Computationally Simulating Spectral Sensing of Planetary Surface Composition

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Key Points

We describe a number of methods and computational tools for simulating the measurement of reflectance spectra of planetary surfaces, and showcase the use of these tools in the development of upcoming spectral sensing systems for the ESA ExoMars Rosalind Franklin Rover and the JAXA Martian Moons eXploration spacecraft.

Abstract

Reflectance spectroscopy and spectral imaging are efficient methods for exploring the distribution of materials across a planetary surface. To be spectrally distinct, the materials of a given set must have distinct chemical and crystalline properties that result in statistically distinct signals across the spectral range and resolution of the sampling instrument. The statistical distribution of a material signal can depend on a number of properties, some intrinsic to the material (e.g. variation of grain size and chemical composition), some intrinsic to the instrument (e.g. counting and electronic noise), some intrinsic to both (e.g. scale of macroscopic mixing of materials compared to the instrument spatial sampling), and some extrinsic to both (e.g. atmospheric scattering, illumination incidence angle). This large parameter space of mostly uncontrollable properties is a challenge to the task of evaluating the ability of a spectral sensing system to distinguish a set of materials. We showcase a number of computational tools and methods we have developed for simulating spectral sensing, toward comprehensive controlled exploration of this large parameter space, for investigating the capabilities and defining the requirements of spectral sensing systems for planetary surface exploration. We showcase applications of simple Gaussian-distributed 1D resampling of laboratory-measured pure mineral reflectance spectra, for establishing and demonstrating fulfilment of requirements of forthcoming instruments (ExoMars Rosalind Franklin *Enfys* spectrometer, MMX *OROCHI* spectral imager), and for comparing the performance of equivalent systems (e.g. ExoMars RF PanCam vs. MSL *Mastcam* & M2020 *Mastcam-Z* spectral imagers), and more comprehensive 3D spectro-radiometric physically-based ray-tracing for simulating image formation.