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Monitoring daily evapotranspiration at a regional scale combining a two-source patch model with satellite data

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The determination of evapotranspiration is a very important issue in meteorology, climatology, and hydrology studies, but the direct measurement of this parameter is usually difficult. In recent years a variety of methods based on remote sensing techniques have been proposed for estimating this surface flux. In this work, we present a micrometeorological approach for estimating surface energy fluxes that can be operationally used together with satellite images to monitor surface energy fluxes at a regional scale. In particular, we will focus on the retrieval of daily evapotranspiration because of its particular significance in the generation of precipitation or in agricultural water resource management. The proposed model is based on a two-source patch representation of the soil-canopy-atmosphere system, which permits estimation of surface fluxes under partial canopy cover conditions directly from component soil and canopy temperatures. The difference with the two-layer models is that in the patch scheme there is a real weighting of the soil and canopy elements and no direct coupling is allowed between soil and vegetation. The feasibility of the model is firstly explored at a local scale using data collected over two completely different ecosystems: a maize (corn) crop in Beltsville, Maryland, USA, and a boreal forest in Finland. This works focuses on the data registered in the corn field during an experimental campaign carried out in the summer of 2004, encompassing all the stages in the corn growing season, from the plant emergence to the cob formation. A measurement campaign was also performed from April to June of 2002 at Sodankylä, in a northern boreal forest area of Finland. Analysis of the energy balance yields a closure ratio around 0.9 in both ecosystems, indicating that approximately 10% of the estimated available energy is not accounted for. Comparison of the model results with ground measurements shows errors between 15 and 60 W m-2 for the retrieval of net radiation, soil heat flux, and sensible and latent heat fluxes in both sites. The residual technique, using measured values of the sensible heat flux and assigning all closure error to the latent heat flux, yields the best agreement between modeled and measured fluxes. For operational monitoring over regional scales, using satellite-derived inputs and non-local meteorological data, uncertainties in the inputs of the model may lead to significant errors in estimated fluxes. To assess the impact of typical errors in remotely derived model inputs, a sensitivity analysis is performed. Errors in radiometric and air temperatures show the greatest impact on the modeled sensible heat flux. These inputs, together with the incoming shortwave and long-wave radiation, have the greatest effect on the evapotranspiration retrieval, always showing relative errors below 25% on average. The model uncertainty is also investigated as a function of the vegetation cover. A detailed methodology to apply the model to Landsat imagery is presented. The different surface cropland features are characterized from CORINE Land Cover maps, and the required meteorological variables are obtained by interpolating the data of a network of agro-meteorological stations distributed within the region of interest. Finally, we show the application of the methodology to three Landsat scenes, acquired in different dates, covering the whole Basilicata region (Southern Italy), two from Landsat 7-ETM+, and one from Landsat 5-TM. Maps of the different fluxes including the daily evapotranspiration are generated. An analysis of the results is made taking the land use classification as a basis, and differences between the different types of vegetation and dates are stated. To assess the performance of the method, evapotranspiration results are compared with some punctual lysimeter measurements. To reinforce the assessment at a wider scale, data from the CarboEurope project dataset is used. Accuracy close to 1 mm day-1 is finally obtained. Even though a more complete network of ground-measured values, spatially distributed around the study region and representative of the different land uses, would be desirable for a robust validation, the results obtained give some confidence on the proposed methodology to evaluate daily evapotranspiration at a regional scale.