THE LSA-SAF EVAPOTRANSPIRATION PRODUCT: FIRST RESULTS WITH MSG

A. Arboleda, N. Ghilain, F. Gellens-Meulenberghs
Royal Meteorological Institute of Belgium,
Avenue Circulaire 3,
B-1180 Brussels, Belgium

ABSTRACT

In the framework of the EUMETSAT's LSA-SAF project, a method to estimate the evapotranspiration (ET) using satellite remote sensing has been developed. Data derived from Meteosat Second Generation (MSG) is used to drive a physical model of energy exchange between the surface (soil and canopy) and the atmospheric boundary layer. Such data has started to be pre-operationally generated by the LSA-SAF. It can now be used as input into the ET algorithm for the first time in view to test the operational generation of ET maps over Europe.

The methodology, based on the tile approach, is shortly described. Each model mesh, associated to a satellite image pixel, is considered as being a mix of homogeneous land cover types (tiles). Calculation of energy exchange is performed for each tile and then aggregated to derive ET at pixel level.

First ET maps obtained with MSG derived data can now be produced and are illustrated. The method is tested at single-site level, using data from meteorological stations and measurement campaigns from different regions of the world (Europe and America).

INTRODUCTION

Evaluating energy fluxes at the Earth surface is of great importance for weather forecasting and global climate monitoring models. Furthermore, the repartitioning of energy between sensible and latent heat fluxes is a key parameter in hydrology, water management, agriculture in water stressed areas and ecology. Obtaining these energy fluxes is thus of practical relevance.

An evapotranspiration (ET) product is developed in the framework of the EUMETSAT's SAF on Land Surface Analysis (LSA-SAF). It is obtained by a physical model of energy exchange between the surface (soil and canopy) and the atmosphere. The model is driven by input data derived from Meteosat Second Generation (MSG) by the LSA-SAF. Such data has started to be generated in near real time. It can now be used as input into the ET algorithm in view to test the operational generation of ET maps over Europe.

THE PHYSICAL MODEL

The physical model has already been presented in Pieroux et al. (2001), Arboleda et al. (2003). It is based on TESSEL (van den Hurk et al., 2000), the SVAT scheme used by the ECMWF model. In practice, the area for which ET has to be assessed is divided into independent pixels, in an one-to-one correspondence with the pixels of a satellite image. Each pixel is in turn considered as being a mix of homogeneous *tiles*, each tile representing a particular soil surface: bare soil, short canopy, high canopy, *etc* . In the model, some variables are defined at the pixel level and are thus shared by all the tiles composing the pixel, while others are defined at the tile level. Similarly, some variables are computed at the pixel level, while others are computed at the tile level. For these latter, a global pixel value can be obtained through the weighted contribution of each tile.

<u>At tile level :</u>

The energy budget at the skin layer, is calculated for each tile with the equation:

$$(1-\alpha)(1-f_{S_{\downarrow},i})S_{\downarrow}+\varepsilon(L_{\downarrow}-\sigma T_{sk,i}^{4})+H_i+LE_i=\Lambda_{sk,i}(T_{sk,i}-T_1)$$

with $S\downarrow$ the downward surface short-wave flux (DSSF), α the surface albedo (AL), $L\downarrow$ the downward surface long-wave flux (DSLF), LE_i the latent heat flux, H_i the sensible heat flux, T_{ski} the skin temperature, ε emissivity ,σ the Stefan Bolzman constant , $\Lambda_{sk,i}$ the skin conductivity , (1-$f_{S\downarrow}$) is the partial absorption of net short-wave radiation in the skin layer, T_1 the soil temperature. This later is assumed to evolve like the land surface temperature (LST) in this version of the model.

The sensible (H_i) and latent (LE_i) heat flux are respectively given by:

$$H_i=\frac{\rho_a}{r_a}\left[c_p(T_{sk,i}-T_a)-gz_a\right]$$

and

$$LE_i=\frac{L_v\rho_a}{(r_a+r_c)}\left[q_{sat}(T_{sk,i})-q_a(T_a)\right]$$

with

$$r_c=\frac{r_{s,\min}}{LAI}\,f_1(S\downarrow)\,f_2(\bar{\theta})\,f_3(D_a)$$

r_a, r_c	aerodynamic and canopy resistance
ρ_a	air density
c_p	heat capacity of dry air
$r_{s,\min}$	minimum canopy resistance
LAI	leaf area index
q_a	specific humidity
f1, *f2* and *f3*	Jarvis functions
D_a	atmospheric water vapour deficit
θ	average soil water content

At pixel level

$$H = \sum \zeta_i H_i$$

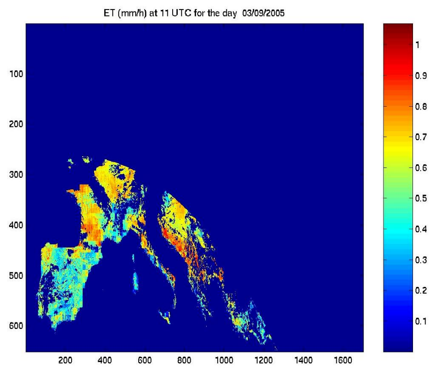
$$LE = \sum \zeta_i LE_i$$

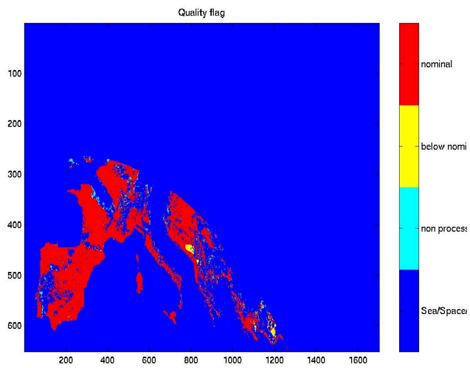
INPUT DATA

In the current version of the algorithm, the variables LST, DSSF, DSLF, AL are taken from corresponding LSA-SAF products. Meteorological data (air temperature, wind speed, dew point temperature, soil moisture, air pressure) are retrieved from the European Centre for Medium-range Weather Forecasts (ECMWF) analyses and forecasts. The land cover database is the International Geosphere-Biosphere Program (IGBP) database, the tiles parameters (ζ_i, r_c, LAI, …) are defined as in the TESSEL model, updated for the IGBP land cover classes.

MODEL OUTPUT

The model output consists in the evapotranspiration map over Europe, for the clear pixels plus a quality flag map containing information about the quality of the ET product based mainly on the quality of input data. Cloudy areas and northern latitudes are not processed in the current version of the model as LST variable from LSA-SAF is needed but is not produced in these cases.





OUTPUT VALIDATION

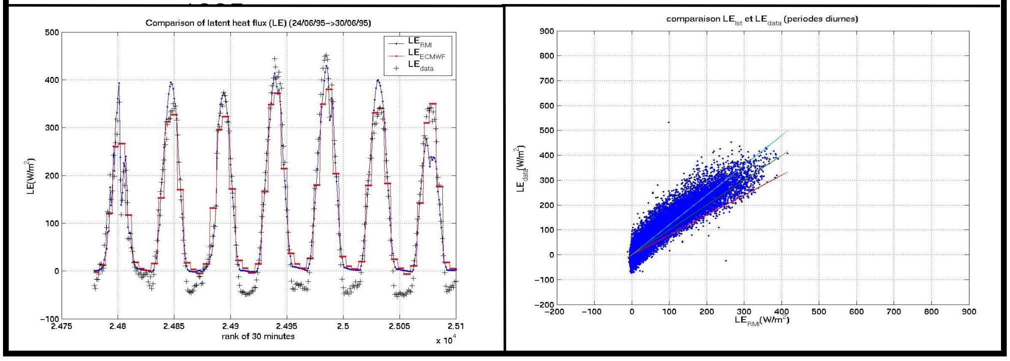
The validation presented here consists in the comparison of the output of the model with reference values obtained at meteorological stations and from measurement campaigns. As LSA-SAF fluxes are not available for past field campaigns, the measured radiative fluxes are used instead. The meteorological variables are taken from ECMWF MARS archives. Time step is either 30 minutes or 1 hour, depending on data availability.

The following figures present examples of time series and scatterplots of the comparisons of model output to in situ measurements in different station in the world: Cabauw (NL), FIFE (USA), Boreas (CA), Santarem (BR), HAPEX-MOBILHY (FR).

CABAUW

CABAUW (the Netherlands), 1987, 1995 and 1996

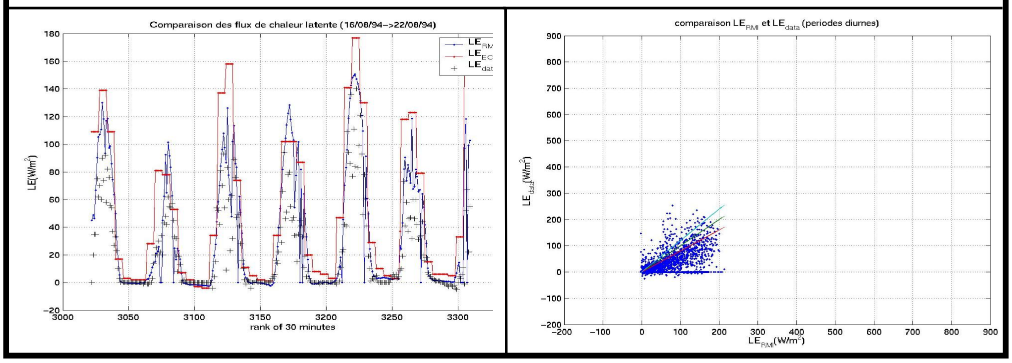
Time series 31 07 to 7 08



BOREAS

Boreas (Canada) #8 data set, from May to June 1994

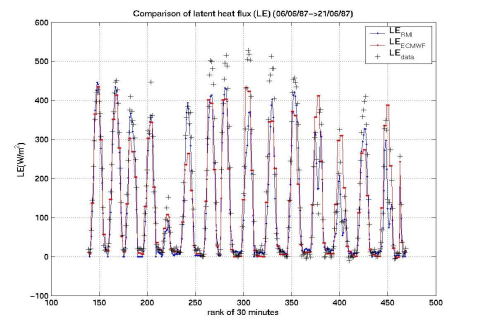
Time series 16 08 to 26 08

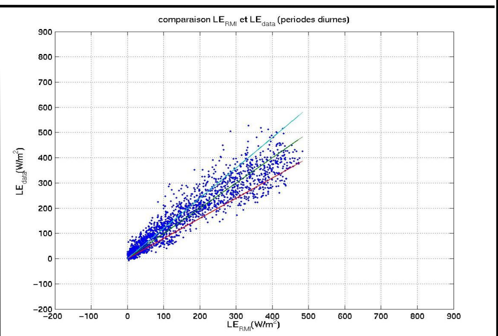


FIFE

FIFE (USA) , June

06/06 to 21/06 1987

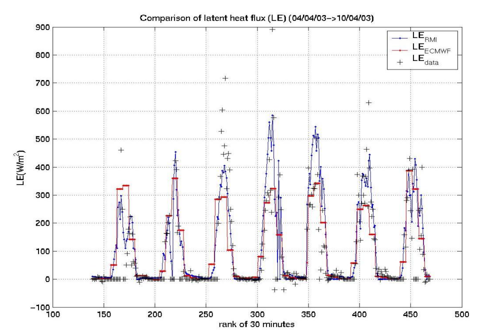


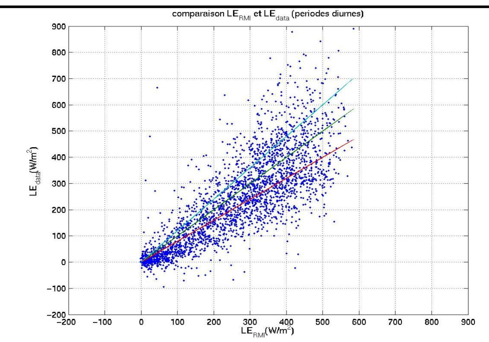


SANTAREM

Santarem (Brazil), 04 to 09 2003

26/06 to 01/07 2003

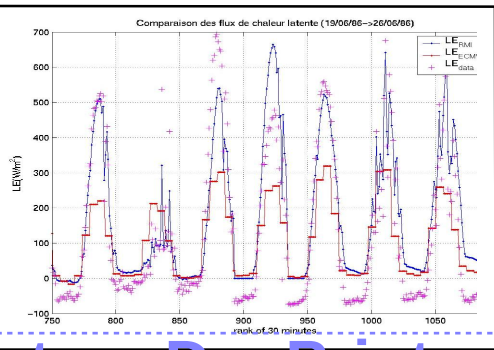


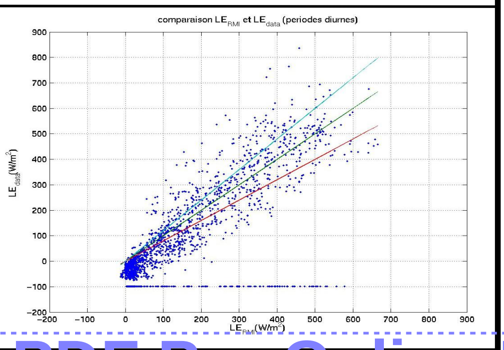


HAPEX-MOBILHY

Hapex-Mobilhy , June to july 1986

19/06 to 26/0 1986





In general, the simulated values are in good agreement with the observed at stations and campaigns reference values. Comparisons with ECMWF previsions are also shown.

CONCLUSIONS

- When aiming at large scales (regional, continental, global) estimation of the water flux between the soil-canopy system and the atmosphere, satellite remote sensing stays the only tool able to provide, at the same time wide area coverage and high temporal repetition rate at economically affordable costs.

- The current version of the algorithm has been validated with data from meteorological stations in different geographical regions. The objective was two-fold: on one hand to assess the accuracy of the proposed method, and on the other hand to evaluate the pertinence of extending it to other geographical zones.

- One of the principal problems to which we have been confronted for the validation of the ET product, based on in situ observations, is the unknown quality of the measurements and the non-closure of the energy balance.

- From the current validation, we remark that for stations considered to provide good quality data and for which the energy balance is closed, the simulation of the ET model are very close to observations.

- New improvements to the method will come from the use of additional variables from LSA-SAF (i.e. vegetation parameters) and from recent land cover databases. In this way, vegetation phenology and geographical properties will be better reflected. Currently the use of the ECOCLIMAP (Masson, et al., 2003) database is investigated and a new version of the model is under test.

BIBLIOGRAPHIC REFERENCES

ARBOLEDA A., HANTON P., GELLENS-MEULENBERGHS F., 2003) Assessment of the evapotranspiration and surface fluxes in the framework of the land-saf: methodology and first results. Proceedings of The 2003 EUMETSAT Meteorological Satellite Conference (Weimar, Germany, 29.09 - 03.10, 2003), pp 244 - 251.

BELJAARS A. C. M. and BOSVELD F. C., (1997) Cabauw data for the validation of land surface-parameterisation schemes, Journal of Climate, 10, pp 1172-1193.

MASSON, V., et al. (2003) : A global database of land surface parameters at 1-km resolution in meteorological and climate models, J. Climate, 16, 1261-1282

PIEROUX D., DEBAL F., GELLENS-MEULENBERGHS F., QUINET A., 2001) Estimation of evapotranspiration all over Europe using MSG remote sensing. Proceedings of The 2001 EUMETSAT Meteorological Satellite Data Users' Conference (Antalya, October 2001), pp 121-128.

VAN DEN HURK B., VITERBO P., BELJAARS A., BETTS A., (2000) Offline validation of the ERA40 surface Scheme. ECMWF Technical Memorandum No. 295, 42 pp.