Data assimilation: effect of agricultural land-use modifications on surface fluxes and microclimate

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Rice field in northern Thailand. Photo: Tanja Suni.

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Evapotranspiration (evaporation from surfaces and transpiration by plants) and microclimate depend on feedback effects between the land surface and the atmosphere and on the spatial and temporal variability of surface characteristics. Therefore, land-use modifications such as crop rotation and reduction or increase of irrigation may have a significant effect on regional climate and water resources.

In order to determine such dependencies and to predict microclimate and land-surface fluxes, we developed a coupled planetary boundary layer – land-surface model (named PBLs [1]) which takes into account landscape heterogeneity. The developed model combines a "Big Leaf" formulation of the surface fluxes (the whole vegetation is approximated as one big "leaf") and a simplified representation of the atmospheric boundary layer [2]. It can predict the evolution of microclimate and land-surface fluxes such as evapotranspiration throughout the day.

The PBLs model considers the heterogeneity of the land surface by dividing the area in patches ("tiled approach"), each with particular characteristics of main vegetation. Some of these, such as the leaf area index (LAI) and albedo, can be estimated from remote sensing images in the solar domain [3]. On the other hand, some important characteristics such as the soil moisture in the root zone and the aerodynamic roughness are impossible to determine directly. To solve this problem, we implemented a meteorological method of variational data assimilation (VDA) [4] into PBLs.

In the VDA method, we defined a cost function "J" that included observed surface temperatures T_s (from thermal infrared images), a priori information (deduced from climatology or expert knowledge) of the desired parameters (aerodynamic roughness and soil moisture), and information of measurement errors. The VDA method minimised J and obtained values for aerodynamic roughness and soil moisture by adjusting them until the observed T_s and the T_s estimated by PBLs were consistent. These values were then included in the patch characteristics in PBLs.

An intensive experiment was conducted in 2006 over the Crau-Camargue region in south-eastern France with numerous ground and airborne measurements [1].

Among the various satellite data recorded during this period, 32 FORMOSAT-2 images were acquired from March to October with a time step of 3 days at a spatial resolution of 8 m, which allowed us 1) to derive accurate information of the vegetation structure such as LAI and f_{cover} (the fraction of green vegetation covering a unit area of horizontal soil) for the patches [5] and 2) to detect the main agricultural practices such as the cut dates of irrigated meadows [1].

In order to estimate evapotranspiration in the region, we mapped the spatial variability of LAI and agricultural practices and used them as input data into two model types: a) the PBLs model with and without VDA and b) a crop model STICS [6] which takes into account the spatial variability of agricultural practices and predicts some future scenarios in case they are modified (used as input to PBLs if no measurements are available). Finally, we compared the evapotranspiration estimates from PBLs and from PBLs+VDA to measurements and found that PBLs+VDA gave better estimates (Fig. 1).

The simulated surface fluxes by PBLs+VDA showed great spatial variation because of differences in soil moisture and surface roughness - both highly dependant on the agricultural practices performed in the region. We concluded that 1) even at a small scale, different crop types and agricultural practices induce significant variations both on temperature and surface fluxes; 2) in order to accurately assess their influence on climate and agricultural production, detailed information of the agricultural practices is necessary.

At the moment, coupling between our two models is passive (output of crop model STICS is used as input for PBLs). However, development of a more integrated approach is in progress. ■

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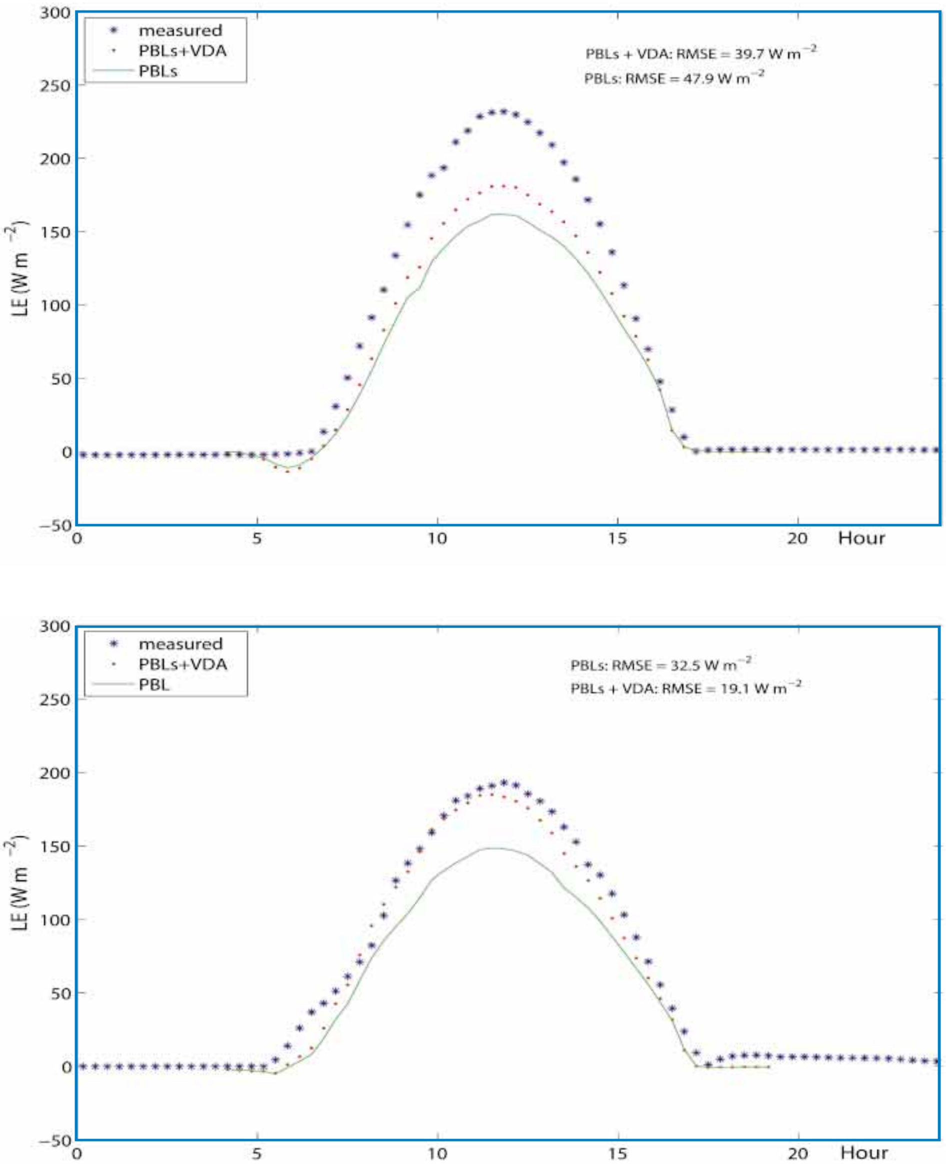

Figure 1. Model estimates of evapotranspiration (latent heat flux LE) compared to measurements over wheat crops in Alpilles – ReSeDA region. (*top*) 26 Mar 1997 (*bottom*) 18 Apr 1997. Root mean square error (RMSE) is given for PBLs only and for PBLs+VDA.

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