IMPACT OF SURFACE HUMIDITY ON THE SPECTRAL SIGNATURE OF INDUSTRIAL AND MINING MINERALS - IMPLICATIONS FOR THEIR DETECTION BY HYPERSPECTRAL IMAGING

Erica UCCELLATORI[1,2], Stéphane JACQUEMOUD[1] , Rodolphe MARION[2]
[1] Université Paris Cité, Institut de Physique du Globe de Paris, CNRS, 75005 Paris, France
erica.uccellatori01@universitadipavia.it, jacquemoud@ipgp.fr
[2] CEA/DAM/DIF, F-91297 Arpajon, France, rodolphe.marion@cea.fr

1. Context and Objectives

Spectroscopy is a tool that measures the absorption or emission of light as a function of wavelength. It can be used to detect, quantify and map minerals and other chemical compounds. Soil moisture content (SMC) is a key variable on the Earth's surface. Its estimation is essential in many fields such as agriculture, hydrology, climate, defense or planetary sciences [1]. The reflectance of dry soils is the spectral signature of certain chemical or mineralogical elements. When the soil becomes wet, the reflectance decreases at all wavelengths of the solar spectrum, the diagnostic absorption features of the minerals of interest tends to disappear, and additional water absorption bands appear in the near infrared (NIR, 750-1300 nm) and shortwave infrared (SWIR, 1300-2500 nm) [2]. We need to define rules for the absorption characteristics required to detect the presence of the minerals of interest,

The aim of this study is to investigate the impact of moisture on the spectral signature of certain minerals of interest related to industrial and mining activities [3] and to analyze the implications for their detection by hyperspectral imagery.

2. Methodology

Measurement of reflectance spectra of several soil types with different SMC

→ Calibration of the MARMIT model and simulation of soil reflectance spectra → Validation of the approach with two hyperspectral images acquired over industrial sites

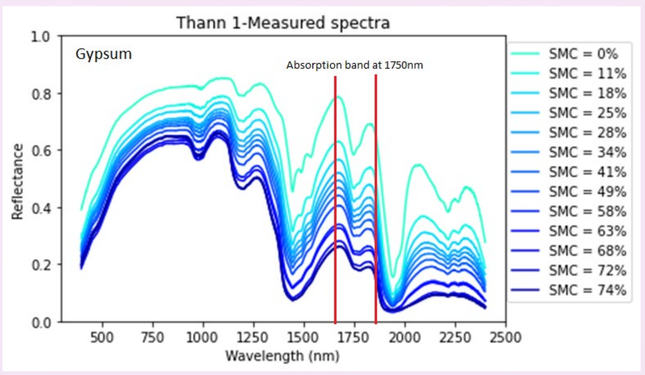
→ Definition of criteria related to the shape of the absorption bands of minerals of interest → Definition of a detection threshold for each mineral of interest

3. Instruments and Protocol Setup

ASD FieldSpec® 4 spectroradiometer covering the solar domain (400-2500 nm).

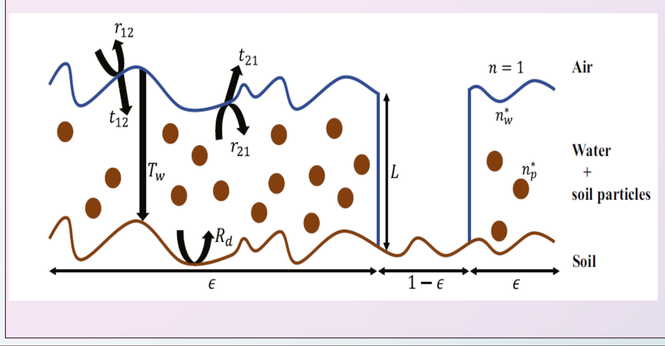
Database made up of 16 samples: 11 from Thann and 5 from Gardanne.
Thirteen different SMC were taken for each sample.
Each measurement is the average of 40 spectra.

4. Radiometric Measurements



When the soil is moistened, the reflectance continuum decreases for all wavelengths of the solar spectrum, diagnostic absorption bands disappear and other absorption bands appear.

5. MARMIT Model



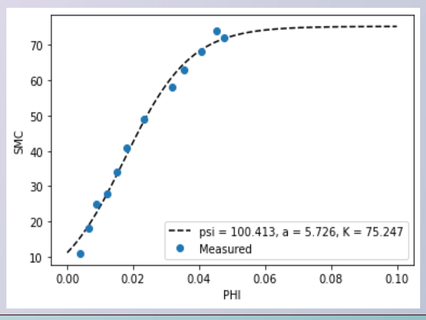
MARMIT [4] is a radiative transfer model that predicts the spectral reflectance of soils in the solar domain as a function of their surface moisture.

MARMIT 2 [5] has three input parameters:
- Water layer thickness L
- Wet soil fraction Ɛ
- Particle volume fraction δ

6. Calibration of the MARMIT Model

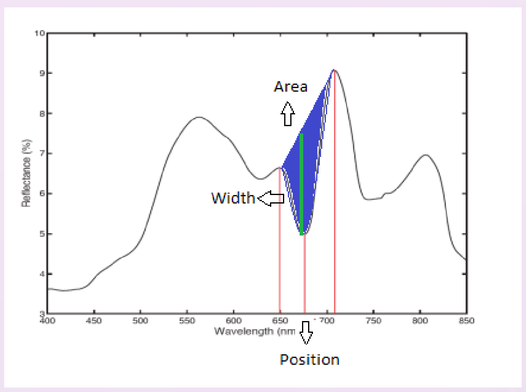
Soil sample: reflectance spectrum and associated SMC → Inversion step: estimation of the three parameters and mean water thickness φ = L x Ɛ → Calibration step: determination of the relationship between SMC and φ

$$SMC = \frac{K}{1 + ae^{-\psi\varphi}}$$



7. Impact of Water on Mineral Detection

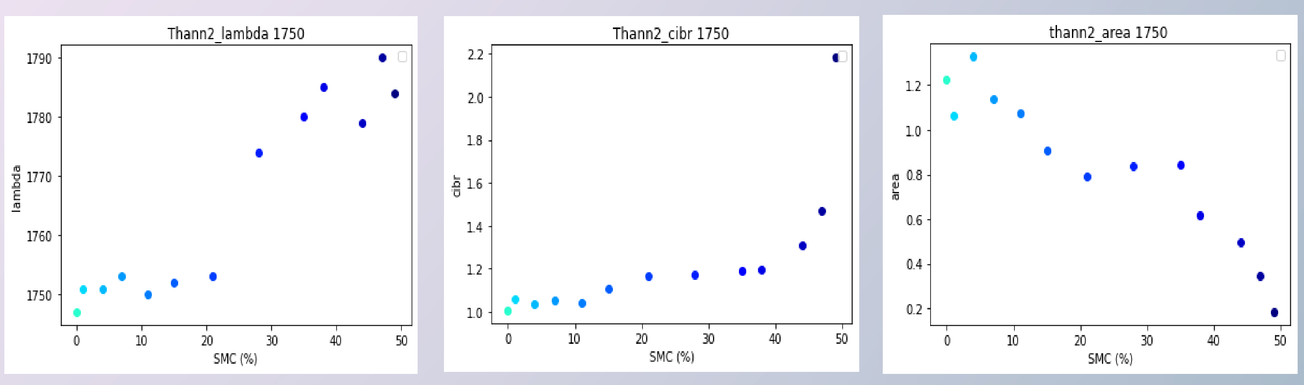
Three main parameters have been established on the absorption bands of minerals: wavelength position of the peak, depth and area.



To calculate the peak depth we used CIBR (Continuum Interpolated Band Ratio) with the following formulas:

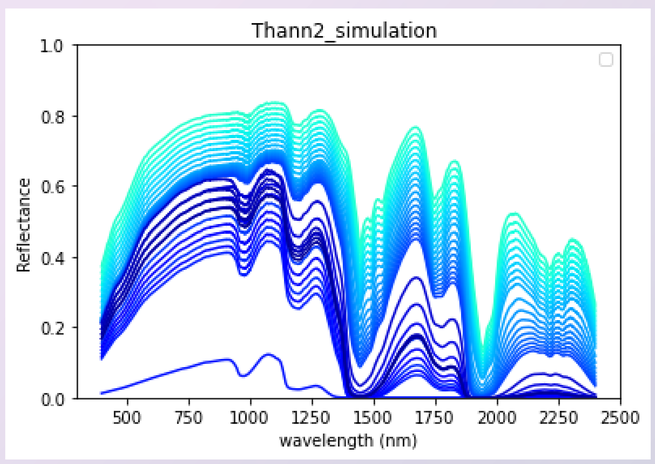
$$CIBR = \frac{R(\lambda_m)}{c_1 R(\lambda_{r1}) + c_2 R(\lambda_{r2})},$$

$$c_1 = \frac{(\lambda_m - \lambda_1)}{(\lambda_{r2} - \lambda_{r1})}, c_2 = \frac{(\lambda_{r2} - \lambda_m)}{(\lambda_{r2} - \lambda_{r1})}$$

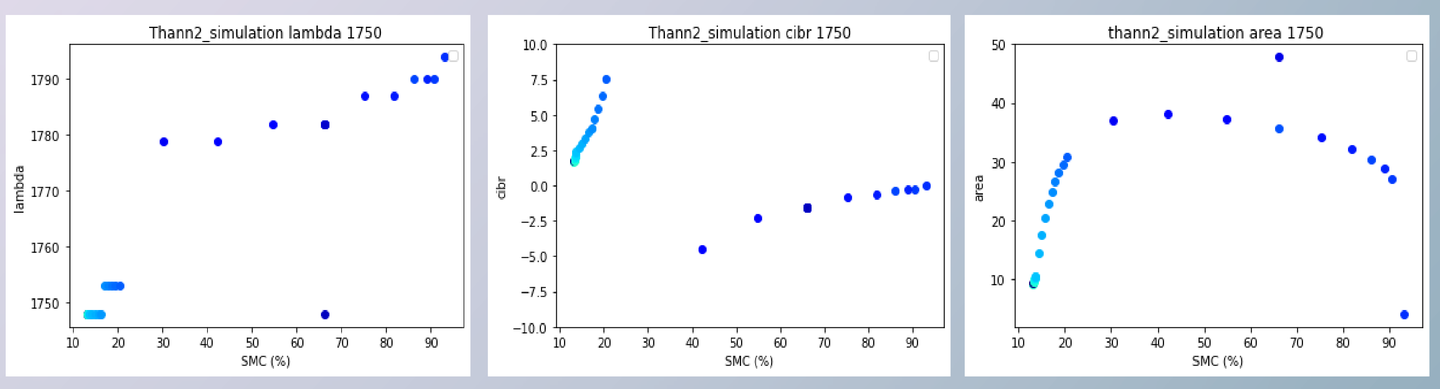


8. Preliminary Results: MARMIT Simulations

Simulation of 30 soil reflectance spectra, starting from the driest one.



L varies from 0.001 cm to 0.5 cm, Ɛ varies from 0.1 to 1.0, and δ is set to 0.005



The problem of MARMIT2 remains the dependence of the δ parameter and, consequently, the relationship between the three parameters.

[1] Susha Lekshmi S.U., D.N. Singh, Maryam Shojaei Baghini, A critical review of soil moisture measurement, Measurement, Volume 54, 2014
[2] Aurélien Bablet, Modelisation de la reflectance spectrale d'un sol nu en fonction de sa teneur en eau dans le domaine réflectif solaire, 2018, Doctorat de l'Institut de Physique du Globe de Paris
[3] Marion R., & Carrère V. (2018), Mineral mapping using the Automatized Gaussian Model (AGM)—Application to two industrial French sites at Gardanne and Thann, *Remote Sensing*, 10(1):146.
[4] Bablet A., Vu P.V.H., Jacquemoud S., Viallefont-Robinet F., Fabre S., Briottet X., Sadeghi M., Whiting M.L., Baret F., & Tian J. (2018), MARMIT: a multilayer radiative transfer model of soil reflectance to estimate surface soil moisture content in the solar domain (400–2500 nm), *Remote Sensing of Environment*, 217:1-17.
[5] Dupiau A., Jacquemoud S., Briottet X., Fabre S., Viallefont-Robinet F., Philpot W., Di Biagio C., Hébert M., & Formenti P. (2022), MARMIT 2: An improved version of the MARMIT model to predict soil reflectance as a function of surface water content in the solar domain, *Remote Sensing of Environment*, 272:112951.