Subject offered for a contract starting October 2019

SUBJECT TITTLE: **Modeling soil spectral and directional reflectance as a function of water content**

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Soil moisture content is an essential variable in the critical zone. It has multiple applications in domains as diverse as agriculture, forestry, ecology, continental hydrology, micrometeorology, defense and planetology. Water is present in soil in several forms: (1) constitutional water in the hydrated minerals or the phyllosilicates; (2) capillary retention water in soil microporosities; and (3) gravity water that fills the soil macropores. To date there is no standard method for measuring soil water content. On the other hand, water varies rapidly in space and time due to the spatial variability of the physical properties of soils, the discontinuous nature of precipitations and the flow dynamics. Spaceborne or airborne remote sensing allows to cover large areas repeatedly. Unlike measurements in the microwaves (backscattering coefficient) that determine water content in the first centimeters of the soil, the solar domain between 0.4 and 3 µm (reflectance) offers the possibility of determining surface water content because sun rays are very little penetrating.

A simple radiative transfer model called MARMIT (Multilayer Radiative Transfer Model of Reflectance) was developed in the framework of Aurélien Bablet's thesis (ONERA-IPGP). It simulates the spectral reflectance of a "smooth" soil in the solar domain as a function of its mass water content. It has been validated on 217 samples of natural soils (agricultural or forest land, sand, etc.) and artificial soils (urban or industrial sites, contaminated soils, minerals, etc.) coming from seven independent data sets and covering a wide range colors and textures. Although the MARMIT model allows to estimate the water content of a soil with good accuracy, the fit between the modeled and the measured reflectance spectrum is not totally satisfactory; it does not simulate the BRDF (*Bidirectional Reflectance Distribution*

Function) of rough soils for different illumination and viewing angles; finally it has not been validated on field measurements or satellite images.

This thesis aims to fill these gaps: a new radiative transfer model simulating the spectral and directional reflectance of a natural soil at different levels of humidity and surface roughness will be developed and validated on the basis of MARMIT. This will involve theoretical work on the complex refractive index of soil constituents (effective medium theory, Kramers-Kronig relations) and on radiative transfer in porous media (Hapke model). This will involve the acquisition of new remote sensing data in the laboratory, in the field and the use of airborne or satellite images to spatially extend the results. Finally, this will involve scientific collaborations with French (IPAG, INRA, CEA) or foreign (Cornell University, University of Arizona, Utah State University) research laboratories.

Applicant profile

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

References

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