Unlocking Hidden Treasures from Above by Hyperspectral Imaging across Scales

– Impact of Increased Spatial Resolution on Mineral Mapping Accuracy –

NV5

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HySpex by neo

ReSe APPLICATIONS

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MOTIVATION

- After the launch of multiple spaceborne hyperspectral instruments, such as the European EnMAP and PRISMA missions, the quality and usability of the acquired spaceborne hypercubes can be compared against existing airborne or drone-based hyperspectral imaging data.
- **This study shows the impact of scale, mainly due to different spatial resolutions (ground sampling distance, GSD) on mineral mapping results.**
- Three datasets from hyperspectral sensors, namely the spaceborne **EnMAP** sensor (30 m GSD), the airborne **AVIRIS-NG** sensor (2.9 m GSD), and the drone-based **HySpex Mjølnir VS-620** (0.18 m GSD) are analyzed for mineral surface cover.
- We present new evaluation results of the above hyperspectral data, based on the scientifically proven **ENVI** technology.

TEST SITE

- All datasets were collected over Cuprite Hills, Nevada, USA (***Figure 1***).
- The Cuprite Hills are characterized by extensive hydrothermal alteration and exposed terrain, making it a prime location for studying argillic and advanced argillic alteration zones and dominating at-surface minerals such as Kaolinite and Alunite (***Figure 2***).
- Therefore, Cuprite was and is used as a validation site for different spectral imaging instruments and the data acquired is frequently used to test and validate processing routines and mapping algorithms.
- Several hydrothermal alteration minerals display distinct spectral features in the 0.4-2.5 µm wavelength region that allows their detection and mapping using airborne, spaceborne, and drone-based hyperspectral imagery.

DATA PRODUCTS

All datasets represent surface reflectance in cartographic geometry (Level-2A products):

- The 07/2023 **EnMAP** dataset was processed by the German Aerospace Center (DLR) with the atmospheric correction over land processor.
- The 07/2020 **AVIRIS-NG** dataset contains Level 2 orthocorrected reflectance, derived by the NASA Jet Propulsion Laboratory (JPL) from measured radiance, with water absorption bands removed, and a slight smoothing applied to the spectra.
- Pre-processing of the 02/2020 **HySpex** data was done in a cooperation of **NEO** and **ReSe Applications**. Position and orientation data from a performance GNSS-Inertial system, a high-resolution digital surface model and accurate sensor / boresight calibration were combined to directly georeference the data. A physical model based atmospheric compensation for reflectance retrieval (DROACOR)[1] was applied.

DATA POST-PROCESSING & ENDMEMBER EXTRACTION

Prior to endmember extraction, the following products had to be post-processed:

- EnMAP: Vegetation suppression to remove the vegetation spectral signature. The algorithm models the amount of vegetation per pixel using a vegetation transform.
- AVIRIS NG: **Minimum Noise Transform (MNF)** -based denoising to minimize the impact of a vertical oscillation on the subsequent classification results.
- Mapping differences in the data variance as a function of the variable surface mineralogy using the MNF technique. Increasing differentiation, from mineral alteration types to the mineral species level, is achieved with increasing spatial resolution (***Figure 3***).

Unsupervised extraction of mineral endmembers using the **Sequential Maximum Angle Convex Cone (SMACC)** algorithm.

Endmember identification using comparisons with the Cuprite ground truth spectra of the USGS v7 spectral library[2].

ENDMEMBER CLASSIFICATION

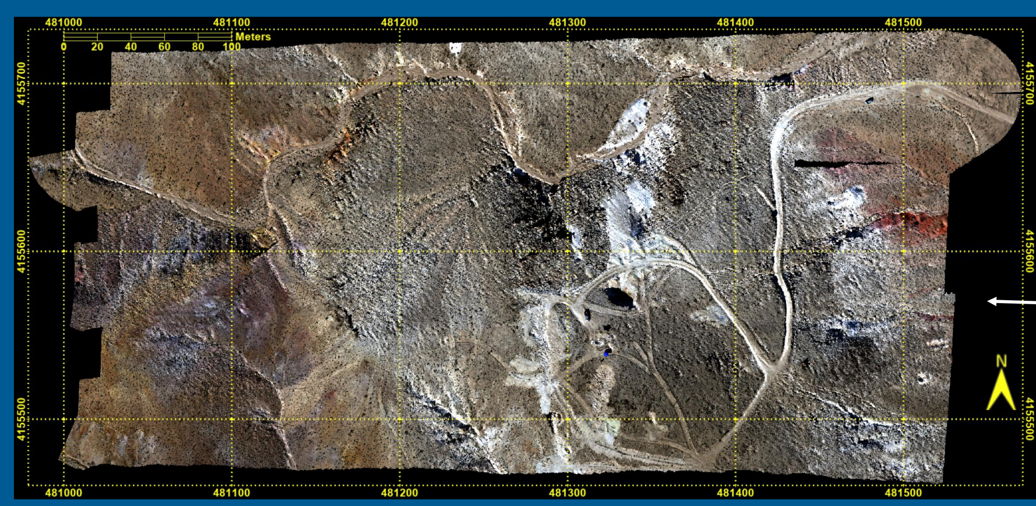
For this study, we focused on two K-bearing Alunite minerals with characteristic absorption features in the SWIR range (***Figure 4***), Alunite K High Temperature and Alunite K Medium Temperature.

- Classification of the two Alunite endmembers with **Spectral Feature Fitting (SFF)**. SFF is an absorption-feature-based methodology. It compares the fit of image spectra to reference spectra using a least-squares technique. The reference spectra are scaled to match the image spectra after the continuum is removed from the datasets (***Figure 5***).
- Improved classification of the two Alunite endmembers with **Multi Range Spectral Feature Fitting (MRSFF)**. MRSFF allows to split the compound Alunite absorption feature (doublet) near 2.2 µm in two wavelength ranges and to apply different weights (***Figure 6***).
- **MRSFF** was then applied on a larger AOI for comparison with the mapping *by G. Swayze et al. (2014)*[3] (***Figures 7, 8***).

CONCLUSIONS

- Accurate detection of alteration minerals such as Alunite from spaceborne hyperspectral imagery as EnMAP shows the potential of this technology, especially considering that data is available free of charge over many areas globally interesting for mineral exploration.
- The results demonstrate the value of mineral mapping by spaceborne hyperspectral imagery to identify areas of interest but also that higher-resolution data is necessary for detailed analysis via airborne or drone-based data for a precise local investigation of mineral patterns.

- [1]*Schläpfer, D. et al.: "Drone data atmospheric correction concept for multi-and hyperspectral imagery – the DROACOR model." ISPRS, vol. XLIII-B3-2020, pp. 473–478, 2020, doi: 10.5194/isprs-archives-xliii-b3-2020-473-2020.*
- [2]*Kokaly, R. F. et al.: "USGS Spectral Library Version 7." U.S. Geological Survey Data Series 1035 (2017).*
- [3]*Swayze, G. A. et al.: "Mapping Advanced Argillic Alteration at Cuprite, Nevada, Using Imaging Spectroscopy." Economic Geology 2014, 109 (5): 1179–1221. doi: https://doi.org/10.2113/econgeo.109.5.1179.*



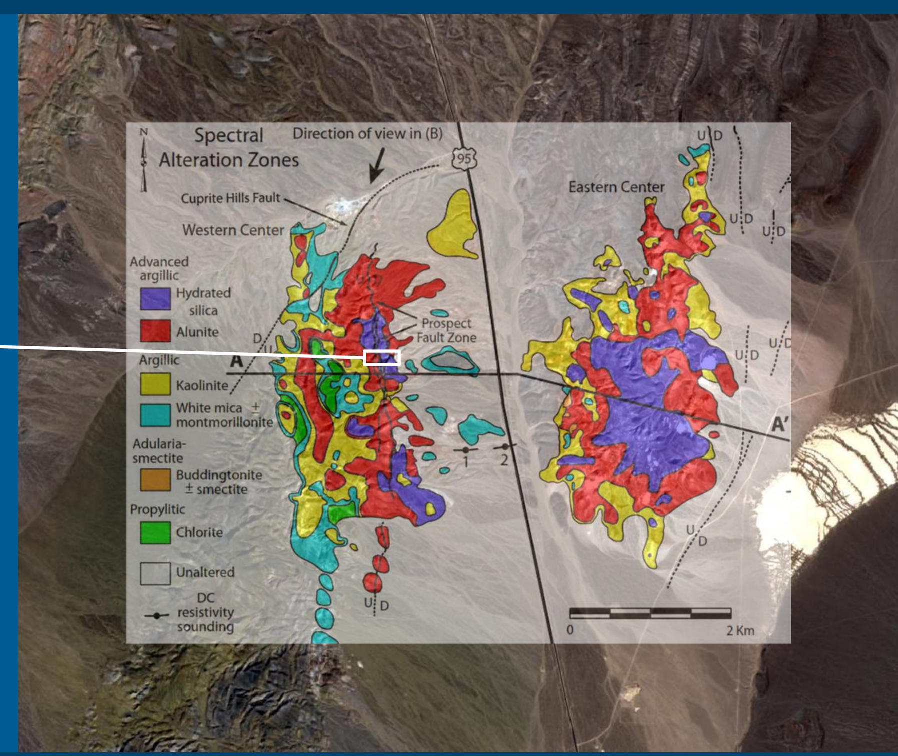


Figure 1 (above): *AOI as defined by the 2020 HySpex Cuprite Benchmark campaign and its location in the Cuprite study area in the South-Western Nevada volcanic field (Figure 2).*

Figure 2 (right): *Cuprite study area, Copernicus Sentinel-2 data, acquired February 8, 2020. Overlaid is the spectroscopic alteration map by G. Swayze et al. (2014)[3].*

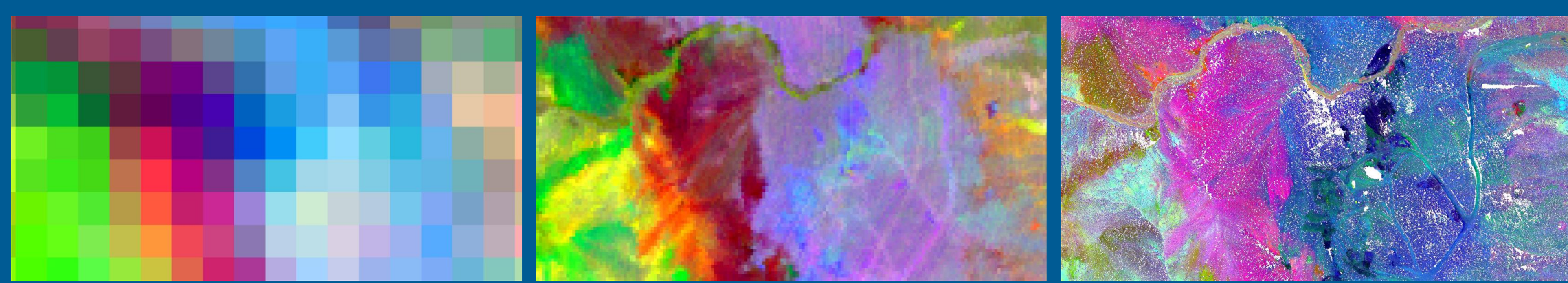


Figure 3: Impact of scale due to different spatial and spectral resolutions on Minimum Noise Fraction Transform colour composites [RGB 321], reflecting local mineralogy. *(Left) EnMAP 30 m GSD, (Centre) AVIRIS-NG 2.9 m GSD, (Right) HySpex 0.18 m GSD. The dominant mineral surface covers, represented as coloured areas, are visible in all MNF products.*

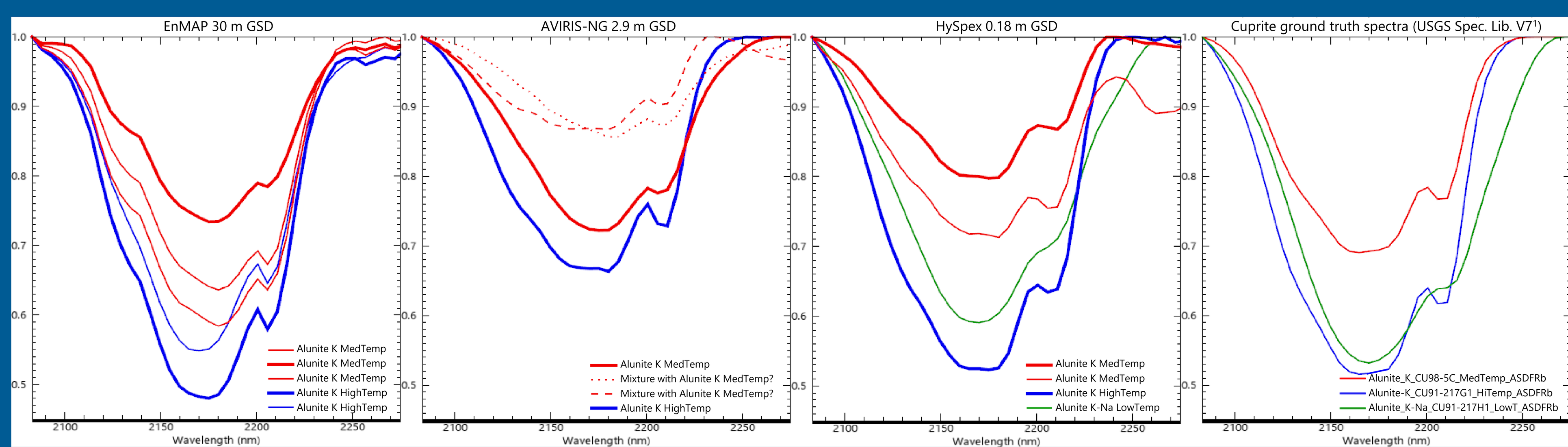


Figure 4: Alunite endmembers, extracted unsupervised with Sequential Maximum Angle Convex Cone (SMACC) from the AOI in Figure 3. *For comparison, the spectral libraries of the USGS, EnMAP and AVIRIS-NG endmembers were resampled to the HySpex wavelengths. Spectra used for classifications in Figure 5 & 6 are plotted in bold. The Alunite K-Na LowTemp (Green) was not extracted by SMACC for EnMAP and AVIRIS-NG. EnMAP's high signal-to-noise ratio enables SMACC to extract both Alunite K HighTemp and MediumTemp endmembers, comparable to USGS and HySpex, despite its coarser 30 m resolution.*

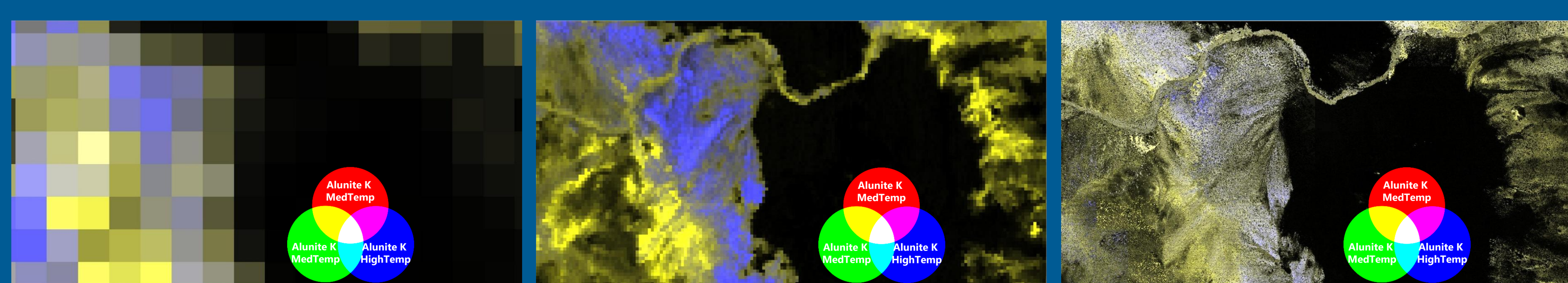


Figure 5: Impact of scale on Spectral Feature Fitting RGB classifications, reflecting the distribution of Alunite K HighTemp (Blue) and MediumTemp (Yellow). *(Left) EnMAP 30 m GSD, (Centre) AVIRIS-NG 2.9 m GSD, (Right) HySpex 0.18 m GSD. The main mineral features match well in all classifications.*

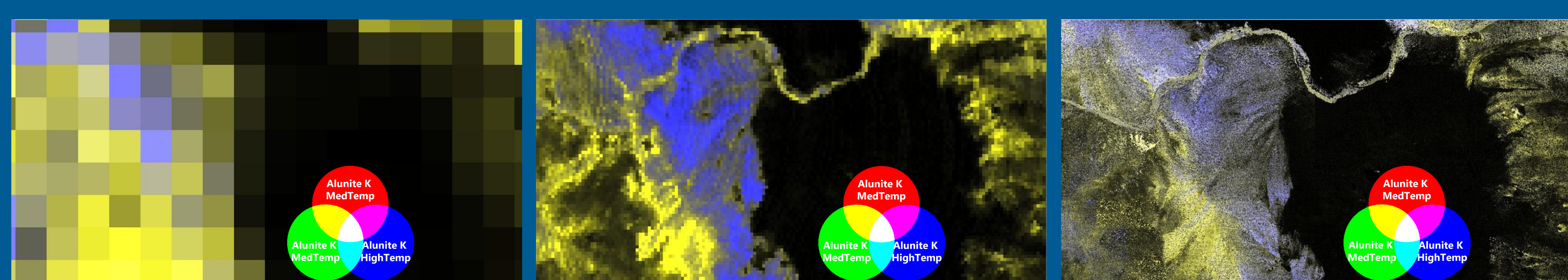


Figure 6: Impact of scale on Multi Range Spectral Feature Fitting RGB classifications, reflecting the distribution of Alunite K HighTemp (Blue) and MediumTemp (Yellow). *(Left) EnMAP 30 m GSD, (Centre) AVIRIS-NG 2.9 m GSD, (Right) HySpex 0.18 m GSD. The distribution of the main mineral features is improved compared to SFF (Figure 5).*

Figure 7: Impact of scale on Multi Range Spectral Feature Fitting (MRSFF) classifications, reflecting the distribution of Alunite K HighTemp and MediumTemp. *(Left) EnMAP 30 m GSD, (Centre) AVIRIS-NG 2.9 m GSD, (Right) Subset of the spectroscopic alteration map by G. Swayze et al. (2014)[3] in Figure 2 with all Alunite variations represented in Red colour (including Alunite K-Na, not classified in this study). The distribution of the Alunites in the EnMAP classification matches well with the AVIRIS-NG classification and the mapping by G. Swayze et al. (2014)[3].*

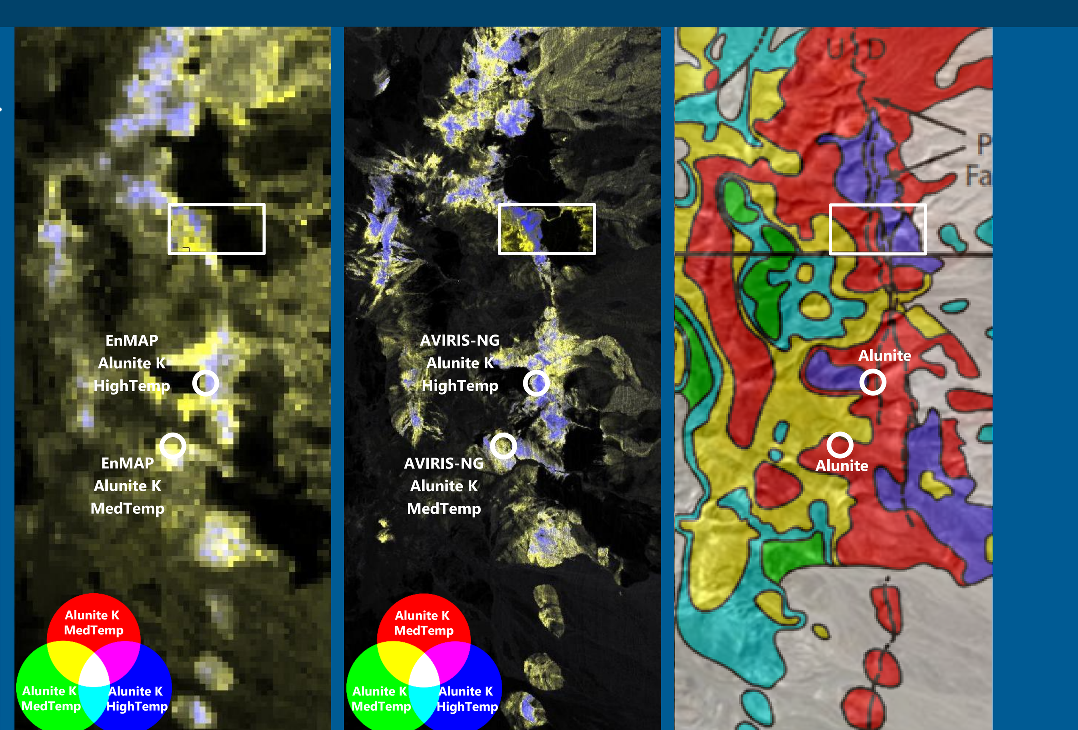
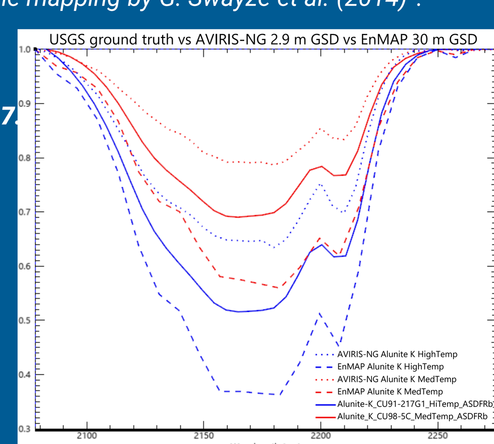


Figure 8: Alunite image endmembers from labelled white positions in Figure 7. *The EnMAP and AVIRIS-NG spectra of Alunite K HighTemp and MediumTemp match well with the USGS ground truth endmembers Alunite K CU91 HiTemp and Alunite K CU96 MedTemp.*



ENVI ECOSYSTEM

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