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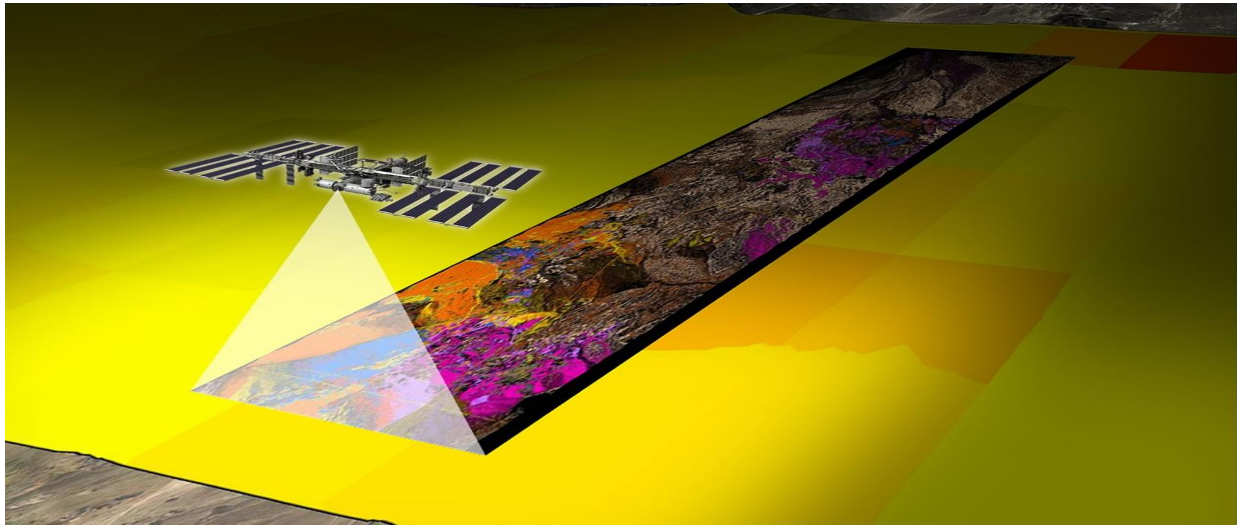
EMIT
EARTH SURFACE MINERAL DUST SOURCE INVESTIGATION

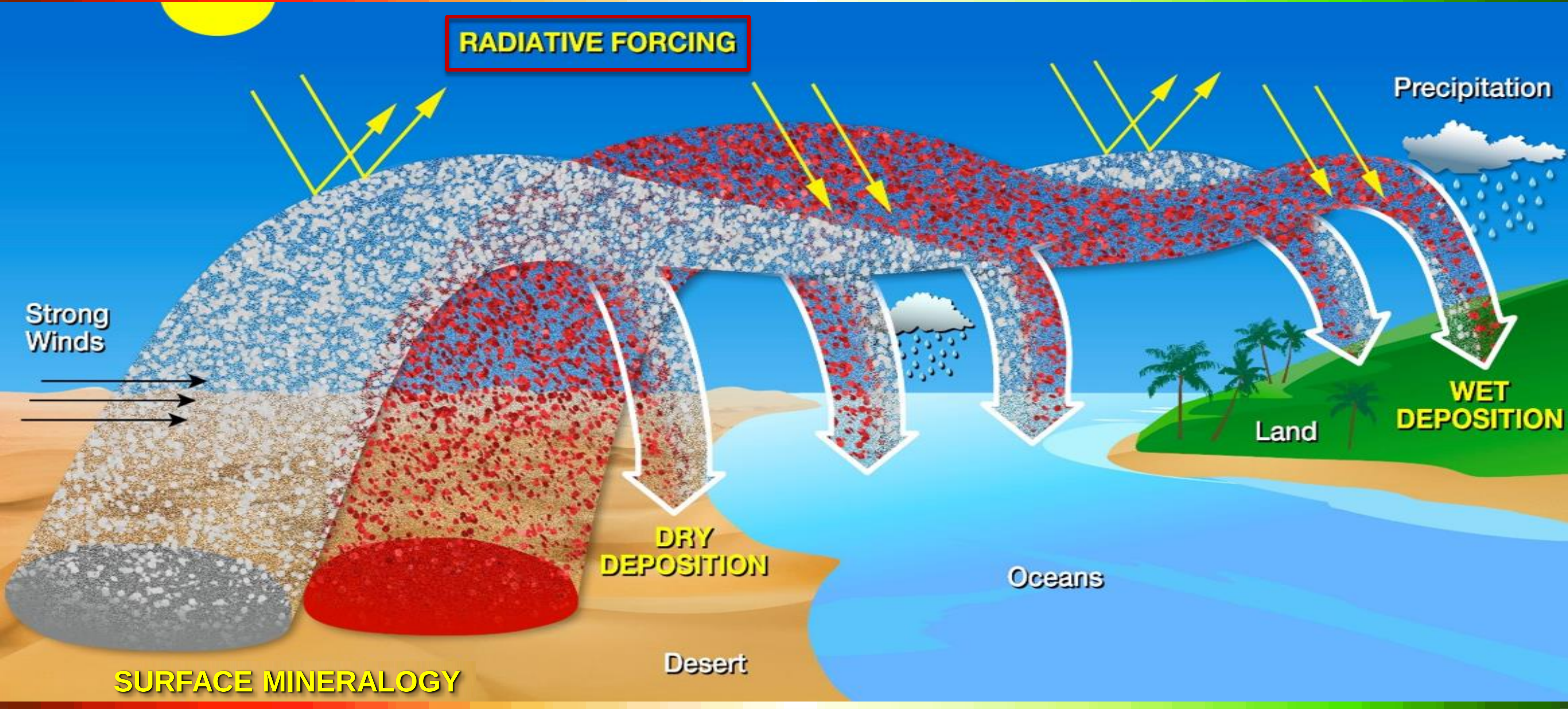
Objectives, Measurements, and Data Products of the NASA Earth Surface Mineral Dust Source Investigation



Robert O. Green[1], Natalie Mahowald[2], Roger Clark[3], Bethany Ehlmann[4], Paul Ginoux[5], Olga Kalashnikova[1], Ron Miller[6], Greg Okin[7], Thomas H. Painter[7], Carlos Perez Garcia-Pando, Vincent Realmuto[1], Gregg Swayze[9], David R. Thompson[1], Elizabeth Middleton[10], Luis Guanter[11], Eyal Ben Dor[12], Benjamin Phillips[13]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [2]Cornell University, Ithaca, NY, USA, [3]Planetary Science Institute, Tucson, AZ, USA, [4]California Institute of Technology, Pasadena, CA, USA, [5]Princeton University, Princeton, NJ, USA, [6]NASA Goddard Institute for Space Studies, New York, NY, USA, [7]University of California Los Angeles, Los Angeles, CA, USA, [8]Barcelona Supercomputing Center, Barcelona, Spain, [9]Gregg Swayze, US Geological Survey, Golden, CO, USA, [10]Goddard Space Flight Center, Greenbelt MD, USA, [11]GFZ German Research Center for Geosciences, Potsdam, Germany, [12]University of Tel Aviv, Tel Aviv, Israel, [13]NASA Headquarter, Washington, DC, USA

Mineral Dust and the Earth System



EMIT Science Objectives

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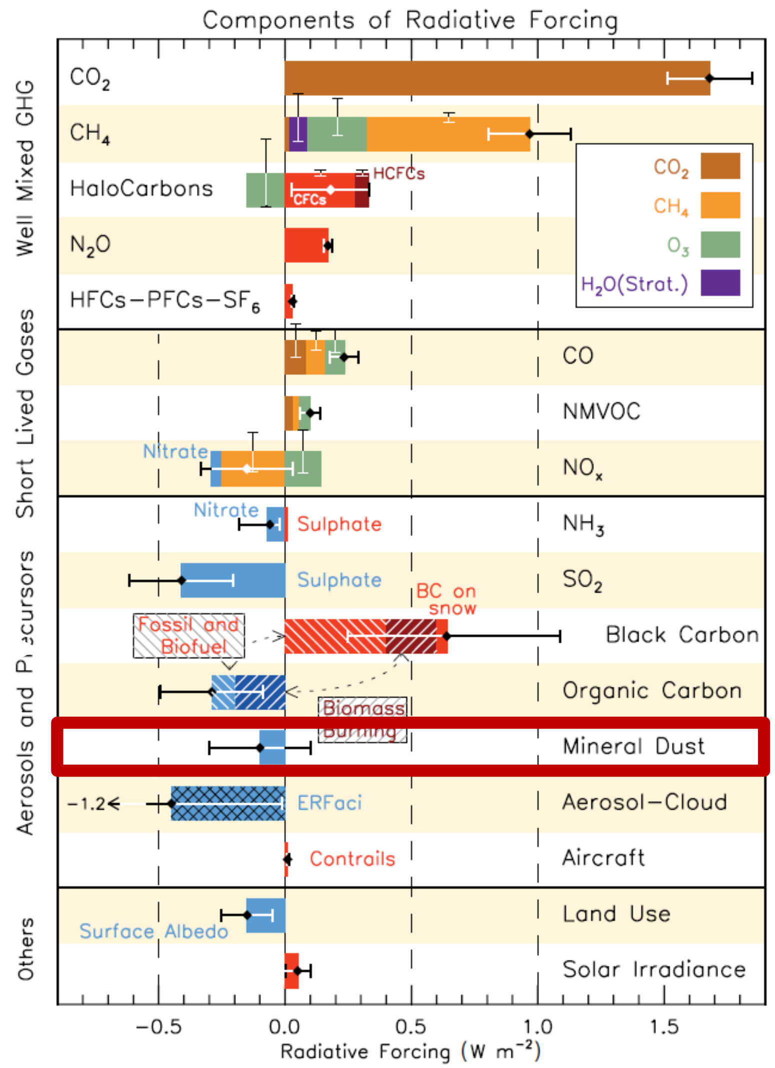
EMIT
Earth Surface Mineral Dust Source Investigation

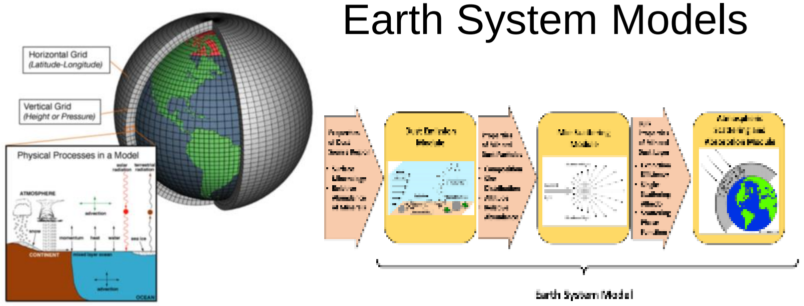


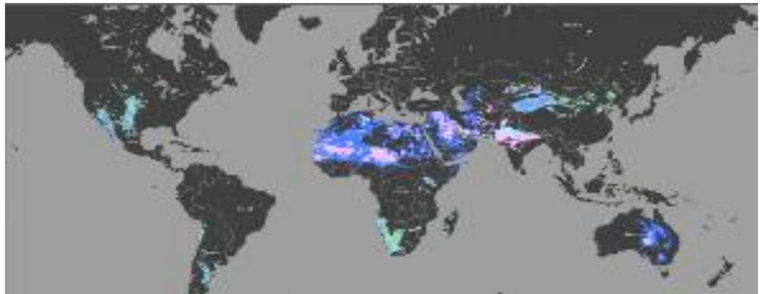
from IPCC AR5, 2015

1) Constrain the sign and magnitude of dust-related RF at regional and global scales.
- EMIT achieves this objective by acquiring, validating and delivering updates of surface mineralogy used to initialize Earth System Models.

2) Predict the increase or decrease of available dust sources under future climate scenarios.
- EMIT achieves this objective by initializing Earth System Model forecast models with the mineralogy of soils exposed within at-risk lands bordering arid dust source regions.

Earth System Models



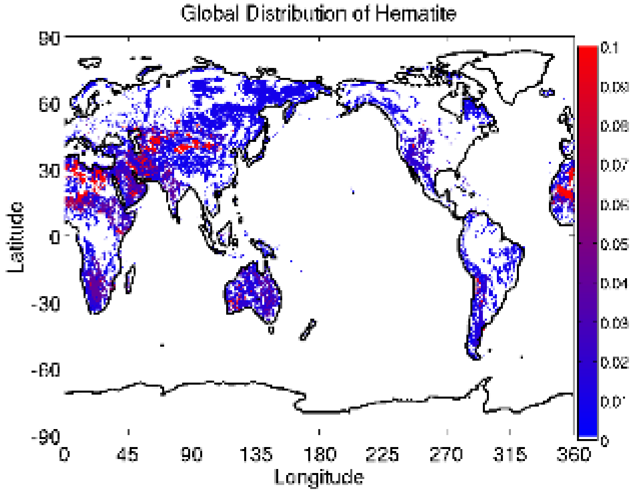


Adjacent Lands: Regions extending 50 km beyond the current dust sources.

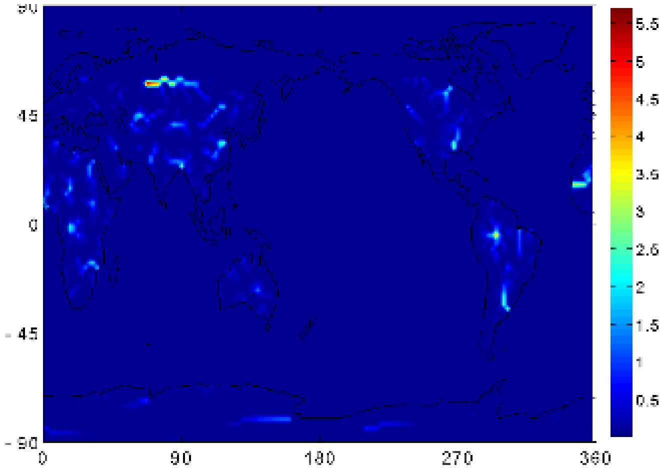
Ginoux, Paul, Joseph M. Prospero, Thomas E. Gill, N. Christina Hsu, and Ming Zhao. "Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products." *Reviews of Geophysics* 50, no. 3 (2012).

Example Work Building Dust into Models

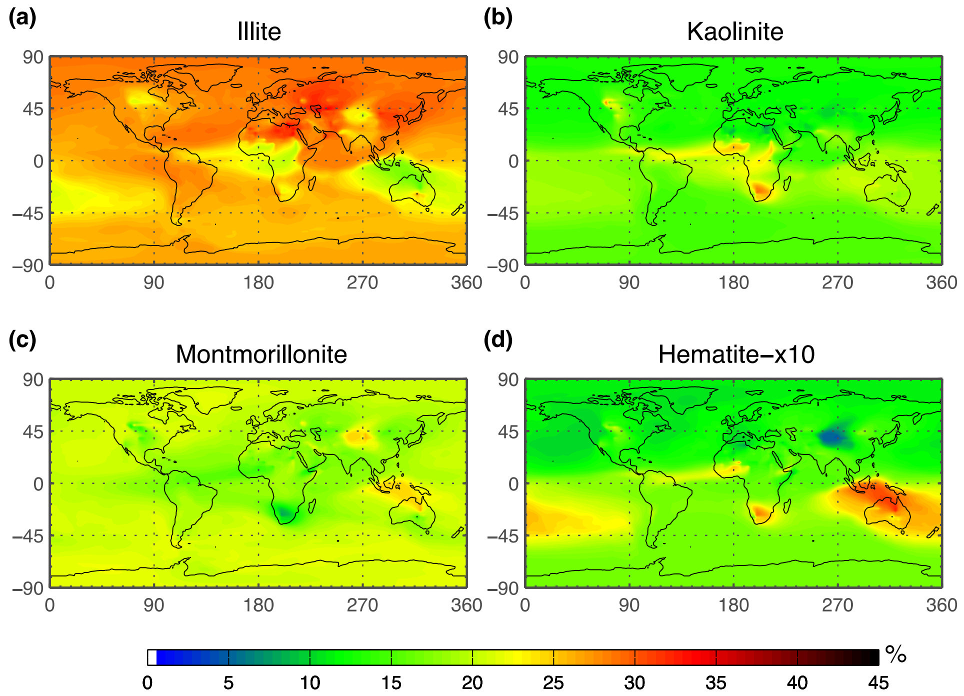
Using UN Food and Agriculture Organization (FAO) soil datasets and “average” minerals in each soil type



Dust emissions

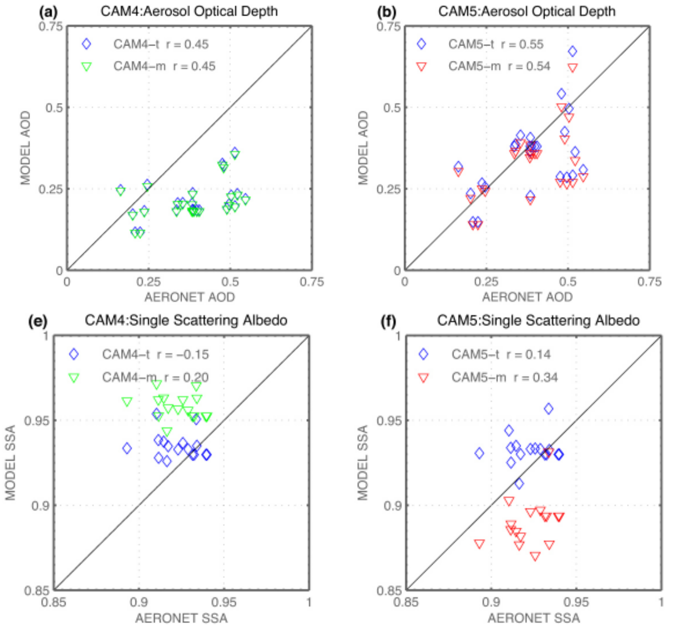


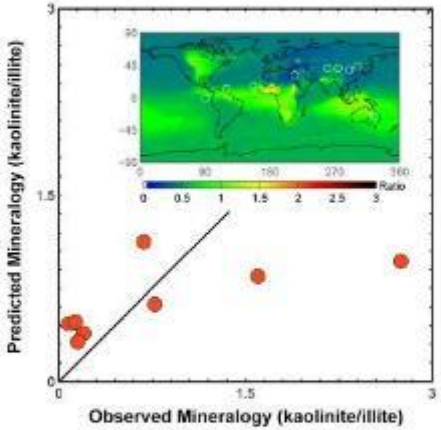
Modified from Scanza et al., 2015



=>

- In this implementation, including mineralogy details, the sign of radiative forcing switched from slightly cooling to slightly warming. An important difference.
- However, forecasts of AOD and SSA are not well-correlated with AERONET-based retrievals. Forecasts of mineralogy of dust deposits are not well-correlated with observed mineralogy.





Scanza, Rachel, N. Mahowald, S. Ghan, C. Zender, J. Kok, Xiaohong Liu, Y. Zhang, and Samuel Albani. "Modeling dust as component minerals in the Community Atmosphere Model: development of framework and impact on radiative forcing." (2015).

Current Mineral Dust Source Information

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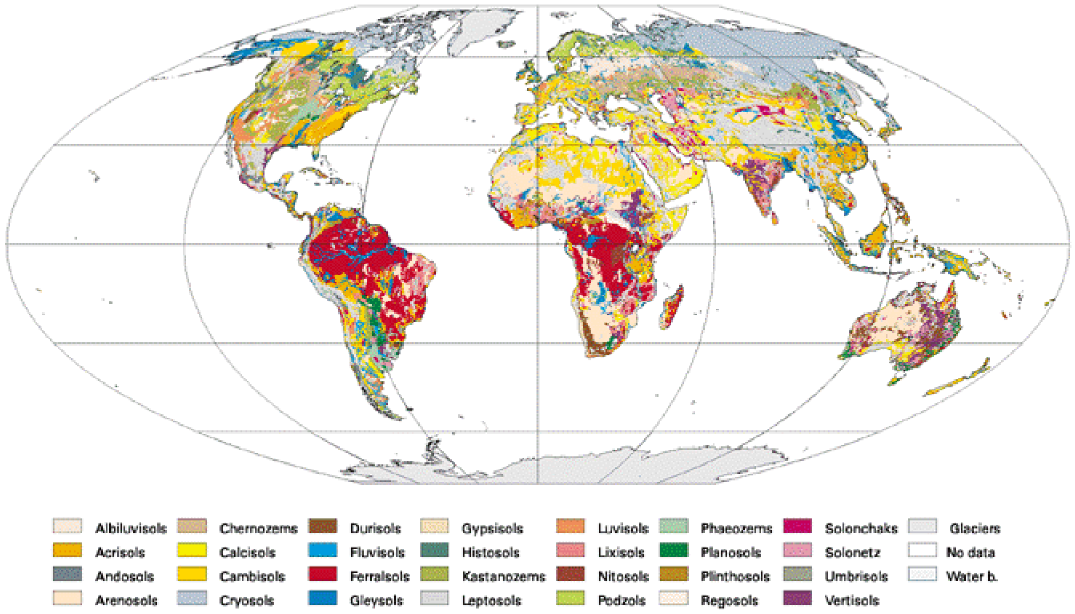
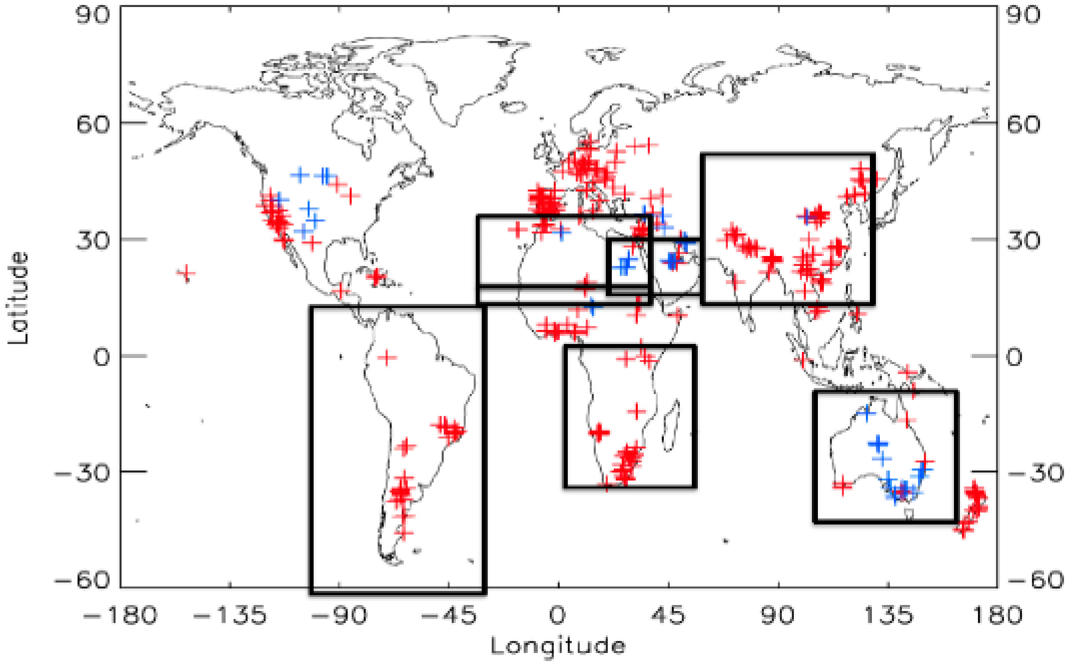
UN Food and Agriculture Organization (FAO) Soil Map Interpolated/Extrapolated



Current Soil Sample Locations



modified from Journet et al., 2014

Challenge: Using FAO soil data sets and “Average” soil properties from ≤5000 soils samples (mostly not in deserts) doesn’t fully capture actual distribution and diversity of the mineral dust source regions.

EMIT observations (~10^9) of arid land regions can advance the science.

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EMIT: Update Dust Source Surface Mineralogy

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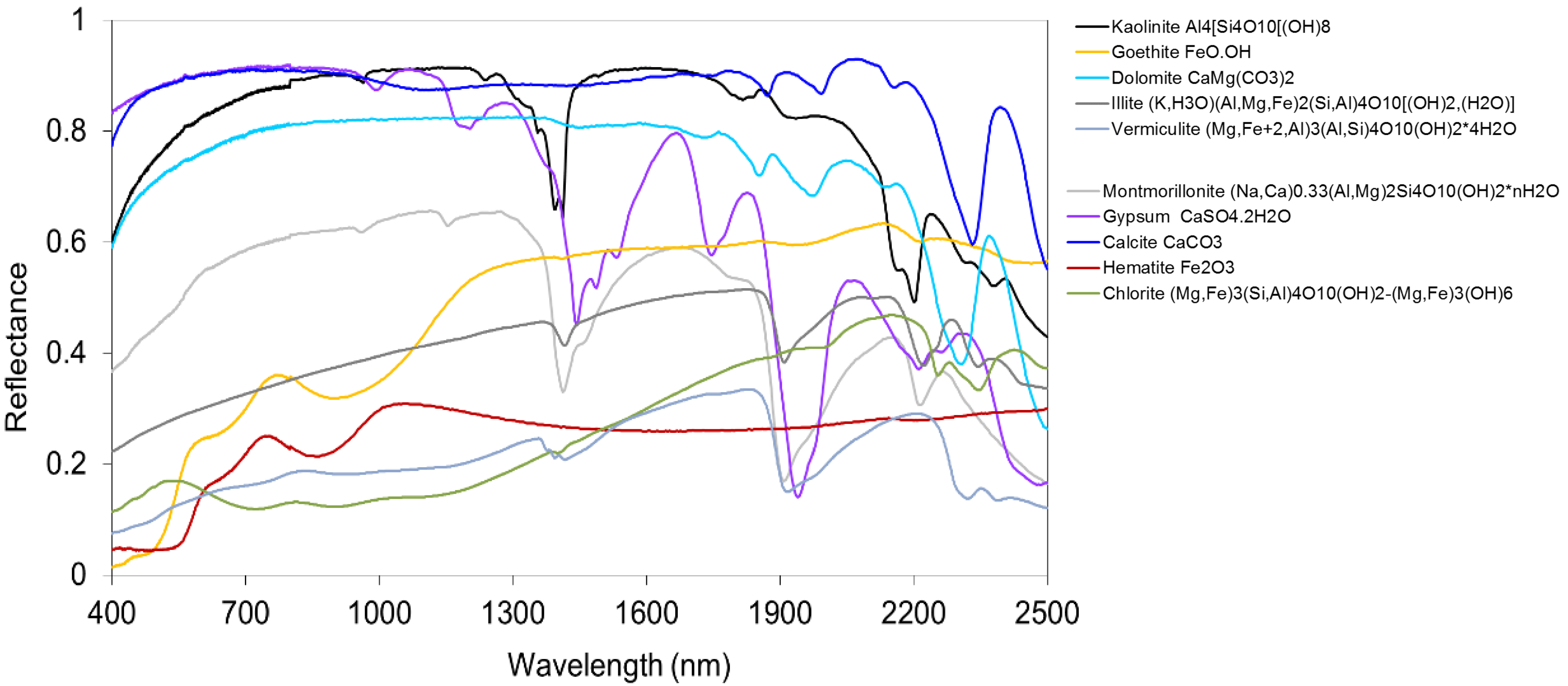
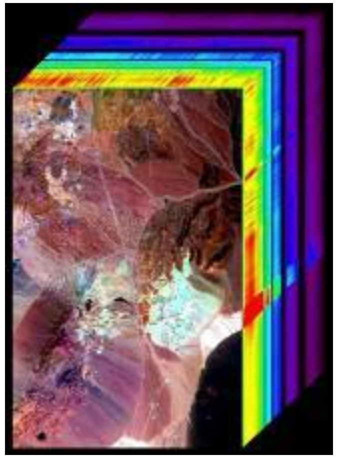
Earth Surface Mineral Dust Source Investigation

EMIT Spectroscopic leverage: Key Dust Minerals of Interest have Distinct Spectral Signatures

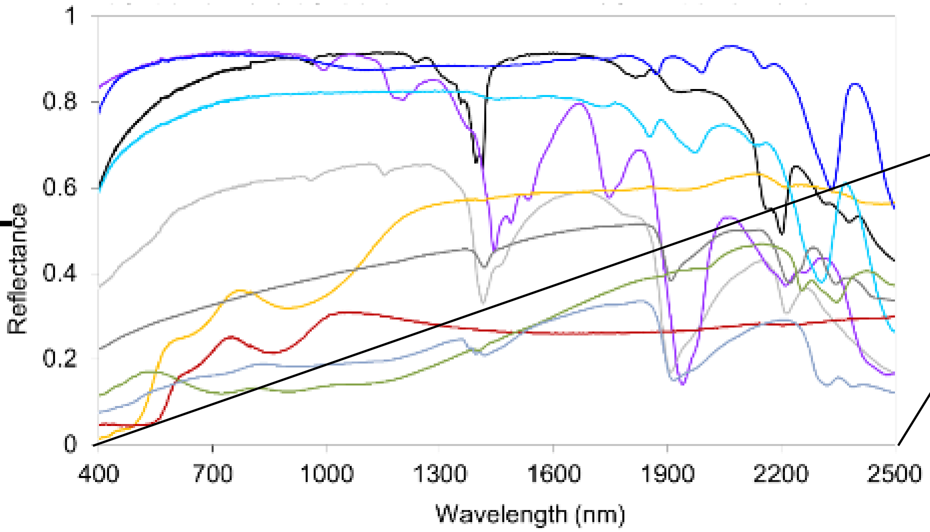


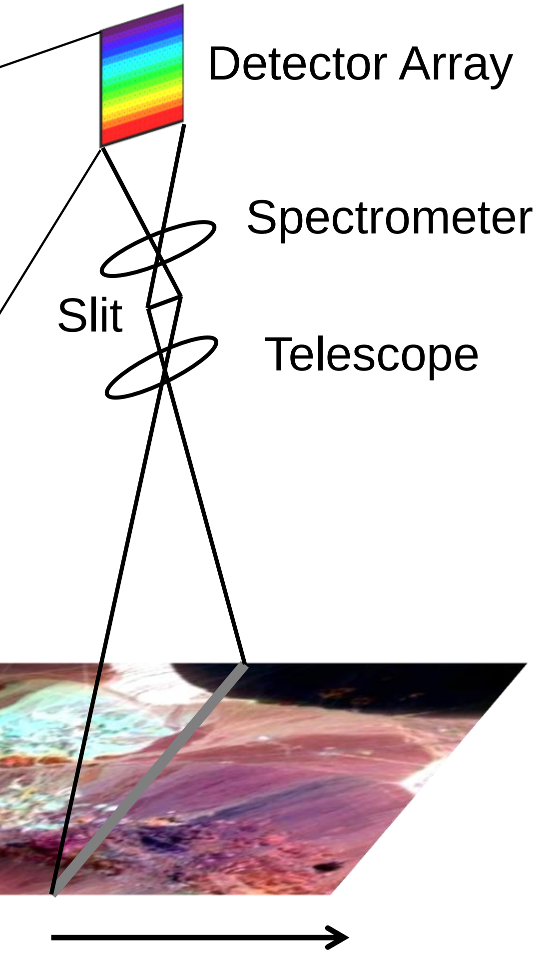
Imaging Spectroscopy Offers a Tested Approach to Measure Surface Mineralogy

Calibrated Image Cube

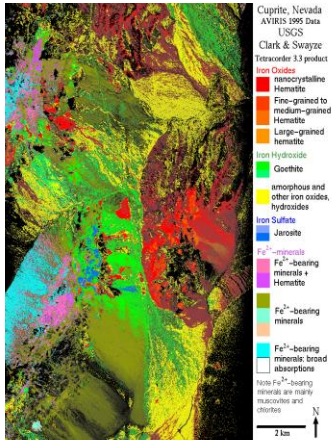


100s of Parallel Spectrometers





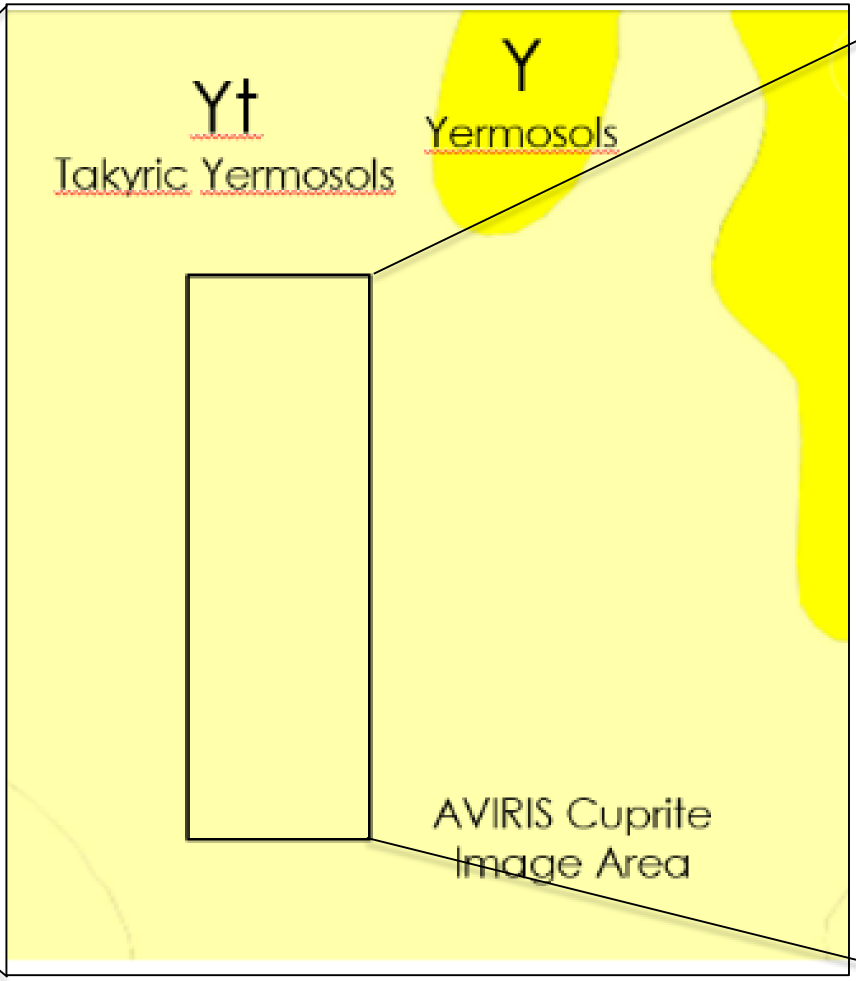
Material Map



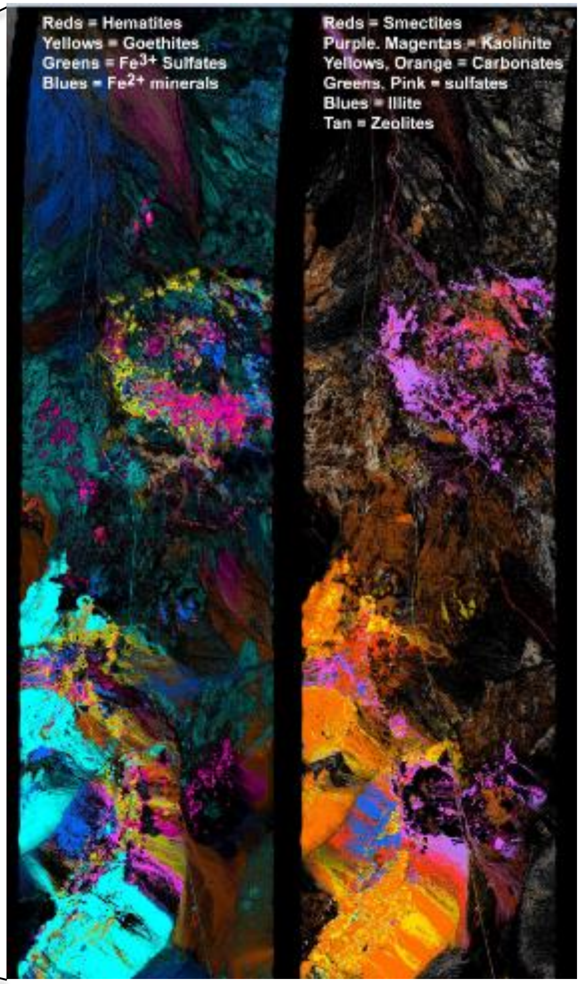
FAO Soil Map Compared to Airborne VSWIR Imaging Spectroscopy at Cuprite, Nevada

Cuprite, Nevada Region

FAO Soil Map



VSWIR Imaging Spectroscopy



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Mineral Mapping Test in the Salton Sea, CA Dust Source Region

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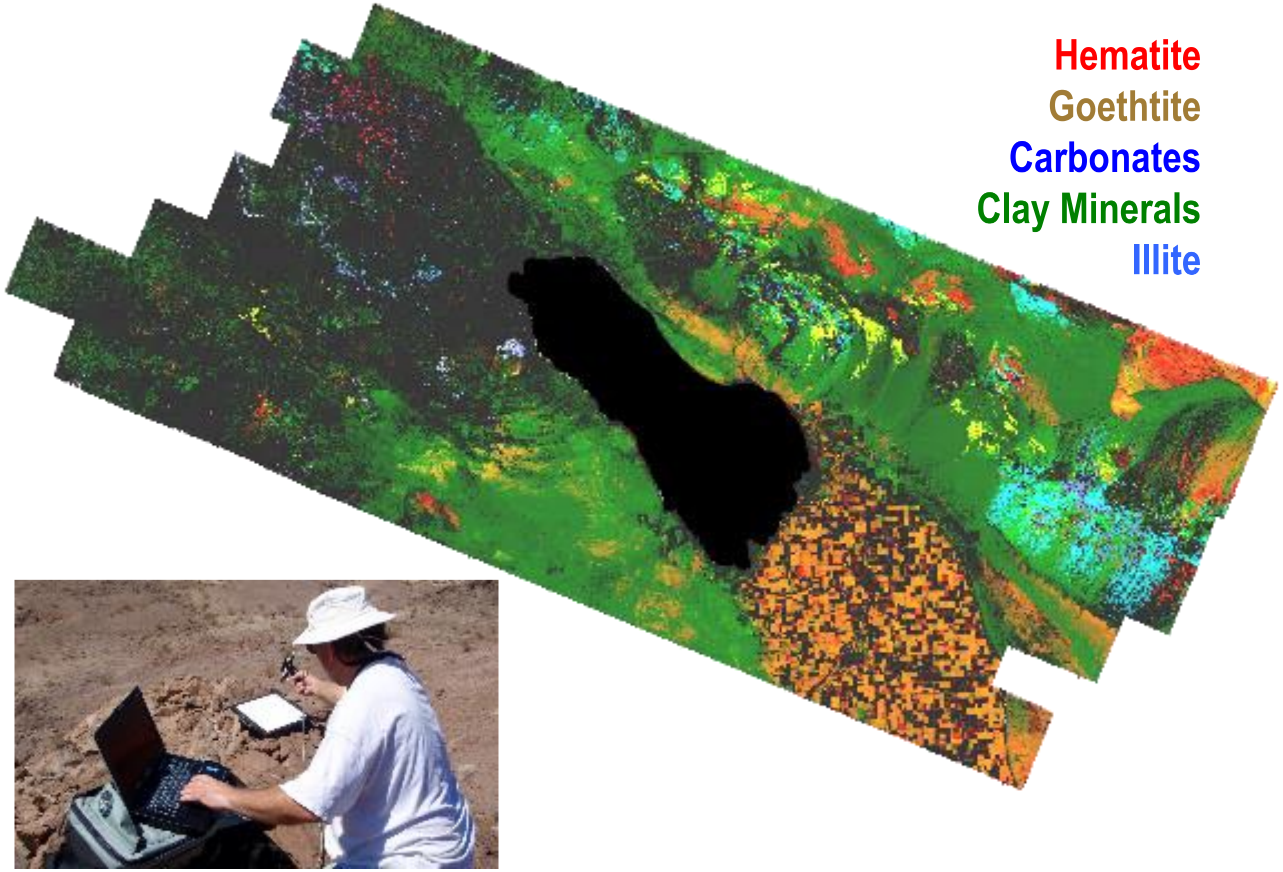
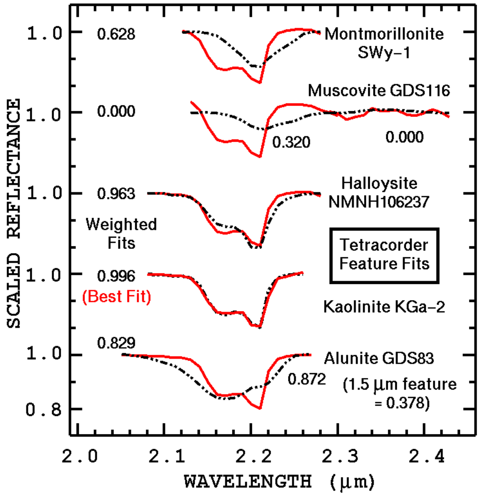
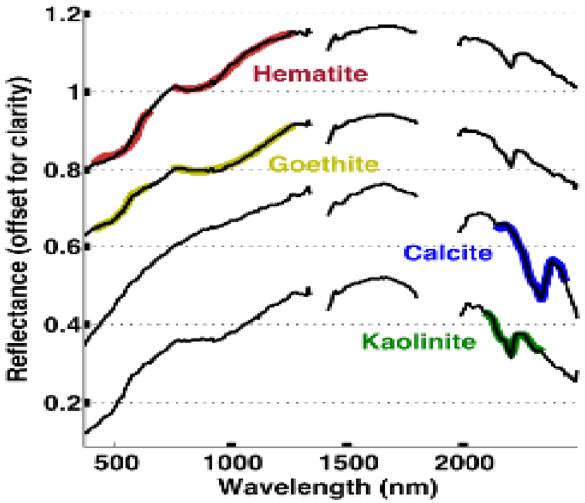
Earth Surface Mineral Dust Source Investigation

AVIRIS imaging spectroscopy measurements of the Salton Sea region in Southern California acquired as part of the 2014 NASA HyspIRI airborne campaign.







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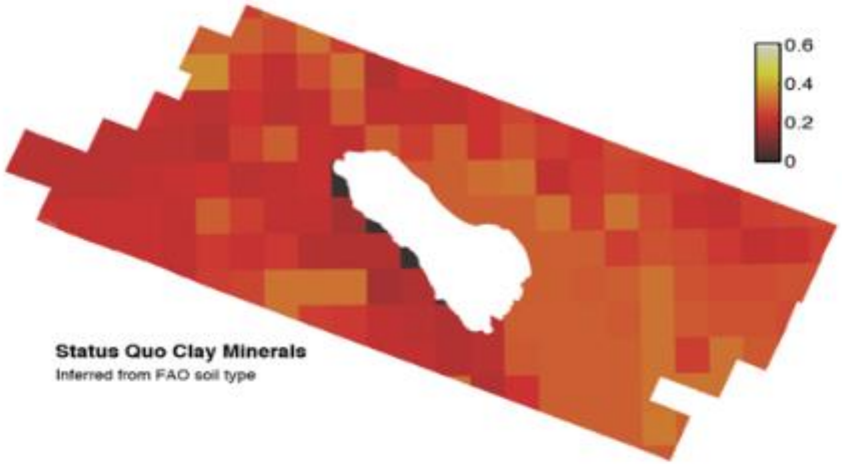
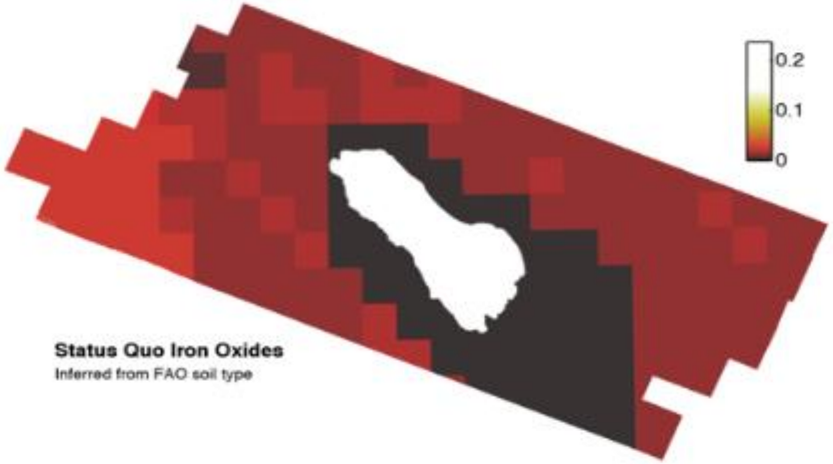
Testing FAO Mineralogy versus Imaging Spectroscopy Mineralogy

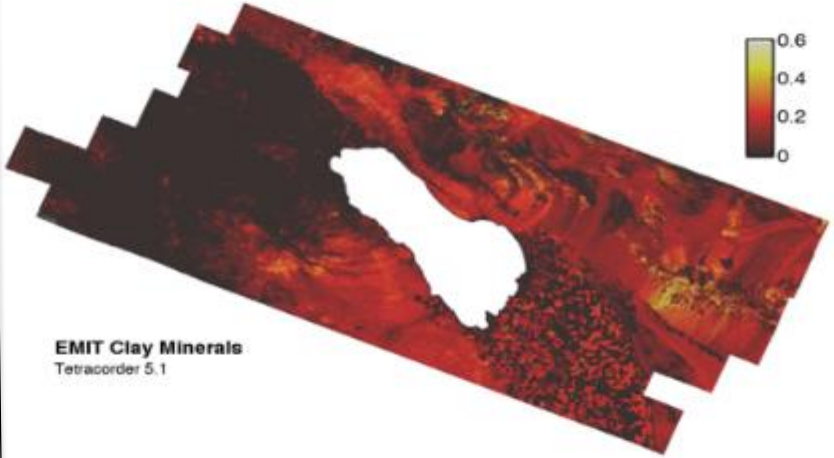
EARTH SURFACE MINERAL DUST SOURCE INVESTIGATION

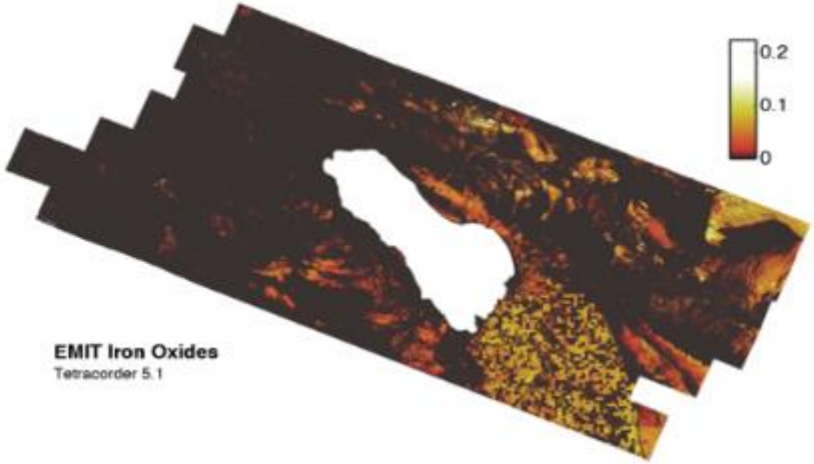
FAO Based Minerals



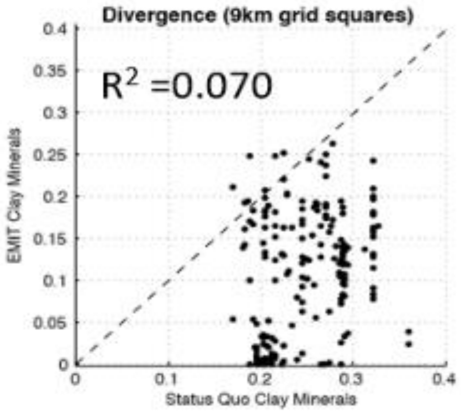


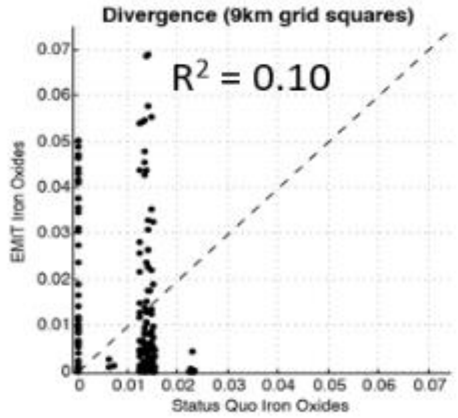
VSWIR Spectroscopy



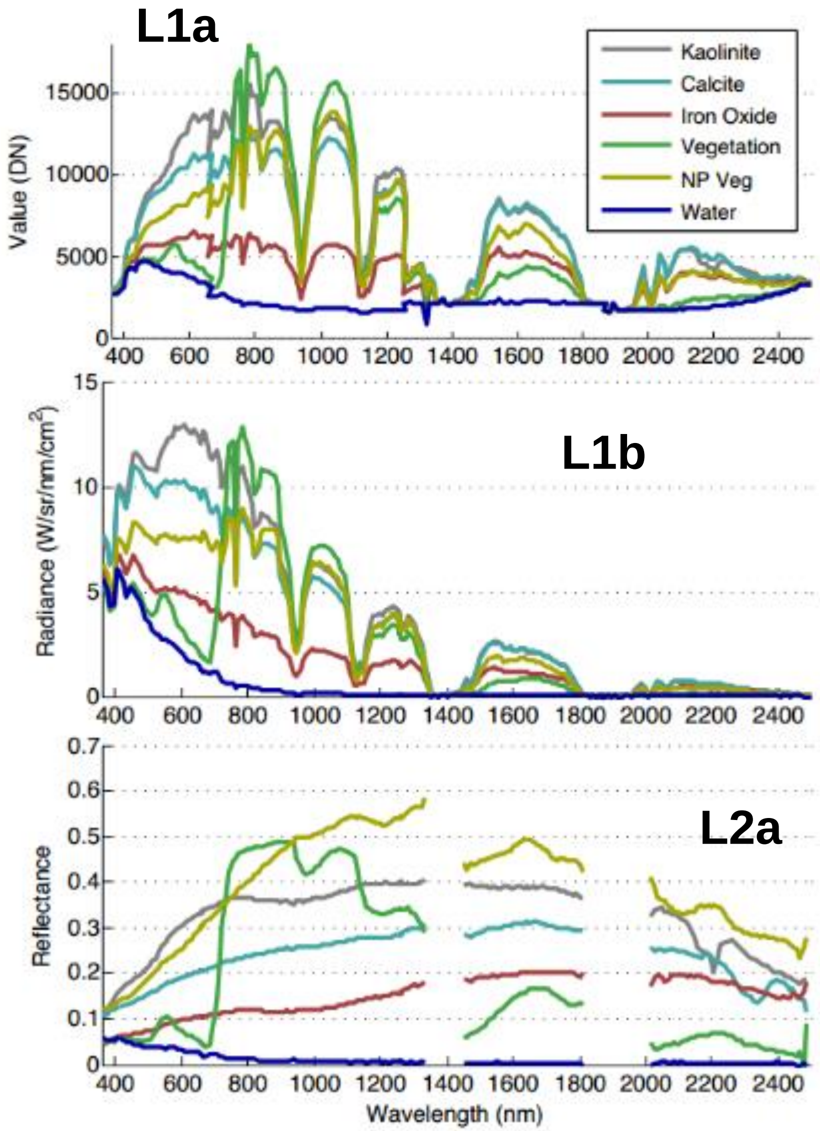


Comparison

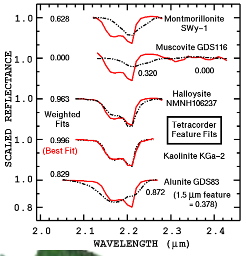


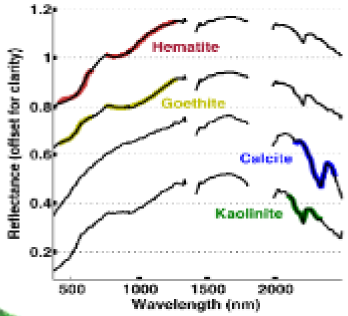


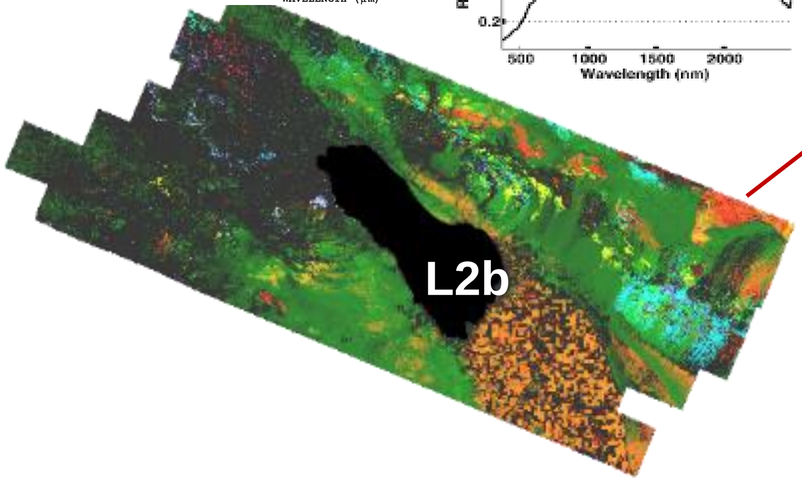
Example: Level 1a, 1b, 2a, 2b and L3 Products



Hematite
Goethtite
Carbonates
Clay Minerals
Illite

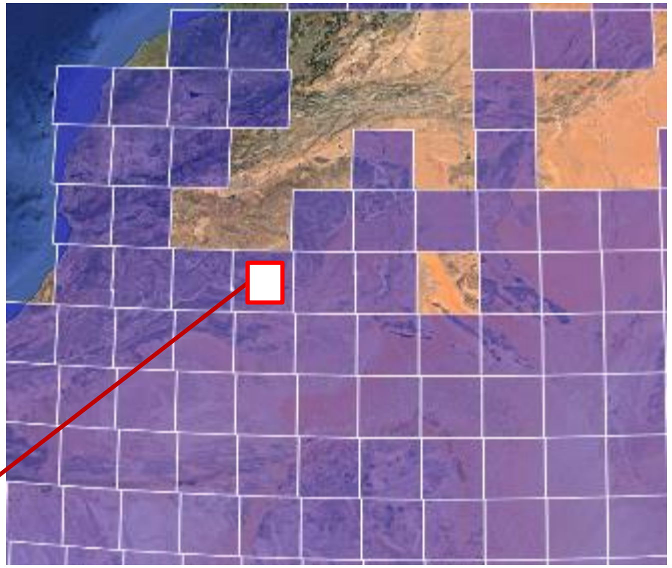






Mineral dust source composition products at grid scale for Earth System Models

L3



Key prototype algorithms are running

4.6 Table 1: EMIT Data Products

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EARTH SURFACE MINERAL DUST SOURCE INVESTIGATION

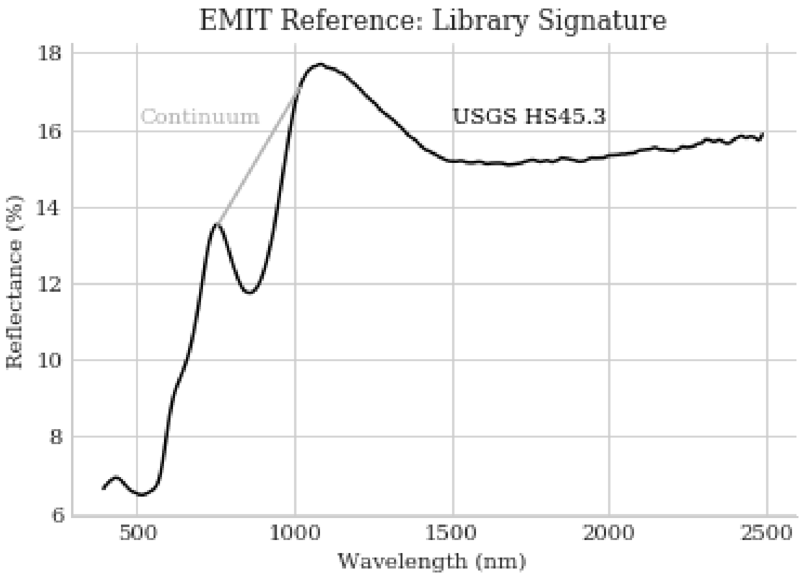
Data Product	Description	Initial Availability to NASA DAAC	Median Latency in Product Availability to NASA DAAC after Initial Delivery	NASA DAAC Location
Level 0	Raw collected telemetry	4 months after IOC	2 months	LP DAAC
Level 1a	Reconstructed, depacketized, uncompressed data, time referenced, annotated with ancillary information reassembled into scenes.	4 months after IOC	2 months	LP DAAC
Level 1b	Level 1a data processed to sensor units including geolocation and observation geometry information	4 months after IOC	2 months	LP DAAC
Level 2a	Surface reflectance derived by screening clouds and correction for atmospheric effects.	8 months after IOC	2 months	LP DAAC
Level 2b	Mineralogy derived from fitting reflectance spectra, screening for non-mineralogical components.	8 months after IOC	2 months	LP DAAC
Level 3	Gridded map of mineral composition aggregated from level 2b with uncertainties and quality flags	11 months after IOC	2 months	LP DAAC
Level 4	Earth System Model runs to address science objectives	16 months after IOC	2 months	LP DAAC

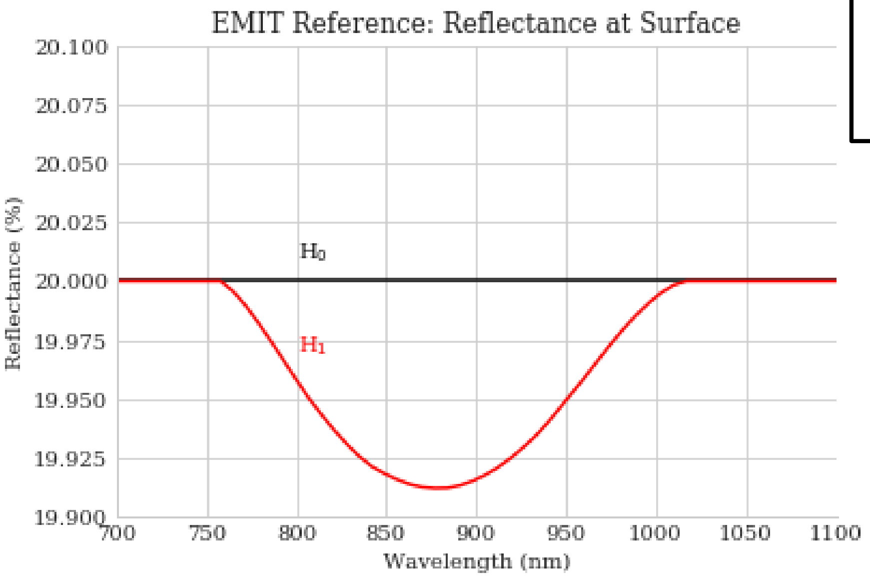
LP DAAC Assigned

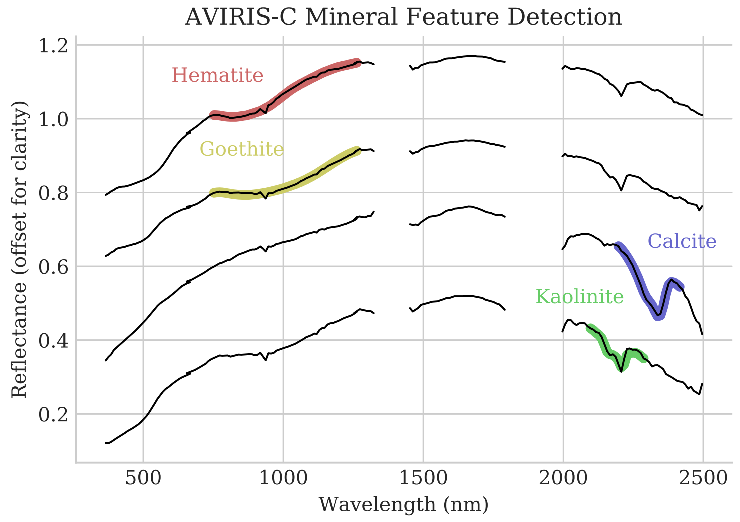
Iron Oxide Reference Case

- An arrangement of pure Hematite HS45.3 subtending a 2% fractional area within each pixel,
- Against a substrate with a uniform 20% reflectance.
- This coarse grained sample provides a conservatively-small signal.

$$H_0 : \rho_s = \rho_{20\%} \quad H_1 : \rho_s = \rho_{20\%} + 0.02\kappa_{hem}$$



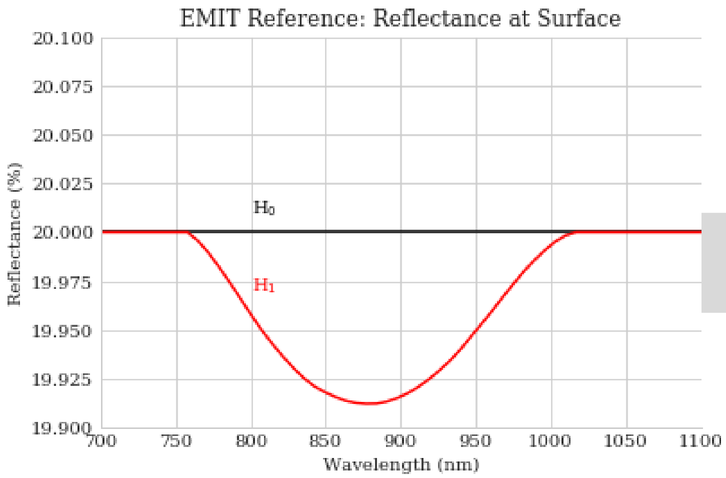


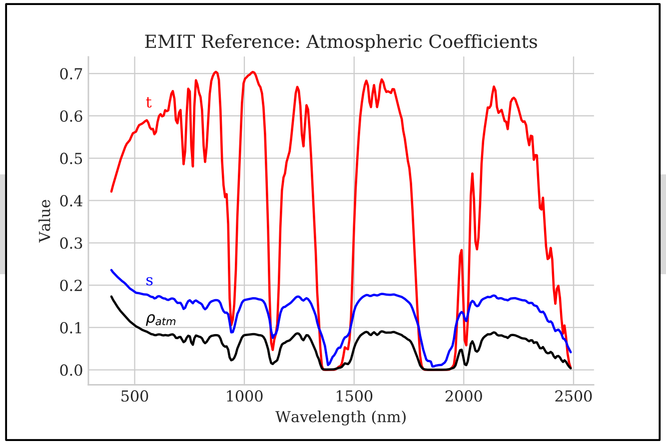


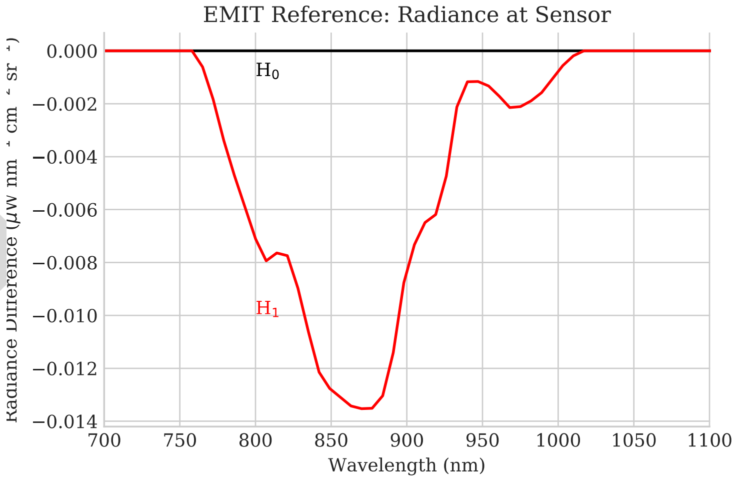
Hypothesis Test (Radiance at Sensor)

- Translating to the at-sensor measurement, we calculate the resulting hypothesis test
- This allows us to evaluate the separability in the presence of instrument noise, after combining all channels.

Atmospheric and solar effects

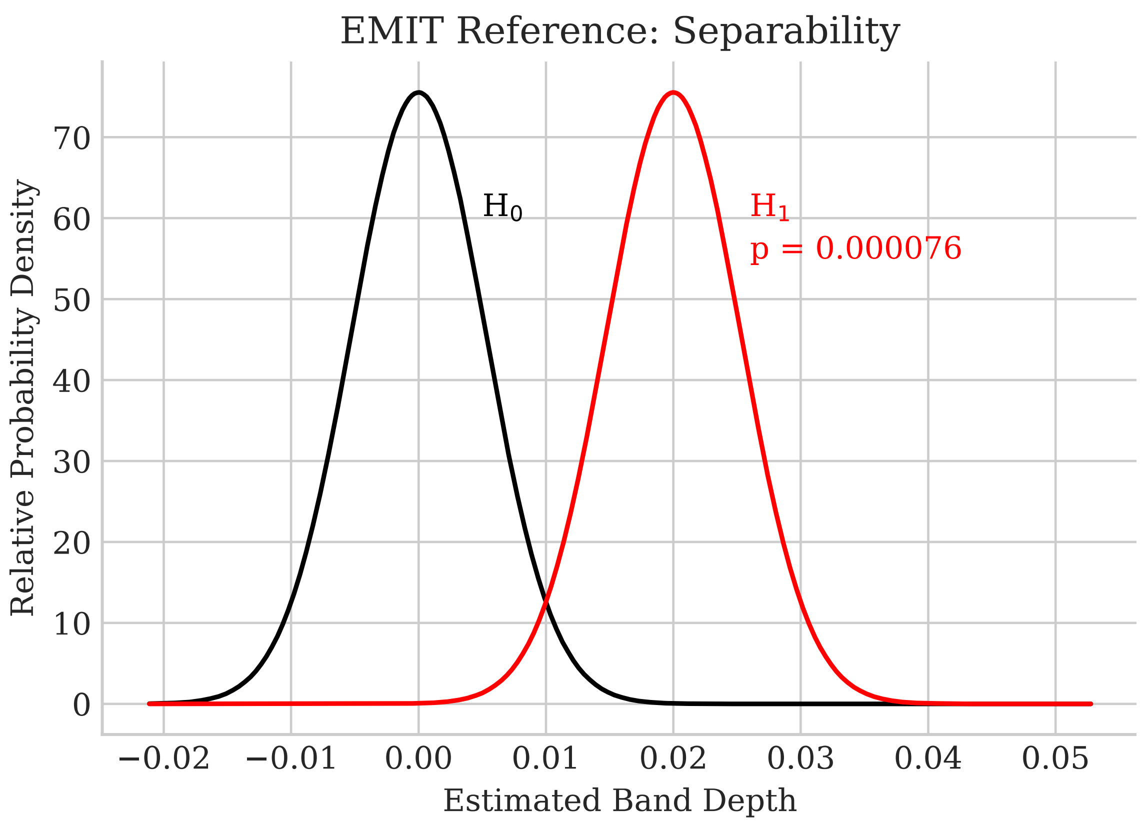


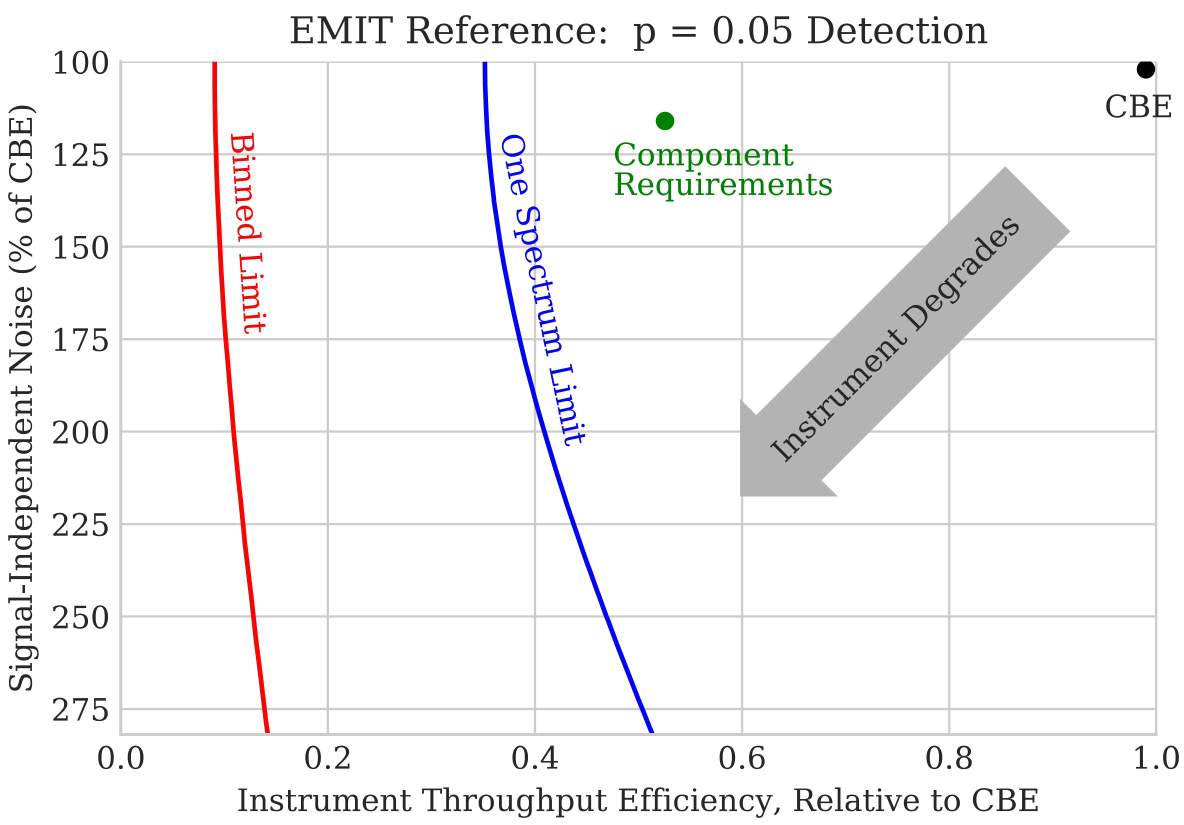




SNR, Performance, and Margin

Estimated band depths for a single-spectrum detection case (left) and for estimating band depth accurately by aggregating spectra (right)





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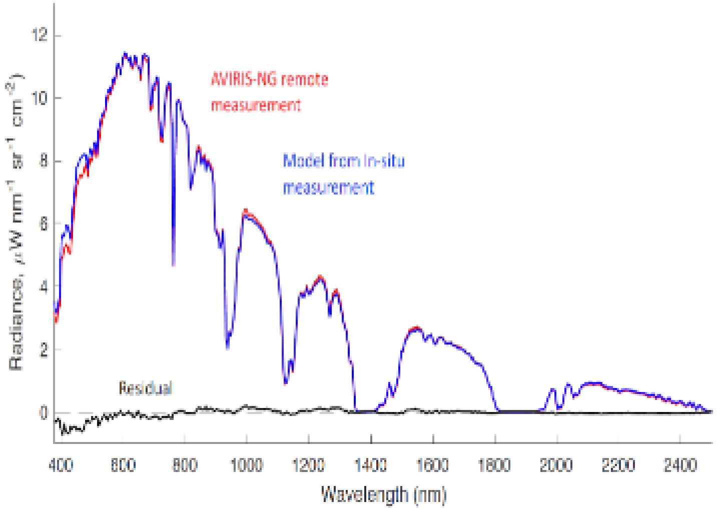
Science Product Validation Approach

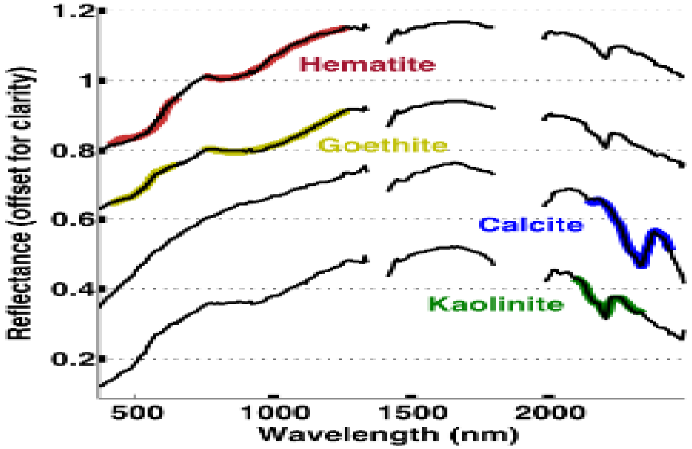
EMIT
Earth Surface Mineral Dust Source Investigation

Level 1b

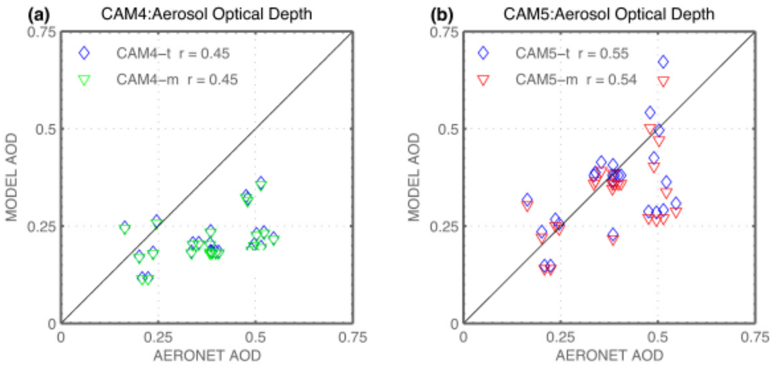


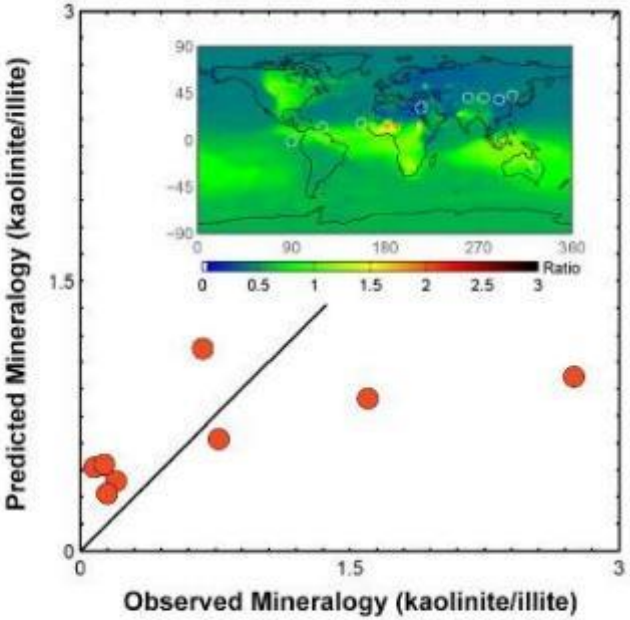
Level 2a, 2b and 3

Field Spectroscopy with Laboratory/Analyses

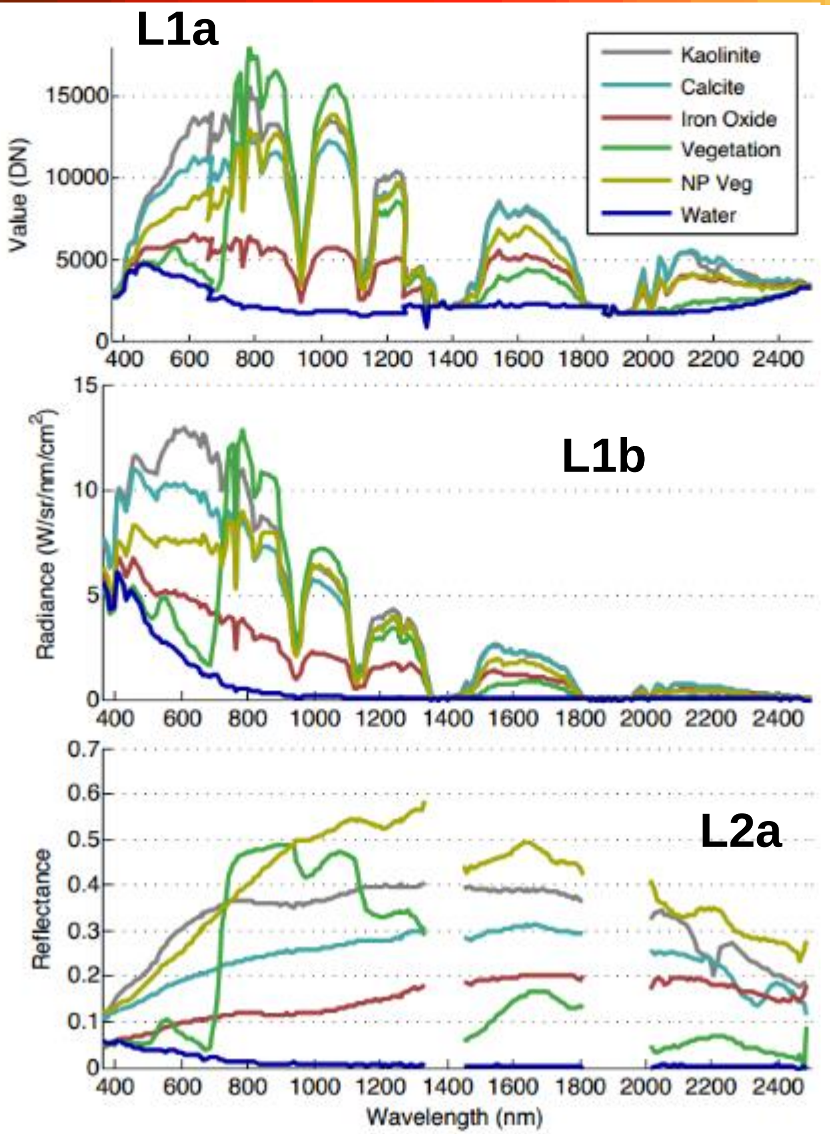


Level 4 follows Scanza 2015 Approach

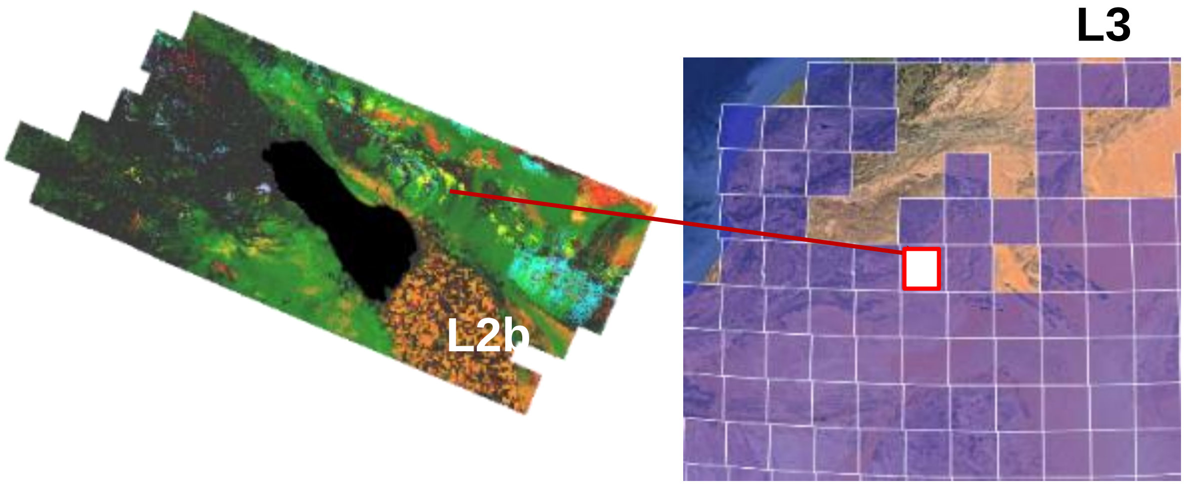


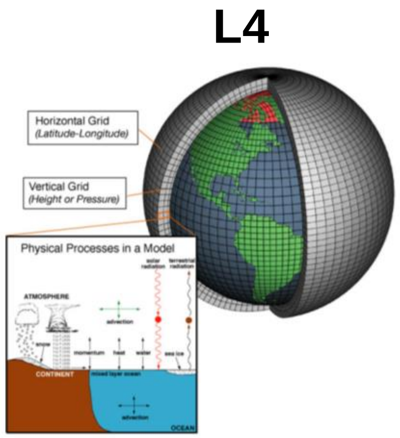


Initial Draft Algorithm Theoretical Basis Documents



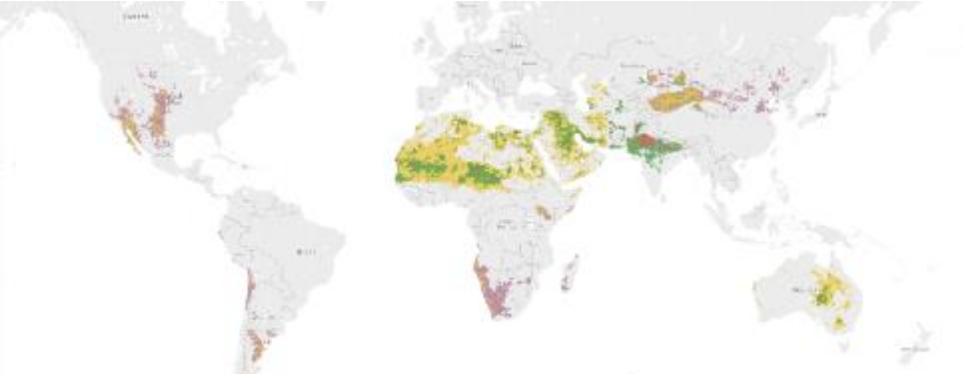
Description	Product	Lead Author	Document Number
Transforms L1A data to at sensor radiance units including geolocation and observation geometry information.	Level 1B	David R. Thompson	D-104254
Corrects L1B measured radiance to surface reflectance with generation of cloud mask.	Level 2A	David R. Thompson	D-104255
Determines EMIT mineralogy derived from L2A reflectance spectra.	Level 2B	Roger Clark	D-104479
Geneartes aggregated mineralogy from L2B to the required EMIT grid scale for ESMs.	Level 3	Greg Okin	D-104480
Earth System Model and model runs to achieve science objectives.	Level 4	Natalie Mahowald	D-104481



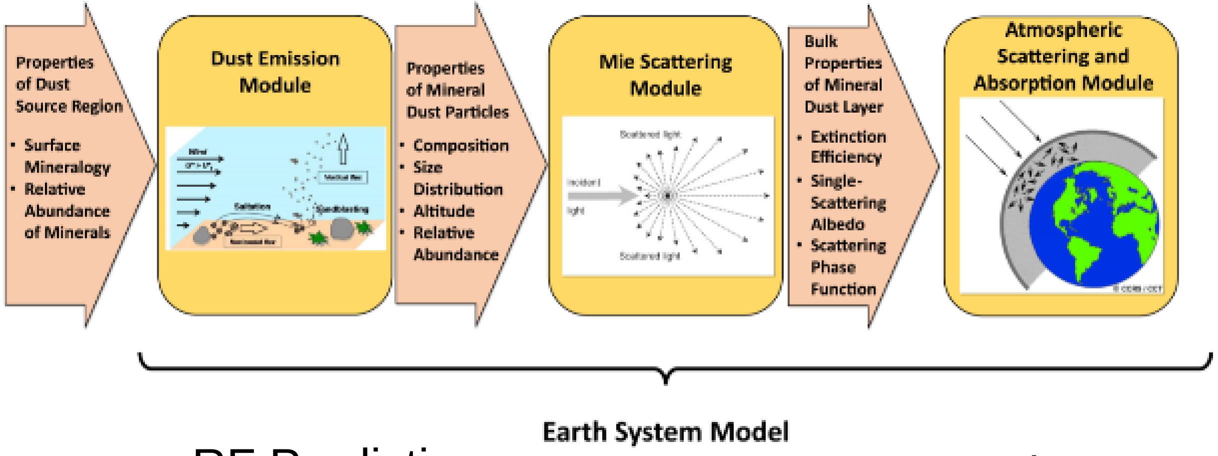


Summary
EMIT Science Flow to Objectives and Hypotheses

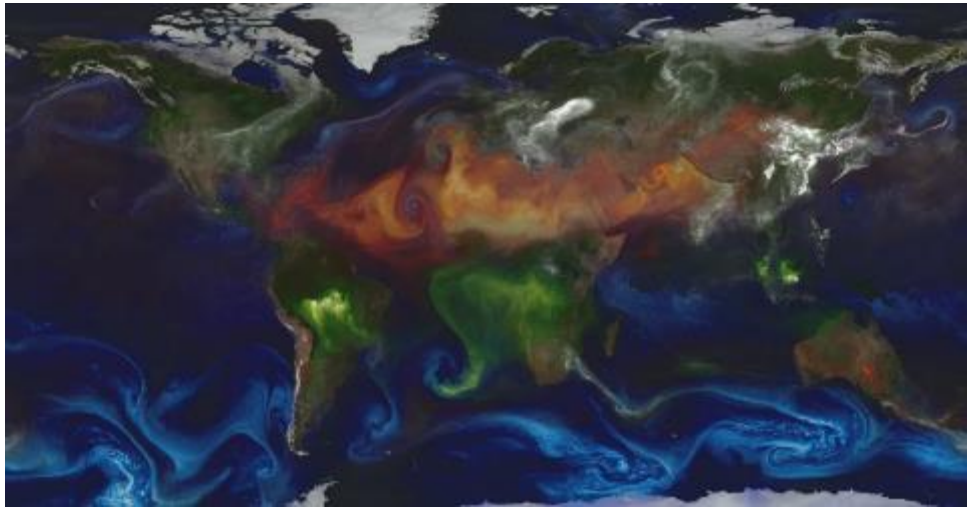
EMIT mineral composition aggregated for models



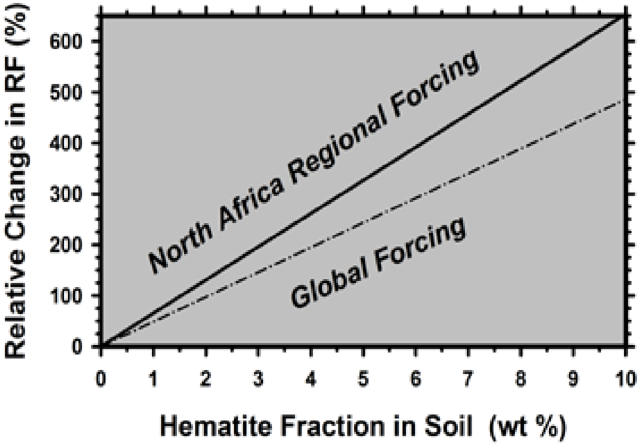
EMIT initialized ESM



ESM Model Runs



RF Predictions



Test Hypotheses

The net contribution of mineral dust to regional and global radiative forcing is to warm the atmosphere (positive forcing).

The impact of mineral dust on regional precipitation and radiative forcing will promote the expansion of dust source regions.