Interactive comment on "Impact of gravels and organic matter on the thermal properties of grassland soils in southern France" by J.-C. Calvet et al.

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General comments:

This paper investigates the influences of quartz fraction, soil organic matter (SOM) and gravel component on soil thermal conductivity. Field observations of soil temperature and water content from 21 weather stations in southern France, along with the information of soil texture and bulk density, were used to estimated soil thermal diffusivity and heat capacity, and then thermal conductivity. The quartz fraction was inversely estimated with an empirical thermal conductivity model. A pedotransfer function was further proposed for estimating quartz content from soil texture information. The effects of SOM and gravels on thermal conductivity values were also discussed.

The information of quartz fraction in a soil is usually unavailable but has a major effect on the accuracy of many thermal conductivity models and their applications in other comprehensive model (e.g., the land-surface models). Therefore, the topic is interesting and has general applications in soil sciences and related areas. However, I have some concerns about the current approach for estimating soil thermal properties and quartz content, the presentation of the results, and the conclusions.

First, the method presented in the paper is based mainly on the 1D heat transfer equation and the de Vries (1963) mixed model for soil heat capacity. The authors estimated the apparent soil thermal diffusivity at 10-cm depth from temperature measurements at 5, 10, and 20 cm depths, and calculated soil heat capacity from the information of soil texture, bulk density, and water content at 10 cm. To apply the 1D Fourier heat transfer equation, they assumed that the soil physical properties were uniform and isothermal in the 5-20 cm layer, which was not the case. They stated that "soil properties are relatively homogeneous", but it is difficult to accept this because 1) at least 14 soils had a gravel fraction over 10% (as high as 70% in some soils); 2) there were strong soil moisture and temperature gradients in the 0-20 cm layer; and 3) the existence and spatial distribution of grass roots were ignored. The authors are required to convince the readers that the 0-20 cm soil layer was uniform, and soil temperature and water content measurements at each depth were representative values of the depth. Otherwise, the soil thermal diffusivity estimates are flawed, and further analysis is invalid.

Second, the de Vries (1963) mixing model was applied to estimate soil volumetric heat capacity. To do so, a fixed value of 2.0 MJ m^{-3} K^{-1} was used for soil solids. The authors should give justification to use a constant value for the 21 soils with different textures. Tarara and Ham (1997) used a value of 1.92 MJ m^{-3} K^{-1}. A soil-specific value may be better for estimating the volumetric heat capacity of soil solids. In addition, what were the volumetric fractions of grass roots in the 0-20 cm soil layer? Does the heat capacity of grass roots have a significant influence on the bulk soil heat capacity?

Third, no independent data or measurements were used to evaluate the estimates of soil thermal conductivity and quartz fraction. In Table 2, for example, the estimated thermal conductivity values for saturated soils ranged from 0.52 to 2.79 W m^{-1} K^{-1} for 15 soils, all were much lower than the published results of Lu et al. (2007) and Tarnawski et al. (2011). The authors may need to verify the results by compare the model estimates against thermal conductivity measurements with the line-source probe or the heat pulse technique.

Finally, I do not think the empirical equations (13) and (14), and related results and discussion, are related to and helpful for the purpose of this paper.

Specific comments:

The current title does not fully represent the content of this paper. The title talks about the effects of gravels and organic matter on soil thermal conductivity values. In the text, on the other hand, the authors spent a lot effort on discussing the influences of quartz content on soil thermal conductivity. The title also addresses the grassland soils, but the detailed information about grass cover and roots was missing.

Page 739 Line 7-8: The authors stated that soil thermal conductivity was hard to obtain directly and in situ. This is not true today. Recent advances in line-source probe and heat pulse method have made it easy to monitor soil thermal conductivity in the field (e.g., Bristow, K.L., G.J. Kluitenberg, and R. Horton. 1994. Measurement of soil thermal properties with a dual-probe heat-pulse method. Soil Sci. Soc. Am. J. 58:1288–129; Zhang, X., J. Heitman, R. Horton and T. Ren. 2014. Measuring near-surface soil thermal properties with the heat-pulse method: correction of ambient temperature and soil–air interface effects. Soil Sci. Soc. Am. J. 78:1575–1583].

The authors may also include the reference of Bristow (1998) who investigated the influences of quartz fraction on soil thermal conductivity.

Page 740 Line 21: Fig. 2 should be cited as Fig. 3 here.

Page 740 Line 23-26: How were gravel and SOM contents determined? Grass roots may also influence soil thermal conductivity and heat capacity in the shallow soil layers, but were ignored in the paper. Please give supporting evidence about this. In addition, what depth was bulk density measured? Did soil bulk density differ with depth?

Page 741 Line 17: ‘Figure 3’ should be ‘Figure 2’.

Sect. 2.5: The estimated thermal conductivity values were used to retrieve quartz content data using the empirical thermal conductivity models. Leong et al. (2009) tried to use the Lu et al. (2007) model to inversely estimate quartz content in soil samples. In this work, the authors used the Yang et al. (2005) model. Please explain why the Young et al. (2005) model was used, and how the quartz content estimates from the two models may differ.

Sect. 2.6: More in-depth explanations are required to explain the calculation of quartz content.

Sect. 3.2: I am not sure how useful to develop the pedotransfer functions for estimating quartz content. It is apparent that all errors in the measurement (e.g., temperature, water content, bulk density, and gravel fraction) and calculations (thermal diffusivity and heat capacity) have been included in the results of quartz content. In addition, I had a hard time to figure out how quartz content was related to the fraction of soil organic matter (Eq. [12]).

Sect. 4.2: The authors suggested that the very low values of quartz content might be caused by (1) the natural heterogeneity of soil properties, (2) the living root biomass, and (3) stones that were not accounted for in the gravel fraction. All these factors lead to inaccurate estimates of soil thermal diffusivity and heat capacity. Therefore, I wonder if it is correct to include all the 21 stations in this work. On those soils with high fractions of gravel (and stones) and grass roots, it is impossible to obtain representative temperature and water content data at each depth, and it is inappropriate to apply the 1D heat transfer equation to estimate soil thermal diffusivity.

Most symbols in this paper are not properly defined.

Table 1: The soil texture should be mentioned together with the particle size distribution.

Figure 2 and 3 do not match with their captions.

Figure 4: How were the solid lines obtained? For the SBR site, why a large variation in thermal conductivity was observed in a narrow range of degree of saturation? How come a gravel soil (the PRD site) had very low thermal conductivity in the degree of saturation range of 0.4-0.5 range?

References:

Horton, R., Wierenga, P.J., 1983. Estimating the soil heat flux from observations of soil temperature near the surface. Soil Sci. Soc. Am. J. 47, 14–20.

Bristow, K.L. 1998. Measurement of thermal properties and water content of unsaturated sandy soil using dual-probe heat-pulse probes. Agric. For. Meteorol. 89:75–84.

Tarara, J.M., and J.M. Ham. 1997. Measuring soil water content in the laboratory and field with dual-probe heat-capacity sensors. Agron. J. 89:535–542.

Lu, S., T.S. Ren, Y.S. Gong, and R. Horton. 2007. An improved model for predicting soil thermal conductivity from water content. Soil Sci. Soc. Am. J. 71:8–14.

Leong W. H., ·V. R. Tarnawski ·T., Momose. 2009. Assessing the impact of quartz content on the prediction of soil thermal conductivity. Géotechnique 59:331-338.

Tarnawski V. R., T. Momose , W. H. Leong. 2011. Thermal Conductivity of Standard Sands II. Saturated Conditions. International Journal of Thermophysics. 32: 984-1005.