Spectral Mixture Analysis under Varying Illumination and Geometric Conditions

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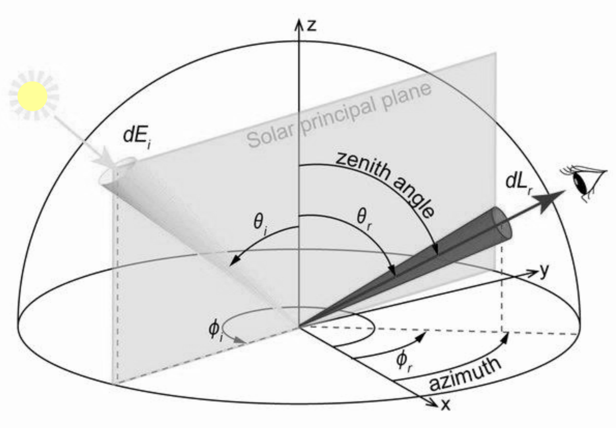
Introduction

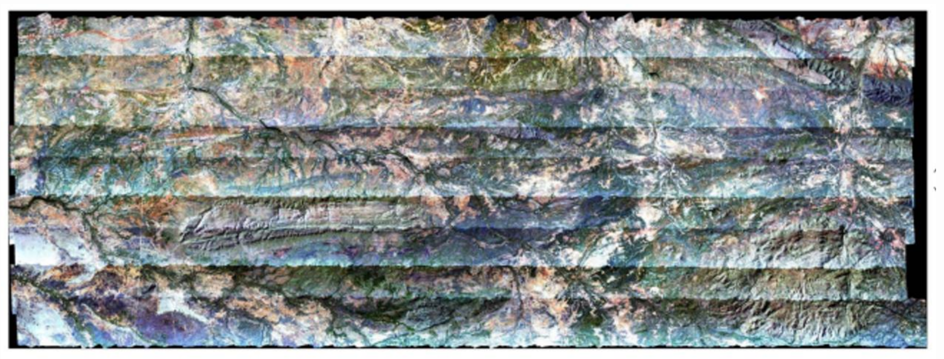
- The Bidirectional Reflectance Distribution Function (BRDF) describes how light reflects off material surfaces, significantly impacting remote sensing data interpretation. While extensive research addressed the BRDF effect and approaches to correct it, too few works have considered the influence of spectral mixture on the correction results.
- This study introduces a novel unmixing-based model, Ross-Thick-Maignan Li-Transit-Reciprocal Unmixing (RTM-LTR-UMx) [1], to correct BRDF effects in spectral data, particularly in mixed pixels. Unlike the traditional RTM-LTR semi-empirical kernel driven model, the proposed unmixing-based model incorporates endmember fractions within the BRDF kernels' weight estimation without requiring land cover classification.
- Experimental evaluations using two datasets mixed natural land cover, and aerial hyperspectral images—demonstrated significant improvements in BRDF correction compared to the traditional RTM-LTR model.

Objective

- This study explores this mutual influence of the BRDF effect and the spectral mixture analysis to improve image correction in studies that rely on spectral data



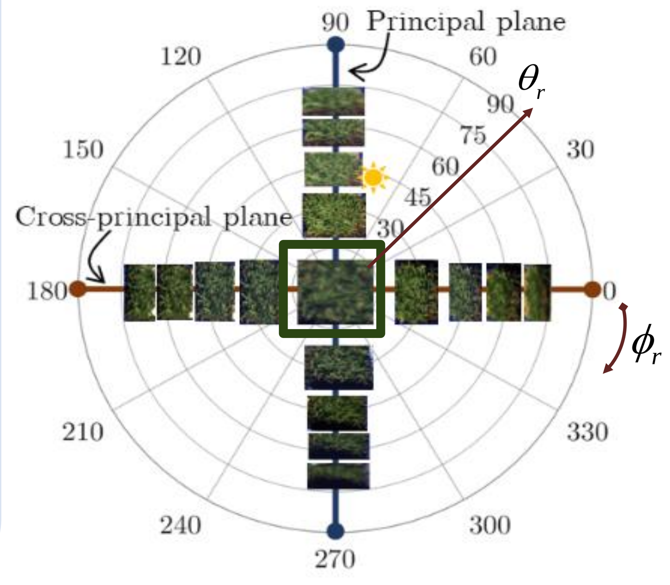
The BRDF correction is necessary in hyperspectral mosaics [2]



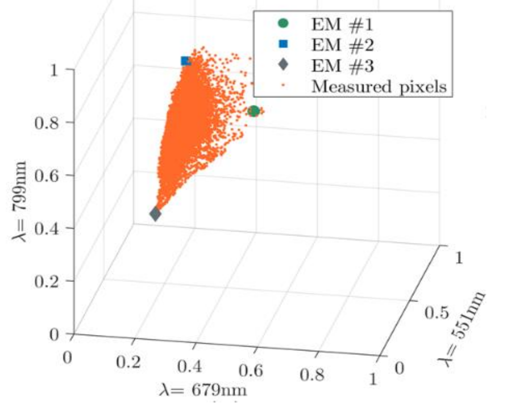
Methodology

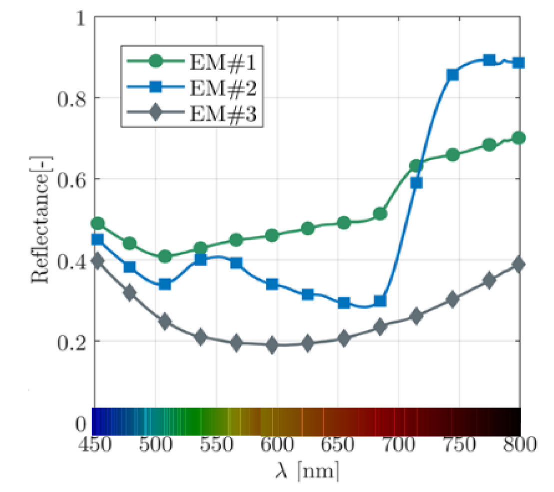
Dataset#1-grass

Multi-angular Images of mixed land cover

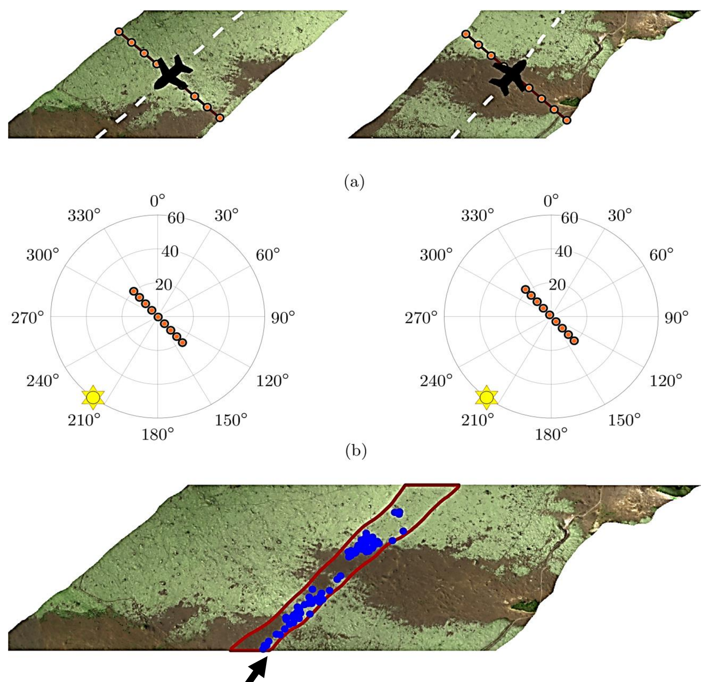


Endmember Extraction Vector Component Analysis

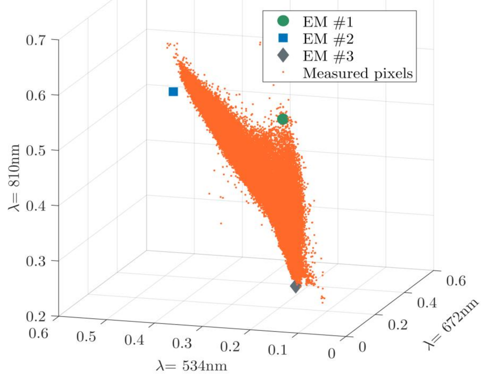


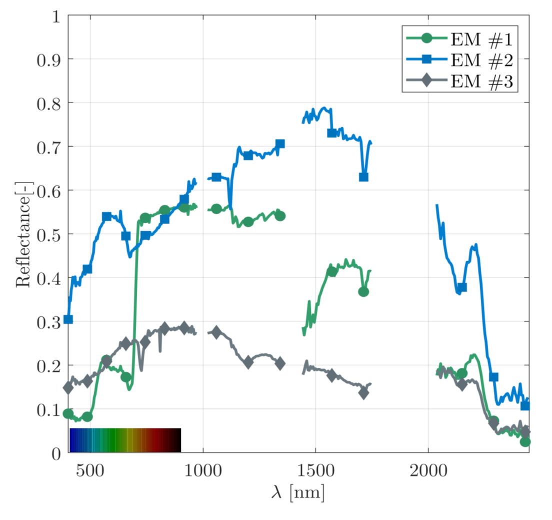


Dataset#2



Overlapping area of two airborne hyperspectral strips





Known geometry and classification

Known geometry and extracted EMs

RTM-LTR model [3]

$$\rho'^{j}_{m}(\lambda,\theta_i,\theta_r,\Delta\varphi) = f^j_{iso} + f^j_{vol}\cdot k_{vol}(\theta_i,\theta_r,\Delta\varphi) + f^j_{geo}\cdot k_{geo}(\theta_i,\theta_r,\Delta\varphi)$$

k_{vol} and k_{geo}, denote the volumetric and geometric kernels, respectively, f_{vol} and f_{geo} are their corresponding weights, and f_{iso} is the weight of isotropic reflectance. Weights are estimated by Least Squares and require prior **classification**

Anisotropy factor

$$\eta' = \frac{\rho'_m(\theta_i,\theta_r,\Delta\varphi)}{\rho'_m(\theta_{i\_ref},\theta_{r\_ref},\Delta\varphi_{r\_ref})}$$

Mixed-pixel content estimation

Fraction maps by VPGDU - Vectorized Projected Gradient Descend Unmixing[4]

$$\alpha = \begin{bmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\end{bmatrix}$$

- % EM#1 (main)
- % EM#2 (background)
- % EM#3 (shaded areas)

RTM-LTR-UMx [1]

model incorporates endmember fractions within the BRDF kernels' weight estimation without requiring land cover classification

$$\rho''_m(\lambda,\theta_i,\theta_r,\Delta\varphi) = \sum_{j=1}^{d}\alpha_j\left(f^j_{iso} + f^j_{vol}\cdot k_{vol}(\theta_i,\theta_r,\Delta\varphi) + f^j_{geo}\cdot k_{geo}(\theta_i,\theta_r,\Delta\varphi)\right)$$

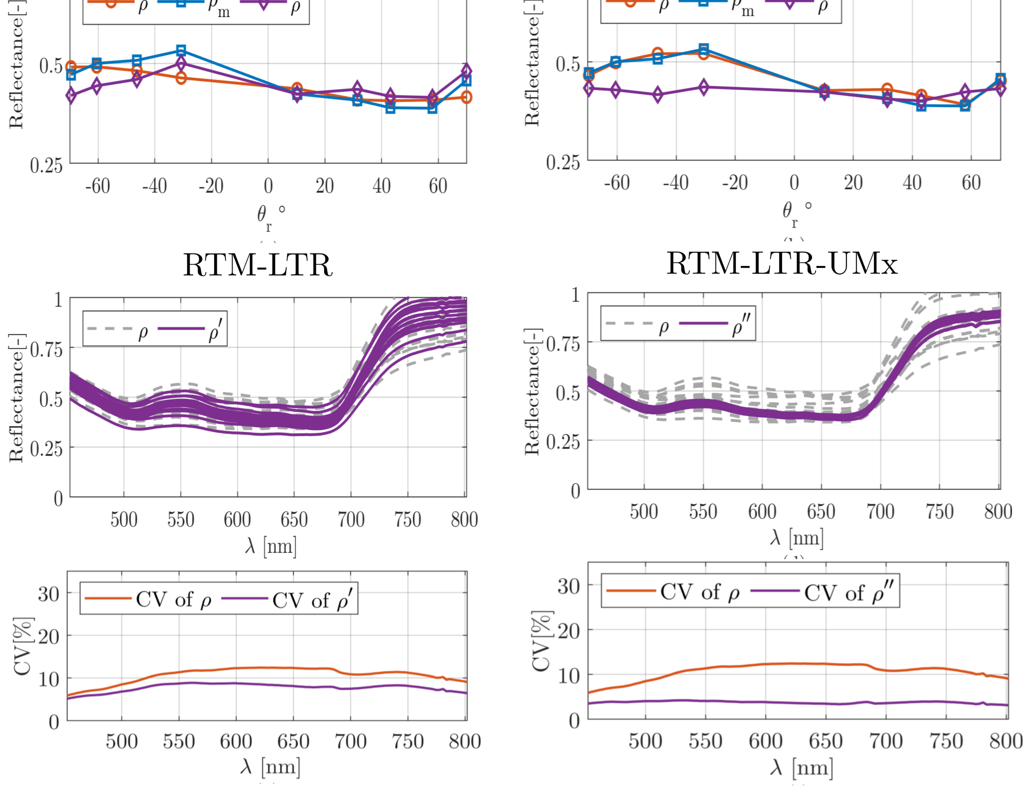
Image correction to nadir view trough mixed anisotropy factor:

$$\eta''_{mixed} = \alpha^T\eta'$$

Results and Conclusions

Dataset#1

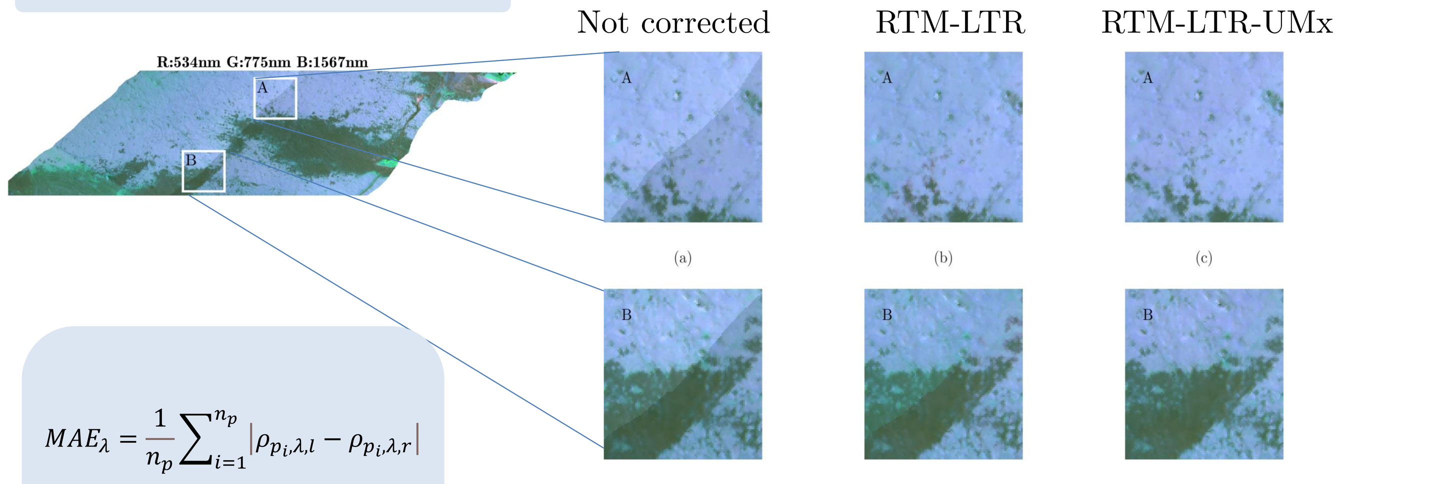
Variation of measured/modeled/corrected reflectance



- The model accurately captured measured reflectance, with lower CV values near hot and dark spots
- The model outperformed the traditional approach, providing critical subpixel information and effectively reducing BRDF effects across various land cover types
- The proposed RTM-LTR-UMx model incorporates endmember fractions within the BRDF kernels' weight estimation without requiring land cover classification
- The spectral unmixing process provides critical subpixel information regarding each pixel's different land cover types, the RTM-LTR-UMx model uses this information and allows for simultaneously estimating BRDF coefficients for all land cover types in the examined scenes

Dataset#2

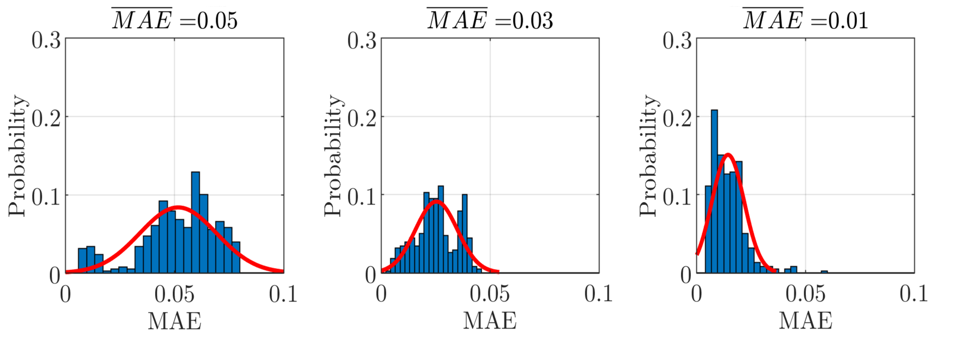
False color image



$$MAE_\lambda = \frac{1}{n_p}\sum_{i=1}^{n_p}\left|\rho_{p_i,\lambda,l} - \rho_{p_i,\lambda,r}\right|$$

$$\overline{MAE} = \frac{1}{n_\lambda}\sum_{j=1}^{n_\lambda} MAE_{\lambda_j}$$

The difference of reflectance of matching points between left and right images



References

1. Kizel, F., & Vidro, Y. (2023). An unmixing-based BRDF correction in spectral remote sensing data. International Journal of Applied Earth Observation and Geoinformation, 118, 103161.
2. Collings, S., Caccetta, P., Campbell, N., & Wu, X. (2010). Techniques for BRDF correction of hyperspectral mosaics. IEEE Transactions on Geoscience and Remote Sensing, 48(10), 3733-3746.
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4. Kizel, F., Shoshany, M., Netanyahu, N.S., Even-Tzur, G., Benediktsson, J.A., 2017. A stepwise analytical projected gradient descent search for hyperspectral unmixing and its code vectorization. IEEE Trans. Geosci. Remote Sens. 55, 4925–4943.