Subject offered for a contract starting october 2015

SUBJECT TITLE: Modeling spectral and bidirectional soil reflectance as a function of soil water content and surface roughness

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Soil moisture is a key parameter in agriculture, meteorology or defense. In agriculture, it provides information that help monitor soil-water-plant conditions and manage irrigation. In meteorology, it has an effect upon incident radiation distribution and, indirectly, temperature and evaporation. Finally, in defense or homeland security, trafficability partly depends on surface characteristics such as soil wetness that can be critical to the success of a military or humanitarian operation.

Soil water content is measured either in the laboratory (gravimetric method) or in the field (portable neutron probe or capacitance probe). Such measurements are reliable but their footprint is small, a few square meters; moreover water content varies rapidly both in time and space due to the spatial variability of soil physical properties and to the discontinuous nature of rainfalls. In order to extend these measurements over large surfaces repeatedly, remote sensing monitoring is the appropriate tool. Up to now most research has focused on thermal infrared (surface temperature) or radar (backscattering coefficient) remote sensing. Meanwhile the solar domain between 0.4 and 3 μm has been little intestigated. In addition, the representativeness of the measurement when scaling up from the lab or field level to the airborne or satellite level is rarely discussed.

Soil reflectance is controlled by many factors such as texture, mineralogy, organic matter, water content, surface roughness, etc. (Bowers & Hanks, 1965). The variation in soil reflectance as a function of soil moisture has been studied for fifty years through empirical or semi-empirical models (Lobell & Asner, 2002 ; Liu et al., 2002 ; Whiting et al., 2004 ; Haubrock et al., 2008 ; Somers et al., 2010 ; Lesaignoux et al., 2013). However, most of them are not generalizable because knowledge of parameters, like soil density or porosity in the field, or granulometry in the lab, is required.

Physical models are sorely needed. Lekner & Dorf (1988) and Bach & Mauser (1994) considered a wet soil as a dry soil covered with a thin film of water; then they calculated the multiple reflections between the two environments to derive the albedo of a bare soil as a function of its water content; Kimmel & Baranoski (2007) developed a ray tracing model taking into account physical and mineralogical properties of a sandy soil; Finally Jacquemoud et al. (1992) tested and extended the Hapke's model to the whole solar spectrum. None of these models, however, has been validated in natural conditions over a wide range of soils.

The objectives of this thesis are the development and validation of a radiative transfer model capable of calculating the bidirectional reflectance of a bare soil in the optical domain, based on its water content and, as a secondary factor, its surface roughness. The PhD student will focus on the determinism of the spectral variation of the single scattering albedo depending on soil water content. First, a laboratory study of the impact of surface roughness and soil moisture on spectral and directional reflectance will be conducted to establish the theoretical model. This study will then be extended to airborne images, where these impacts will be analyzed on a larger scale. Particular attention will be paid to the representativeness of the soil moisture measurement in the field compared to the amount extracted by remote sensing.

Applicant profile

Engineer or student (s) with a Masters in Physics / Geophysics / Remote Sensing; interest in terrestrial and planetary surfaces, modeling of radiative transfer, radiometric measurements.

References

Bach H. and Mauser W. (1994), Modeling and model verification of the spectral reflectance of soils under varying moisture conditions, in *Proc. 14th International Geoscience and Remote Sensing Symposium (IGARSS'94)*, Pasadena (CA), 8-12 August 1994, IEEE, Vol. 4, pp. 2354-2356.

Bowers S.A. and Hanks J. (1965), Reflection of radiant energy from soils, *Soil Science*, 100(2):130-138.

Haubrock S.N., Chabrillat S., Lemmnitz C. and Kaufmann H. (2008), Surface soil moisture quantification models from reflectance data under field conditions, *International Journal of Remote Sensing*, 29(1):3-29.

Jacquemoud S., Baret F., Hanocq J.F. (1992), Modeling spectral and bidirectional soil reflectance, *Remote Sensing of Environment*, 41(2-3):123-132.

Kimmel B.W. and Baranoski G.V.G. (2007), A novel approach for simulating light interaction with particulate materials: application to the modeling of sand spectral properties, *Optics Express*, 15(15):9755-9777.

Lekner J. and Dorf M.C. (1988), Why some things are darker when wet, *Applied Optics*, 27(7):1278-1280.

Lesaignoux A., Fabre S. and Briottet X. (2013), Influence of soil moisture content on spectral reflectance of bare soils in the 0.4-14 µm domain, *International Journal of Remote Sensing*, 34(7):2268-2285.

Liu W., Baret F., Gu X.F., Tong Q., Zheng L. and Zhang B. (2002), Relating soil moisture to reflectance, *Remote Sensing of Environment*, 81(2-3):238-246.

Lobell B.B. and Asner G.P. (2002), Moisture effects on soil reflectance, *Soil Science Society of America Journal*, 66(3):722-727.

Somers B., Gysels V., Verstraeten W.W., Delalieux S. and Coppin P. (2010), Modelling moisture-induced soil reflectance changes in cultivated sandy soils: a case study in citrus orchards, *European Journal of Soil Science*, 61:1091-1105.

Whiting M.L., Li L. and Ustin S.L. (2004), Predicting water content using Gaussian model on soil spectra, *Remote Sensing of Environment*, 89(4):535-552.