

Reflectance Spectroscopy of Global Parent Soils: Application to Aerosol Mineral Dust

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Abstract

Mineral dust particles originate from a variety of arid regions around the world. Mineral dust directly modifies the Earth's radiative balance through absorption and scattering. This radiative forcing varies strongly with mineral composition, yet there is still limited knowledge on the mineralogy of global dust source regions. Previously, 65 surface soil samples were collected worldwide, sieved to $< 38 \mu\text{m}$ fraction and analyzed using XRD, SEM and re-suspended to determine scattering and absorption coefficients at three visible wavelengths (Engelbrecht et al. *Atmos. Chem. Phys.* 16, 2016). This dust collection represents global surface soils with comparable mineral compositions to windblown dust. For this research, we measured spectra of 26 of these samples selected from major dust source regions with compositional diversity. We measured these samples using laboratory reflectance spectroscopy in the visible and near-infrared (0.4 to $2.5 \mu\text{m}$, VNIR) and long-wave infrared (2.5 to $25 \mu\text{m}$, LWIR). These data are relevant to satellite imaging spectrometers, but will particularly inform measurements planned for EMIT and SBG. We compared the measured spectra to standard spectral libraries to identify dominant materials and to compare and contrast these with the major minerals identified via XRD. VNIR spectral analysis detected diagnostic absorptions for minerals such kaolinite, calcite, hematite, and goethite. Common silicates, quartz and feldspar, are abundant in the majority of these samples and are expected to have diagnostic features in the LWIR. LWIR reflectance is strongly dependent on particle size (e.g. Salisbury et al., 1991), though the $0\text{--}74 \mu\text{m}$ grain size fraction of pure silicate minerals still show characteristic signatures between 8 and $10 \mu\text{m}$. Surprisingly, diagnostic silicate features were not observed in many of the samples. We identified quartz absorptions between 4.8 and $5.4 \mu\text{m}$ and at $14.3 \mu\text{m}$. We are still trying to understand why the fundamental vibrational features of silicates are obscured, but it may be related to multiple overlapping features in mixtures, grain coatings, or anomalous dispersion. LWIR spectra also revealed numerous diagnostic carbonate features, particularly those near 4 , 5.6 , and $11.4 \mu\text{m}$. We also identified carbonate in several samples where it had not been identified with XRD.



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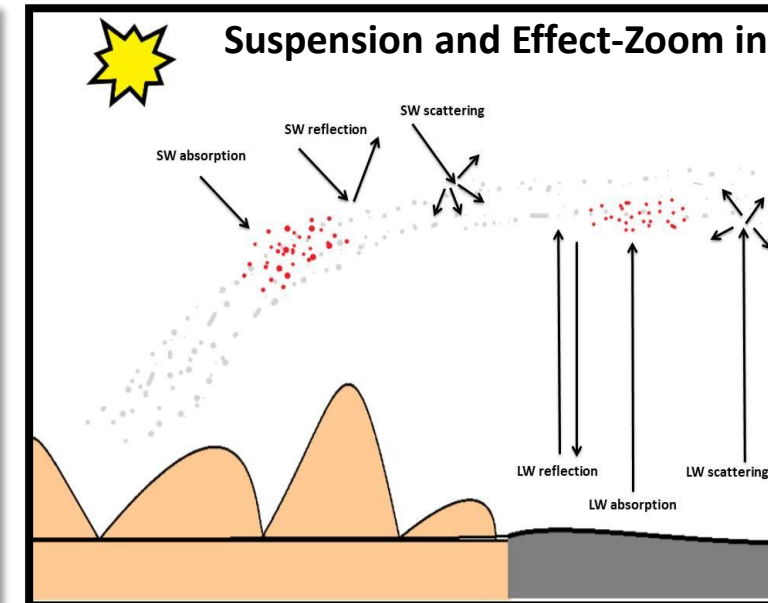
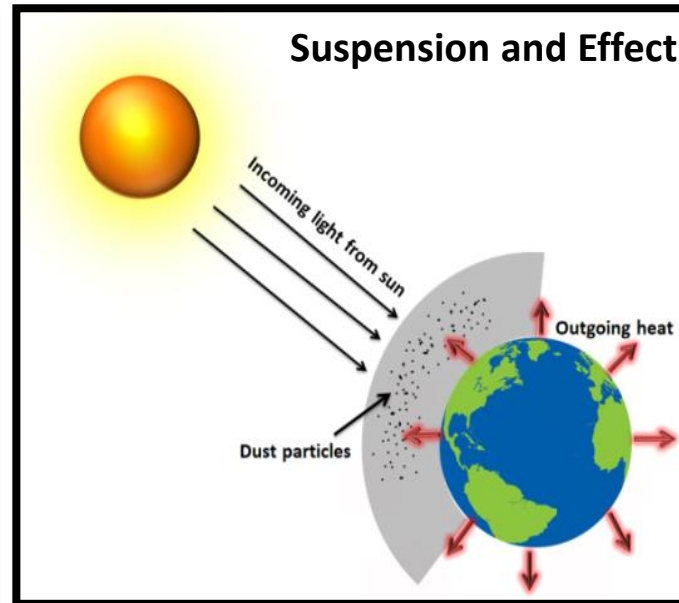
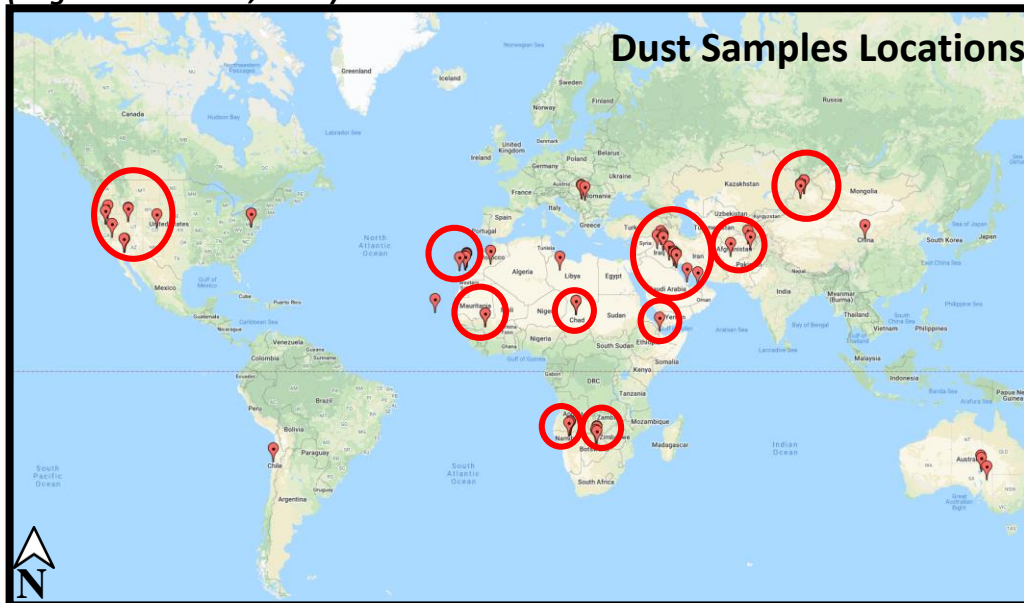
Introduction

- Mineral dust dominates the aerosols mass in atmosphere and cause radiative forcing,
- Mineralogy of dust is an important factor to understand its impact on Earth's radiation budget,
- Therefore, compositional information of windblown parent soil should be investigated to address dust influence on Earth's radiation budget.

Method and Material

26 global soil samples was selected from major dust source regions with compositional diversity. These samples were measured using laboratory reflectance spectroscopy in the visible and near-infrared (0.4 to 2.5 μm , VNIR) and long-wave infrared (2.5 to 25 μm , LWIR).

(Engelbrecht et al., 2016)

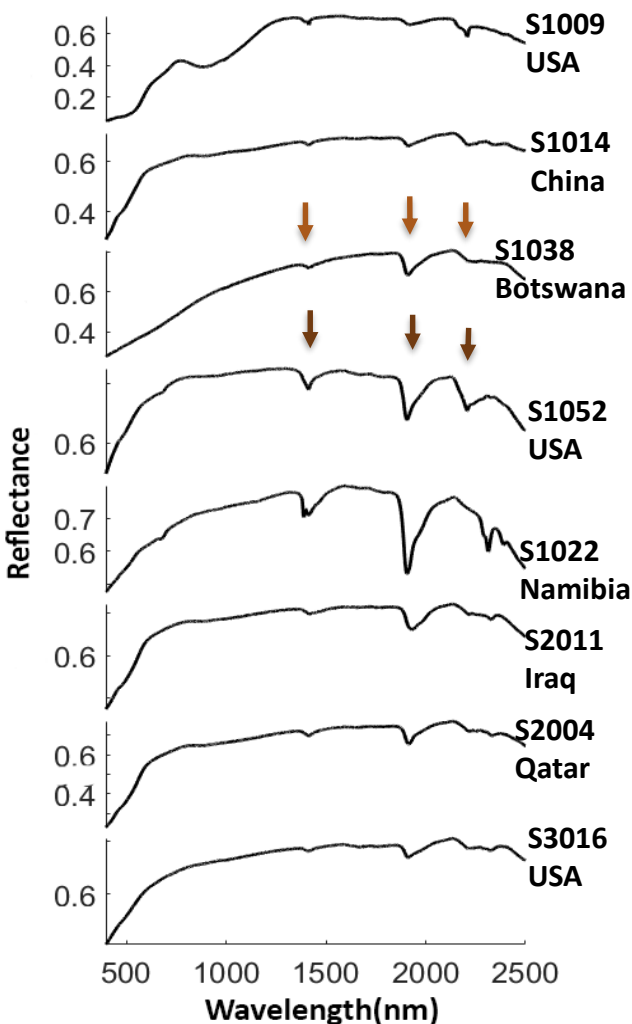


Dust Samples were Measured using VNIR Reflectance Spectroscopy

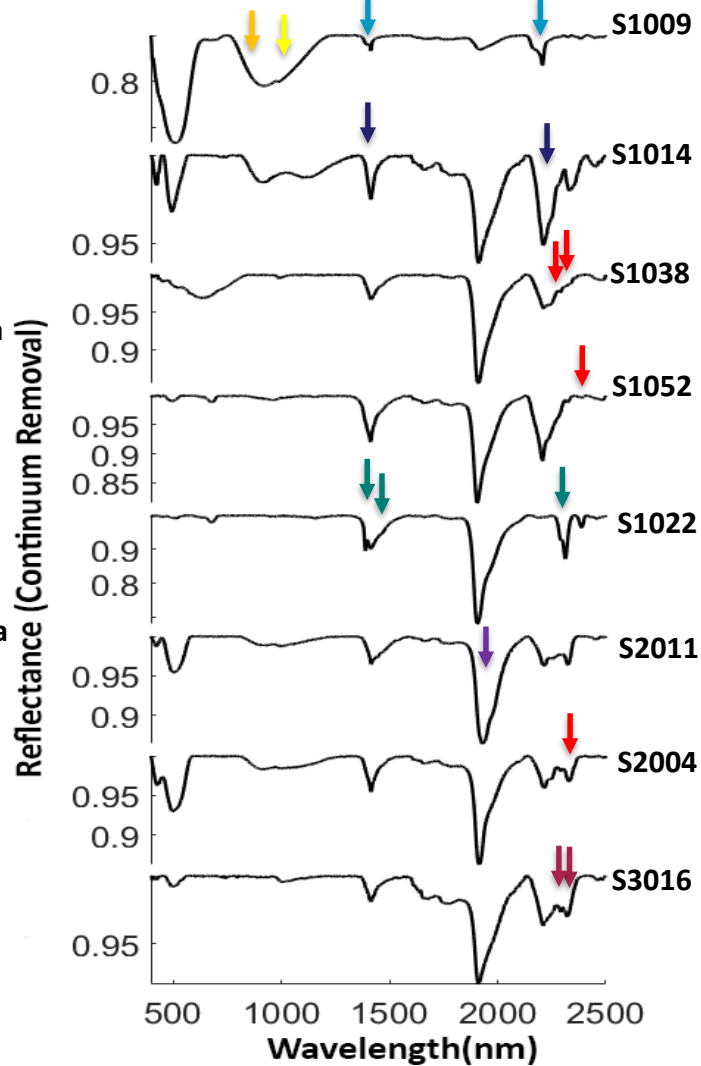
VNIR Measurements

- We compared the measured spectra to standard spectral libraries to identify dominant materials in the samples. Original reflectance (**R**) (left). To emphasize weak absorption features, we show continuum removal (**CR**) as well.

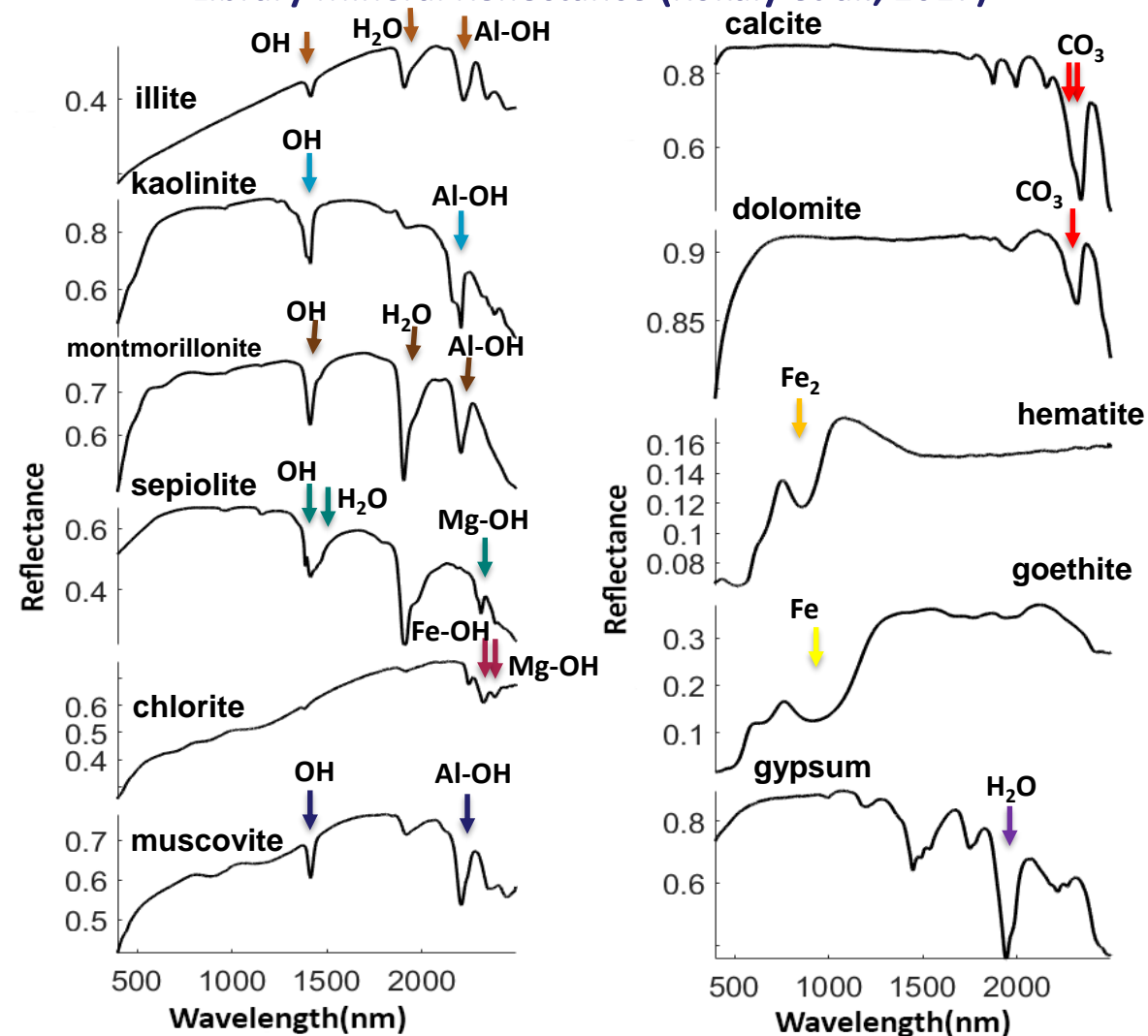
Samples' R Spectra



Samples' CR Spectra



Library Mineral Reflectance (Kokaly et al., 2017)

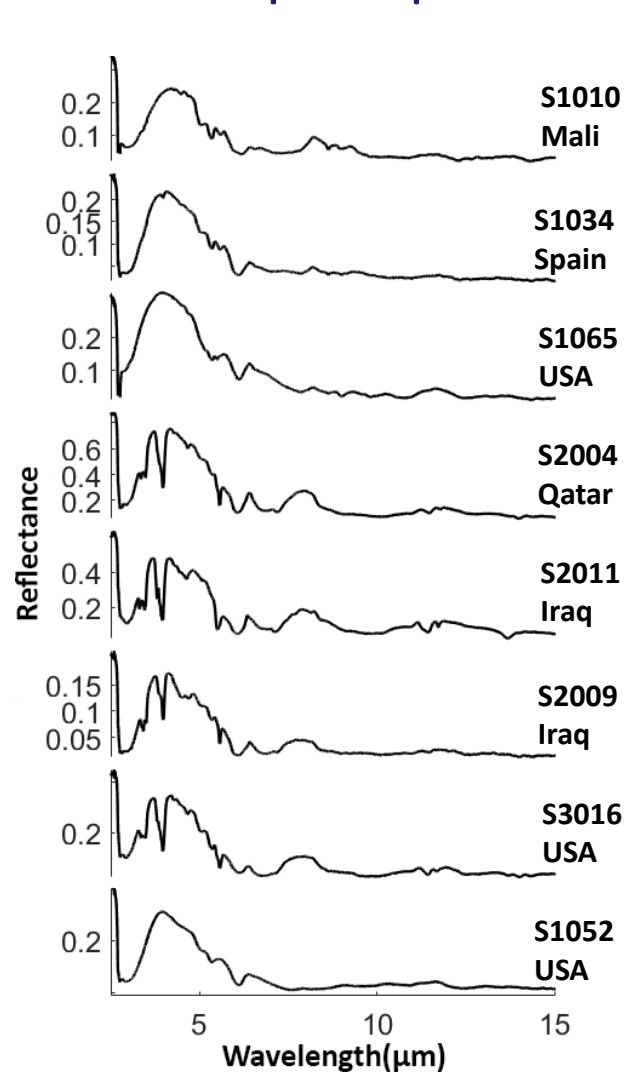


Dust Samples were Measured using LWIR Reflectance Spectroscopy

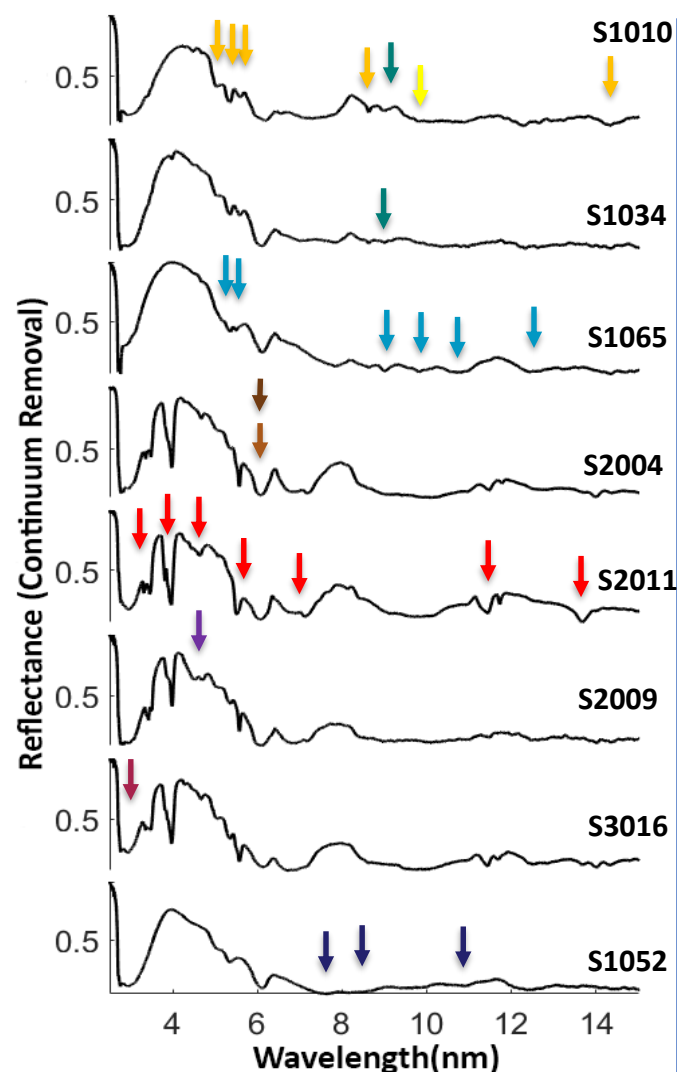
LWIR Measurements

- We compared the measured spectra to standard spectral libraries to identify dominant materials in the samples. Original reflectance (**R**) (left). To emphasize weak absorption features, we show continuum removal (**CR**) as well.

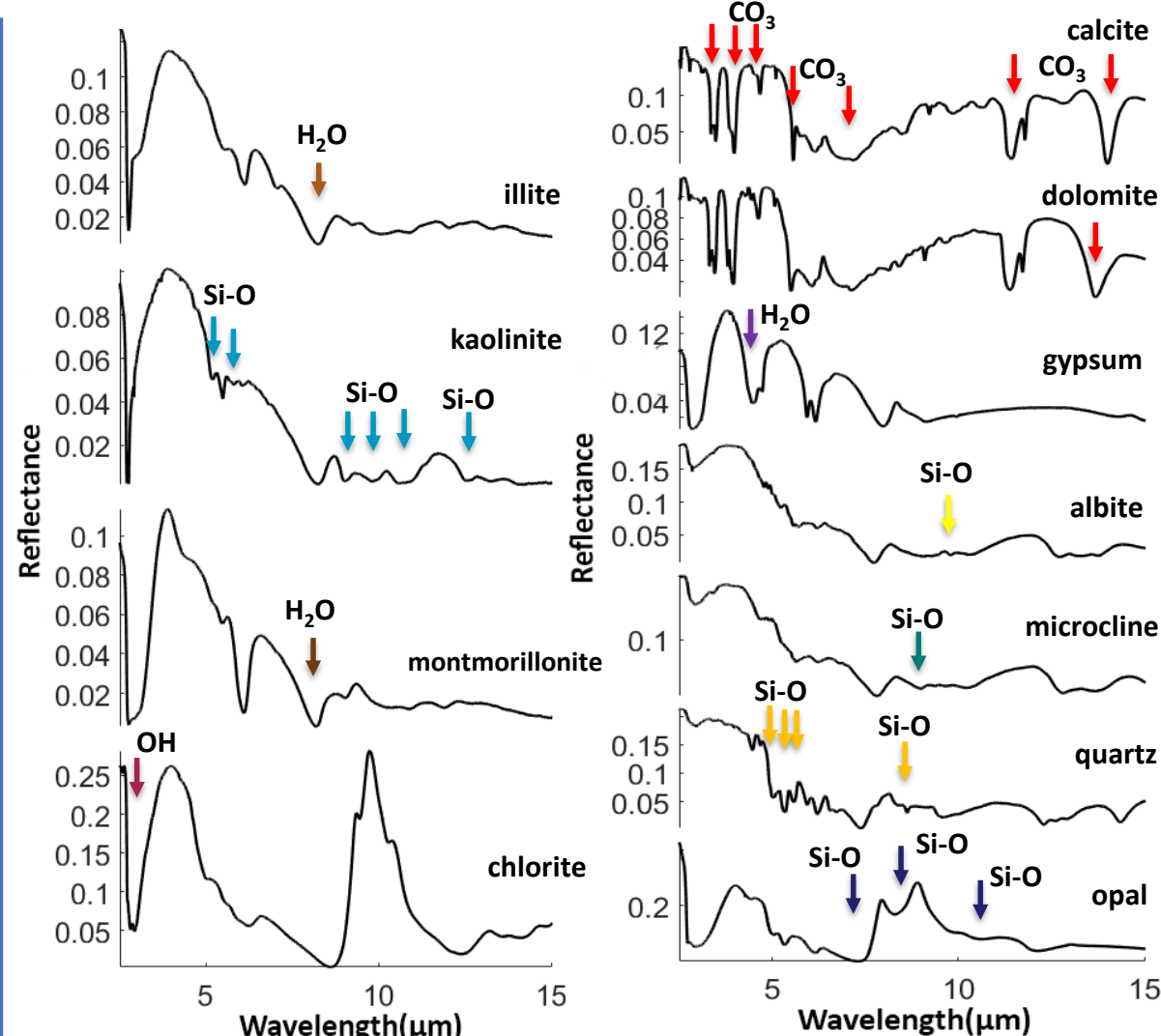
Samples' R Spectra



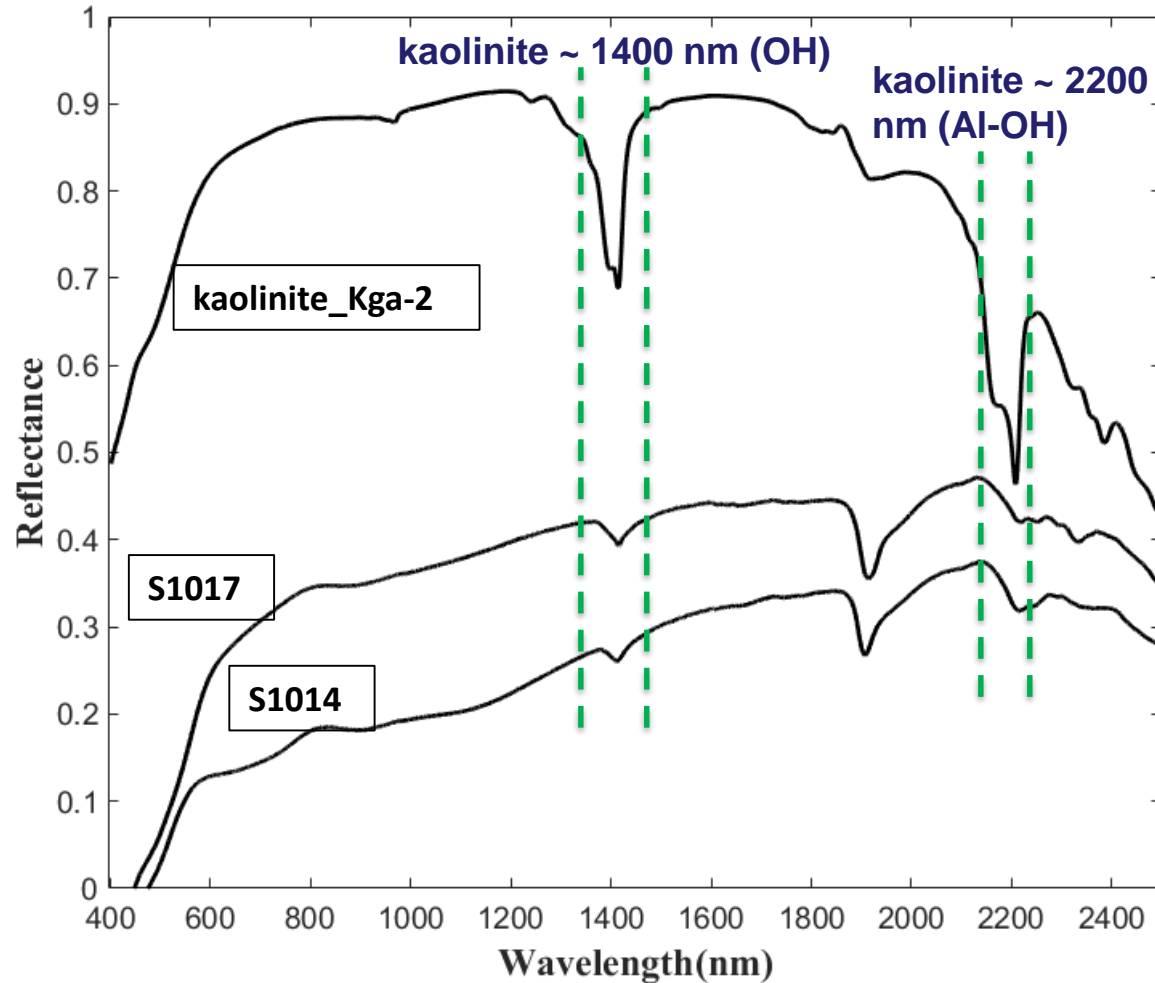
Samples' CR Spectra



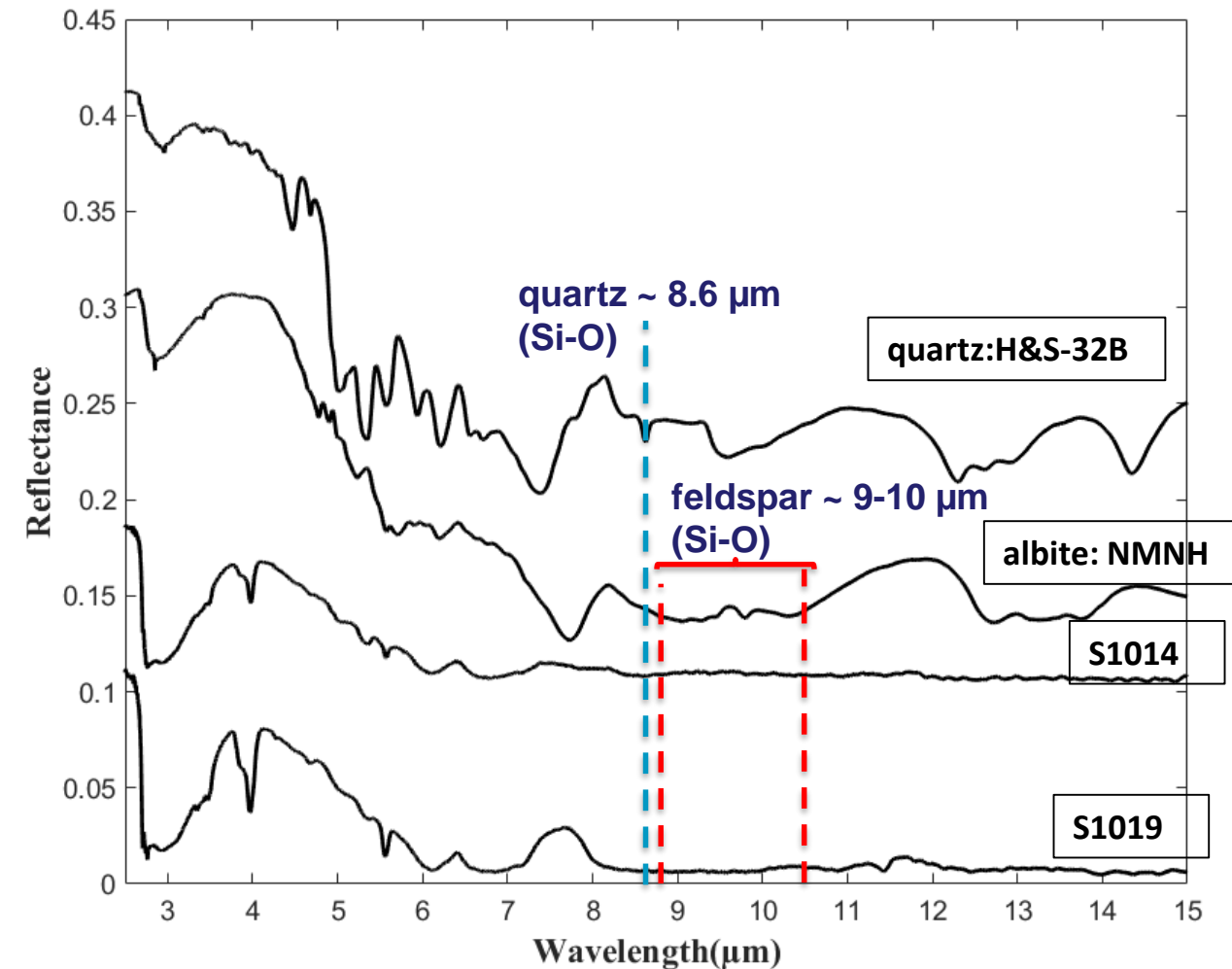
Fine Grain Library Minerals (Salisbury et al., 1991)



Samples' R Spectra – Missing Kaolinite



Samples' R Spectra – Missing Quartz and Albite

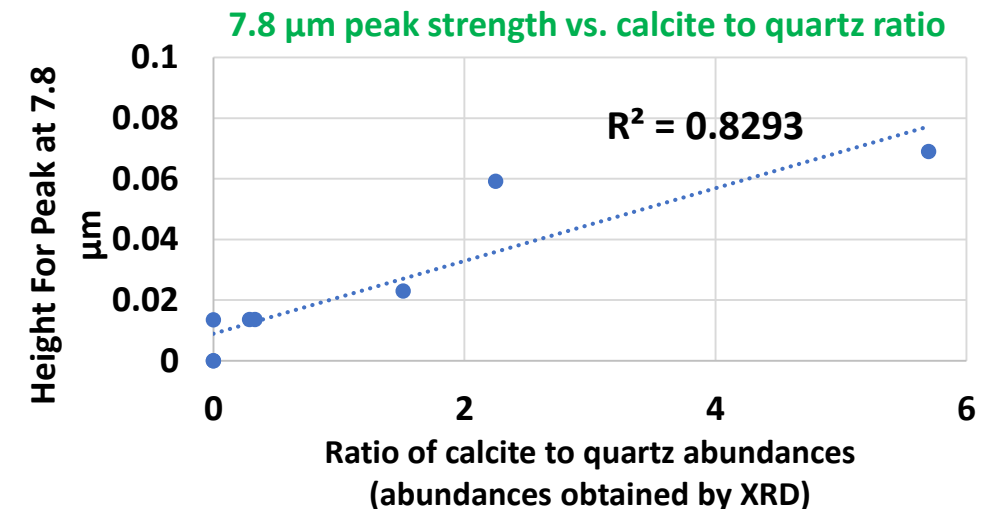
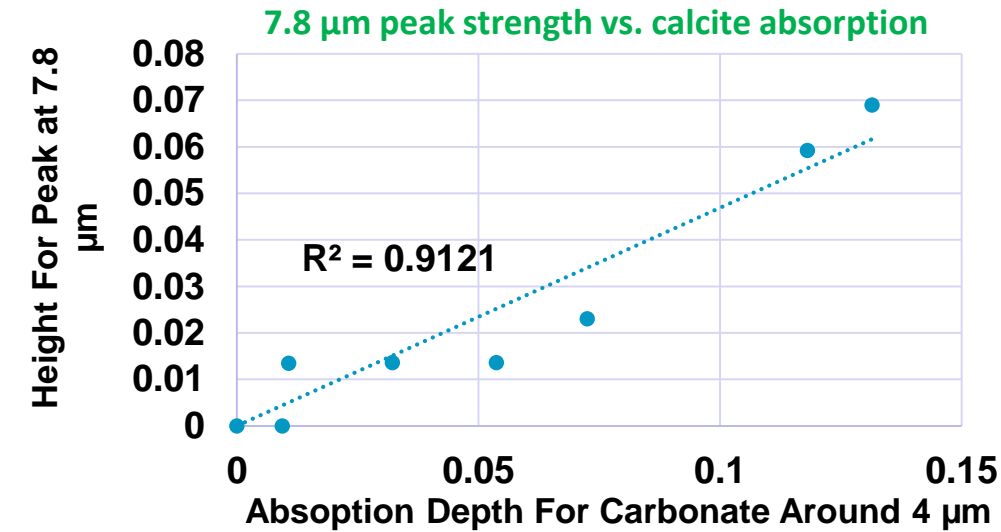
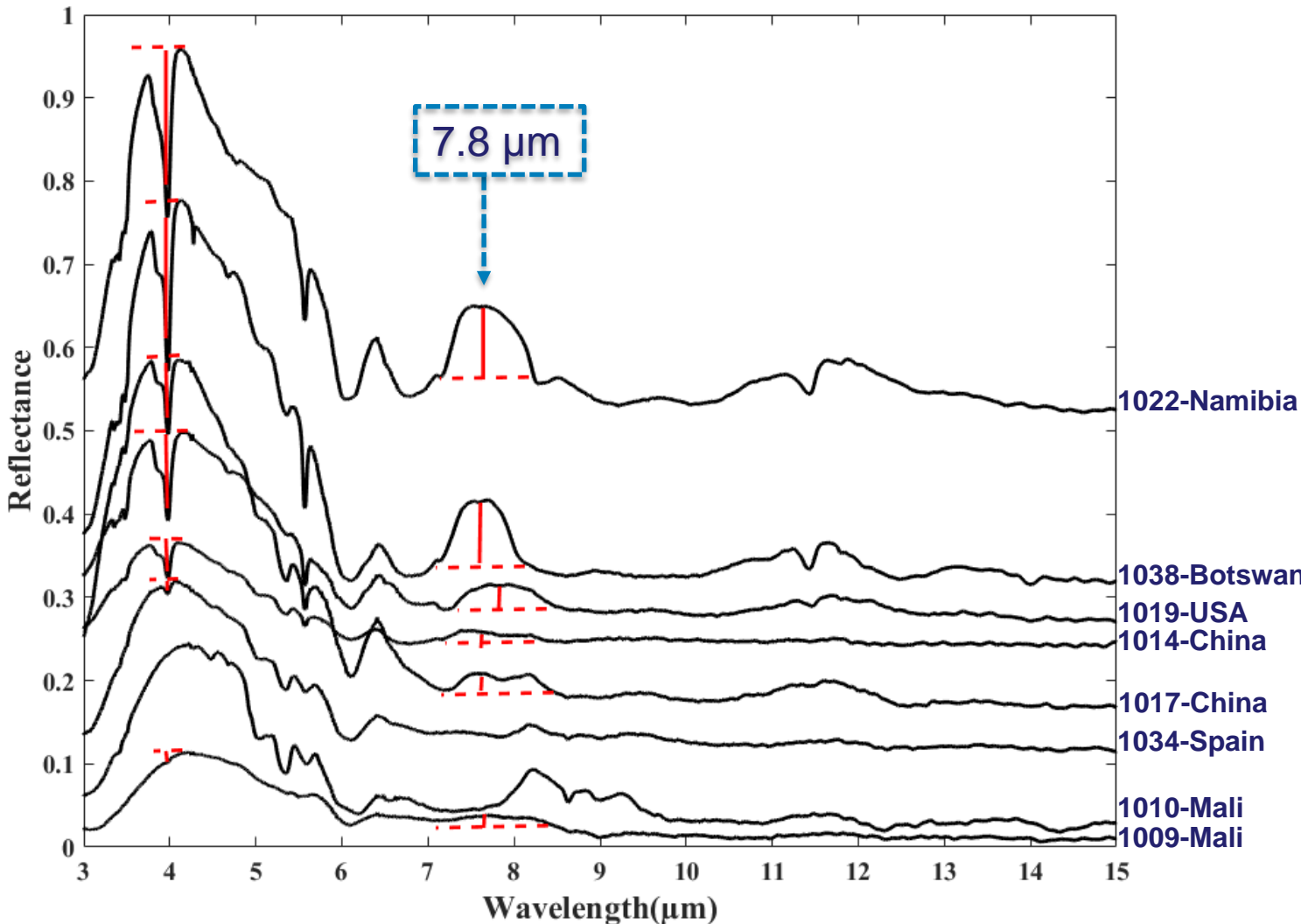


An Odd Peak at 7.8 μm

Investigating the reasons for appearing a peak at 7.8 μm

Possible explanations for peak at 7.8 μm

Presence of the of the peak at 7.8 μm might be related to **anomalous dispersion** or **the interaction of very find grain quartz and calcite**.



Do we identify same minerals in reflectance spectroscopy compared to XRD and OM?

Techniques Comparison

- Minerology determined using VNIR and LWIR reflectance spectroscopy, XRD, and optical microscopy (OM). All minerals in black color are detected by both OM and XRD, the ones shown with italic and bold are detected with VNIR and LWIR, and the red colors are only identified with spectral techniques.

Minerology of a few representative samples determined by VNIR, LWIR, XRD, and OM

Samples	Location	Compositional information by VNIR and LWIR reflectance spectroscopy, XRD, and optical microscopy
S1034	Spain-Las Canarias	<i>quartz, illite, plagioclase, kaolinite, calcite</i>
S2004	Qatar	<i>calcite, quartz, dolomite, illite, kaolinite, chlorite</i>
S1009	Mali	<i>quartz, kaolinite, illite, hematite, goethite</i>
S1022	Namibia	<i>calcite, sepiolite, quartz, dolomite</i>

Conclusion

The results from this research will inform measurements planned for EMIT and SBG.

Research contribution to GEC section

This research aims to identify the mineralogy of dust collection which represents global surface soils with comparable mineral compositions to windblown dust.

Conclusion:

- Minerals such as calcite, hematite, goethite, and kaolinite (and other clays) and common silicates such as quartz and feldspar were identified using VNIR and LWIR spectroscopy.
- In some samples, kaolinite in NIR, around 1400 and 2200 nm and silicates (quartz and feldspars) in LWIR, between 8-12 μm , do not show expected absorption features. This can be due to porosity, grain size, packing, grain coatings or the interaction of multiple minerals.
- We also identified carbonate and chlorite using reflectance spectroscopy in several samples where it had not been identified with XRD.
- We also identify a peak at 7.8 μm which may be attributed to anomalous dispersion or the interaction of quartz and calcite in this spectral range.

Thank you for your attention