., Salama, M., Hoekstra, A. Y., & Su, Z., 2012: Determining irrigated areas and quantifying blue water use in Europe using remote sensing Meteosat Second Generation (MSG) products and Global Land Data Assimilation System (GLDAS) data, Photogrammetric Engineering & Remote Sensing, 78(8), 861-873.

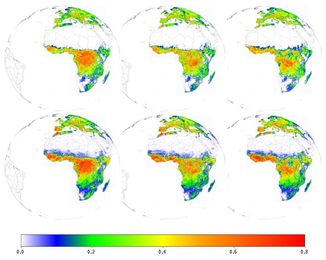
Romaguera, M., Salama, M. S., Krol, M. S., Hoekstra, A. Y., & Su, Z., 2014: Towards the Improvement of Blue Water Evapotranspiration Estimates by Combining Remote Sensing and Model Simulation, Remote Sensing, 6(8), 7026-7049.

Sepulcre Canto, G., Vogt, J., Arboleda, A, Antofie, T., 2014: Assessment of the EUMETSAT LSA-SAF evapotranspiration product for drought monitoring in Europe, Int. J. Applied EO Geoinf, 30, 190-202.

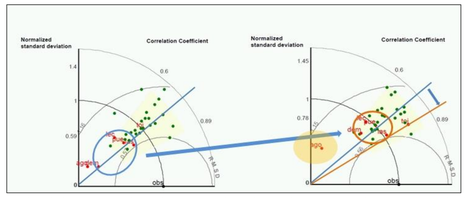
B. LSA ET: preparation of next operational release (v2)

Improvements from the use of vegetation variables (LAI, FVC) from satellite

The use of vegetation state variables derived from satellites presents the advantage that it allows the detection of short-term local fluctuations to inter-annual variability of the vegetation health and productivity. 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. The results of the comparison between ground observations and a version using satellite derived vegetation state variables shows a clear improvement over semi-arid in Europe and Africa. However, scores at sahelian sites are still low, indicating that on this area, the model is more sensitive to soil water availability than vegetation characteristics and that current soil moisture information was not adequate for these region.



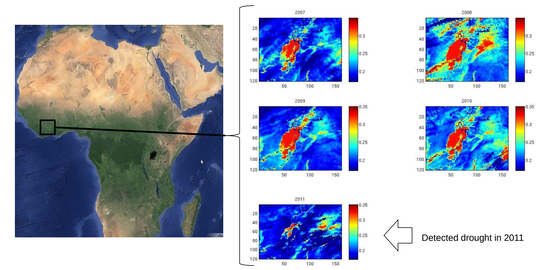
Comparison between operational (upper row figures) and produced with the new vegetation parameterization (low row figures) evapotranspiration for the days 22, 23 and 24 May 2011. It can be seen that results obtained with the new remote-sensing variables produce higher ET values over arid/semi-arid areas with low or no impact on tempered regions of Europe.



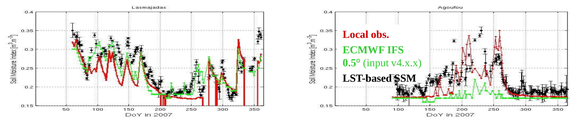
The result of the comparison between the old and new version to ground observations shows a clear improvement over semi-arid areas : correlation scores have been improved, and variability is comparable to the observations. However, the scores at sahelian sites have been found to be still very low, showing 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.

Improvements from the use of Land Surface Temperature (LST) from satellite

Radiative temperature obtained from satellites contains information on water content in the firsts centimetres of the soil. For this study, we have used the Land Surface Temperature derived operationally in the LSA-SAF project given that it presents interesting characteristics for use in an operational contest (accessibility in near real time, spatio-temporal resolution). Based on morning heating rates from LST, we have derived a surface soil moisture index at continental scale for clear sky days over a period between 2007 and 2011. This daily soil moisture estimation 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. In addition, the newly derived soil moisture is capable of detecting irrigated areas and extends of wetlands.



On the SM derived from LST, soil moisture patterns like annually wetlands extends/shrinks emerge as in this example over the Niger inner delta for the month of November from 2007 to 2011



LST derive soil moisture (black dots) show a good performance when compared to ground observation (red). And outperforms the NWP soil moisture forecast used in the current operational LSA-SAF evapotranspiration product at some station

New version is planned to be in production in early 2017

Future work (CDOP-3 phase, 2017-2022): adaptation of current LSA-SAF methodology for exploitation of Meteosat Third Generation (MTG) potential.

C. Research on exploitation of SPOT vegetation products

The spatial resolution of MSG SEVIRI is 3 x 3 km at sub-satellite point and about 4 x 5 km in continental Europe (see point A. above). The temporal resolution of these products and their delivery at near-real time is unprecedented. Nevertheless, their spatial resolution may constrain their full exploitation for a set of applications related to agricultural and water management. In parallel to LSA-SAF developments, research has been started to investigate ET downscaling to a finer spatial scale. A first step is focusing on the assimilation into the algorithm used in the LSA-SAF framework of vegetation products derived from polar satellites. MODIS and SPOT-VEG products have been explored.

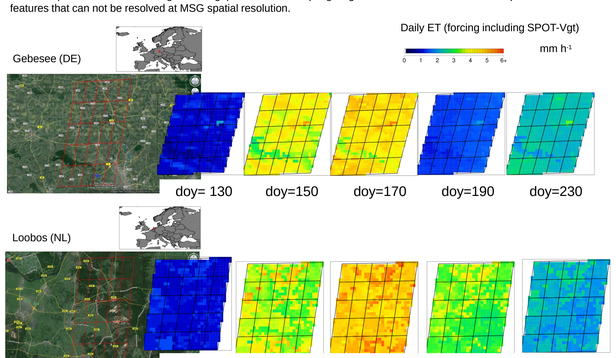
Downscaling in MSG pixels: investigation of Spot LAI content

The vegetation dynamics plays a crucial role in the ET pattern of ecosystems. The following examples show LAI signals (derived from SPOT-Vgt) within a single MSG pixel in contrast to the LAI signal derived from SEVIRI MSG.

Computing ET at 1 km, using Spot LAI

Leading question in this study was: can the strengths of LSA-SAF ET (good validation results, high temporal resolution) be combined with those of polar-orbit satellite (higher spatial resolution) to derive daily ET estimates at moderate spatial resolution?

The following illustrations show maps of daily ET values in a window of 5x5 MSG pixels around the location of a flux tower derived using the SPOT-Vgt forcing instead of the conventional forcing of the LSA-SAF ET product.
These maps show that introducing SPOT-Vgt products and adopting its grid allows the identification of ET patterns for features that can not be resolved at MSG spatial resolution.

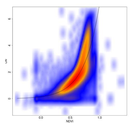


The incorporation of SPOT-Vgt data in the forcing led to ET estimates with similar degree of agreement (mostly better) with the validation dataset as the LSA-SAF ET product (not shown here). The estimates reveal more specificities of the ET pattern of landscape features that can not be resolved at MSG resolution.

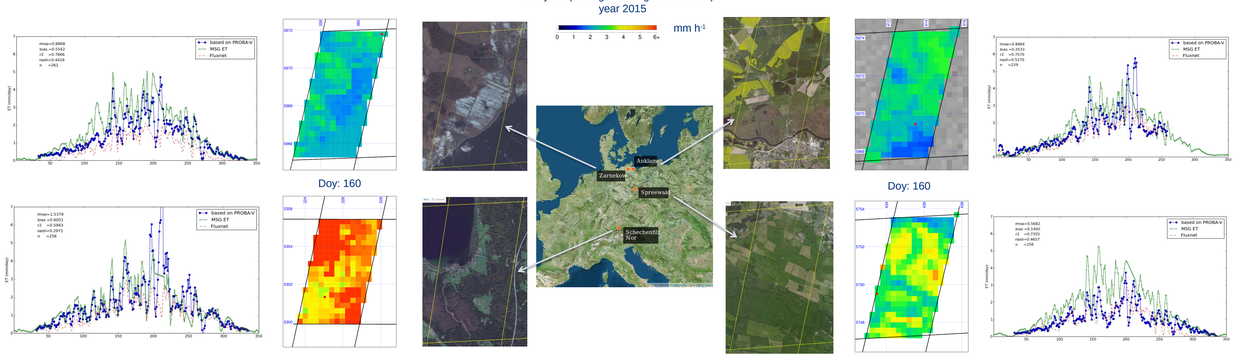
D. Research on exploitation of PROBA-V data

Case of wetlands:

An ongoing specific project (Belspo 'HiWET project', see http://hydr.squarespace.com/projecthiwet/) is dedicated to the study of ET in wetlands allowing to concentrate research on relationship between ET, vegetation characteristics and ecosystem health.



NDVI-LAI cloud and fitted curve obtained from SPOT-Vgt in the period 2000-2013; used as proxy to assess Proba-V LAI in this study.



Future operational perspectives: the exploitation of Proba-V – and Sentinel-3 – products, should allow the developments of new ET products with 1 km to 300 m spatial resolution in the frame of Copernicus Global Land Monitoring Services (http://land.copernicus.eu/).

Acknowledgments

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