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Spatio-temporal soil heat flux estimates from satellite data; results for the AMMA experiment, Fakara supersite.

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The soil heat flux, G, is an important component in the energy balance, especially for sparsely vegetated (semi)-arid regions. In order to obtain large-scale estimates of this flux, for example for land surface model (e.g. GCM) verification, scientists have to rely on remote sensing data. Unfortunately, in these cases G is often estimated using highly empirical methods. Examples are relationships between the ratio of G and net radiation, Rn, and surface variables such as leaf area index (LAI). Other approaches use surface temperature observations to get maximum G/Rn values. However, such approaches are not universal.

In Murray and Verhoef 2007a&b we proposed to use a standard physical equation, involving a harmonic analysis of surface temperatures for the estimation of G, in combination with a simple, but theoretically derived, equation for soil thermal inertia (TI). This method does not require in situ instrumentation. Moreover, such an approach ensures a more universally applicable method than those derived from purely empirical studies.

This method requires knowledge of soil texture, in combination with an estimate of near surface soil moisture content, SM, to obtain spatio-temporal variation in thermal inertia. To get the diurnal and seasonal shape of G we ideally need time series of soil surface temperature, Ts. However, when vegetation obscures the surface these are not available through remote sensing. Therefore, a direct relationship between the harmonic analysis of Ts (Hs) and the harmonic analysis (Hb) of the remotely observed brightness temperature, Tb, obtained from remote sensing equipment was used instead. This relationship was tested for 4 different UK crops in Murray and Verhoef (2007b). Knowledge of LAI, canopy extinction coefficient and IR sensor view angle is required to go from Hb to Hs. To account for phase lag differences between Hs and Hb a time delay of 1.5 hrs was used.

Here, the method is used to calculate spatiotemporal soil heat fluxes for the Fakara supersite domain in the framework of the African Monsoon Multidisciplinary Analysis (AMMA) program. MSG-SEVIRI land surface temperature (spatial resolution at nadir 3 x 3 km, temporal resolution 15 mins, averaged to half-hours, time period 13 July to 31 December 2005) and ENVISAT-ASAR soil moisture products were used to derive Tb and SM. The seasonal evolution of LAI was derived from SPOT-HRV. Soil texture was obtained from existing soil maps. Verification soil heat fluxes were provided by a meteorological station installed at the Fakara experimental site, called Wankama (Ramier et al., 2009). The MSG file contains 266 records (grid points over the super site domain, although only 190 were left once those pixels containing significant water bodies were removed) containing each 16512 values of temperature (172 (days)x 24 x 4 time steps). Soil moisture and LAI images over the same domain were available on 7-8 (non-corresponding) occasions between 13 July and 31 December 2005. Daily estimates of LAI and SM were obtained from interpolation.

Results revealed a large spatial variability in soil heat flux, mainly dependent on the relative fraction of surface components at each pixel (e.g. plateaus bare soil, plateaus vegetation, crops, recent and old fallows) and corresponding pixel-averaged LAI. SM affected thermal inertia, but estimates of SM, and hence TI appeared to

be on the low side, thereby probably underestimating G, although estimated and measured G compared relatively well. Overall, the method appeared promising and work is underway to determine G over the entire AMMA domain in the context of the ALMIP project.

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