Improvement of mineral mapping accuracy by increasing spectral band and spatial resolutions of multispectral optical sensor imagery

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Multispectral optical sensor images widely used in geologic remote sensing have covered all Earth land areas for a long time and vast data have been accumulated. However, their numbers of spectral bands are few (usually around ten) and spatial resolutions are relatively low, which decreases discrimination accuracy of mineral and rock types. Observation areas by hyperspectral imagery and high-resolution imagery are limited locally and costly. For this problem, this study aims to develop two transformation methods of general multispectral satellite imagery all over the scene into (1) hyperspectral imagery with many bands and (2) high spatial resolution imagery equivalent to the highest resolution level in the present geologic remote sensing, towards finally a simulation of hyperspectral, hyperresolution imagery for advanced exploration of metal and geothermal resources and precise monitoring of geologic environments. In this study, ASTER, AVIRIS, and WorldView-3 (WV-3) images were selected as representative multispectral (MS), hyperspectral (HP), and high spatial resolution (HSR) imagers, respectively. The spatial resolutions in the short-wave infrared region (SWIR), essential to discrimination of minerals, are ASTER: 30 m and WV-3: 7.5 m.

As for the first hyperspectral transformation, we use PHITA developed by the authors (Pseudo-Hyperspectral Image Transformation Algorithm: Hoang and Koike, 2017; 2018). This method is based on multiple regression model for correlations between MS and HP band reflectance data, and selects the best model through Bayesian model averaging. One pixel of MS image consists of several pixels of overlapped HP image (e.g., one pixel of ASTER = 4×4 pixels of WV-3 image). As for the second hyperresolution transformation, an assumption that a radiance at one pixel of MS image is summation of radiances at several, corresponding pixels of HSR image is set, and their relationship is quantified by a generalized additive model (Stasinopoulos et al., 2018) that is more versatile and rigorous than traditional multiple regression model.

A part of the Cuprite hydrothermal alteration area in the western United States for which ASTER, WV-3, and AVIRIS images were available was selected as training area for the two methods, and a principle of machine learning was adopted for the targeted Goldfield near Cuprite, a world-famous epithermal deposit area. An ASTER image in Cuprite was transformed into a pseudo-AVIRIS image by PHITA and their regression model was applied to an ASTER image of Goldfield. As the result, detection accuracies of hydrothermal alteration minerals such as alunite and kaolinite were largely increased. Four SWIR bands whose wavelengths were common between ASTER and WV-3 were used for the hyperresolution. By applying a correlation rule between the ASTER and WV-3 images obtained for Cuprite to Goldfield, the ASTER image of Goldfield was downscaled to the WV-3 resolution and consequently, mapping of minerals such as alunite was achieved more in detailed than the ASTER resolution. These two outcomes were verified by a ground-truth survey in 2018 and an XRD analysis of the samples by it, which demonstrates correctness and effectiveness of the proposed hyperspectral and hyperresolution methods.

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Keywords: Hyperspectral imagery, Hydrothermal alteration mineral, Multiple regression model, Short-wave infrared region, Cuprite, Goldfield