Perspectives on modeling dust mineralogical composition and its effects upon climate

Carlos Pérez García-Pando

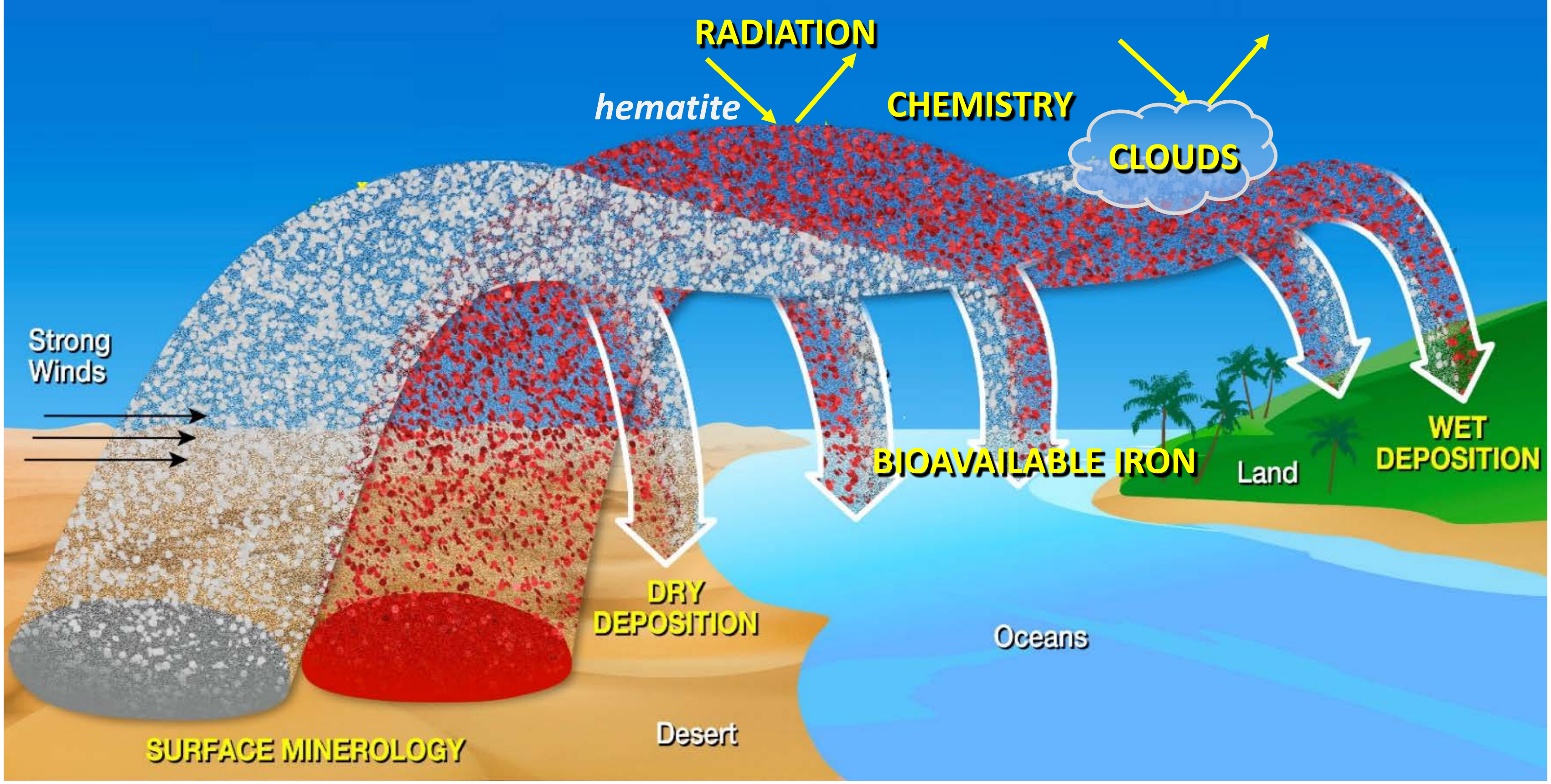
Acknowledgements:

EMIT and FRAGMENT TEAMS

24.09.2019

18th AEROCOM Workshop, Barcelona

Dust mineralogy and climate



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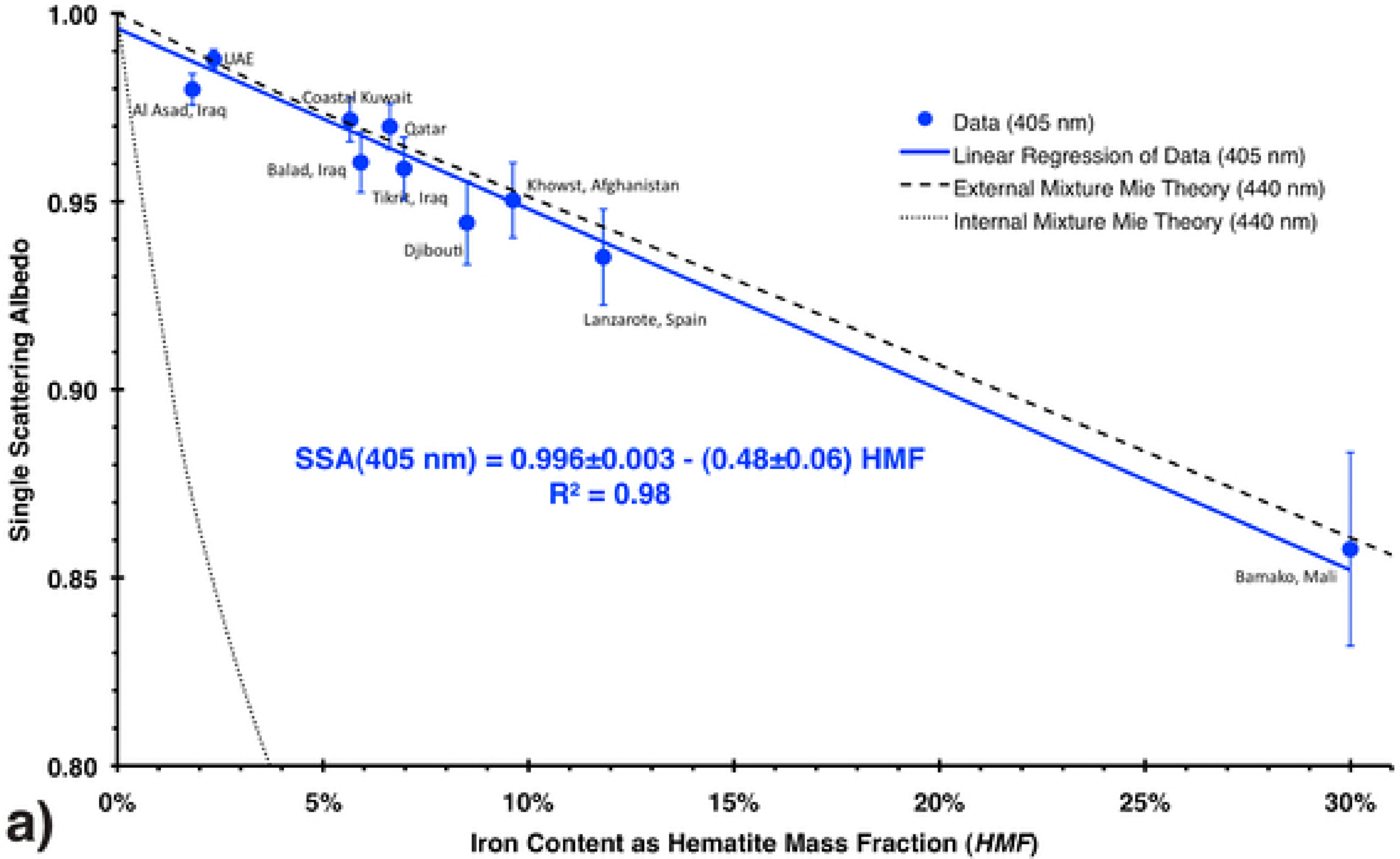
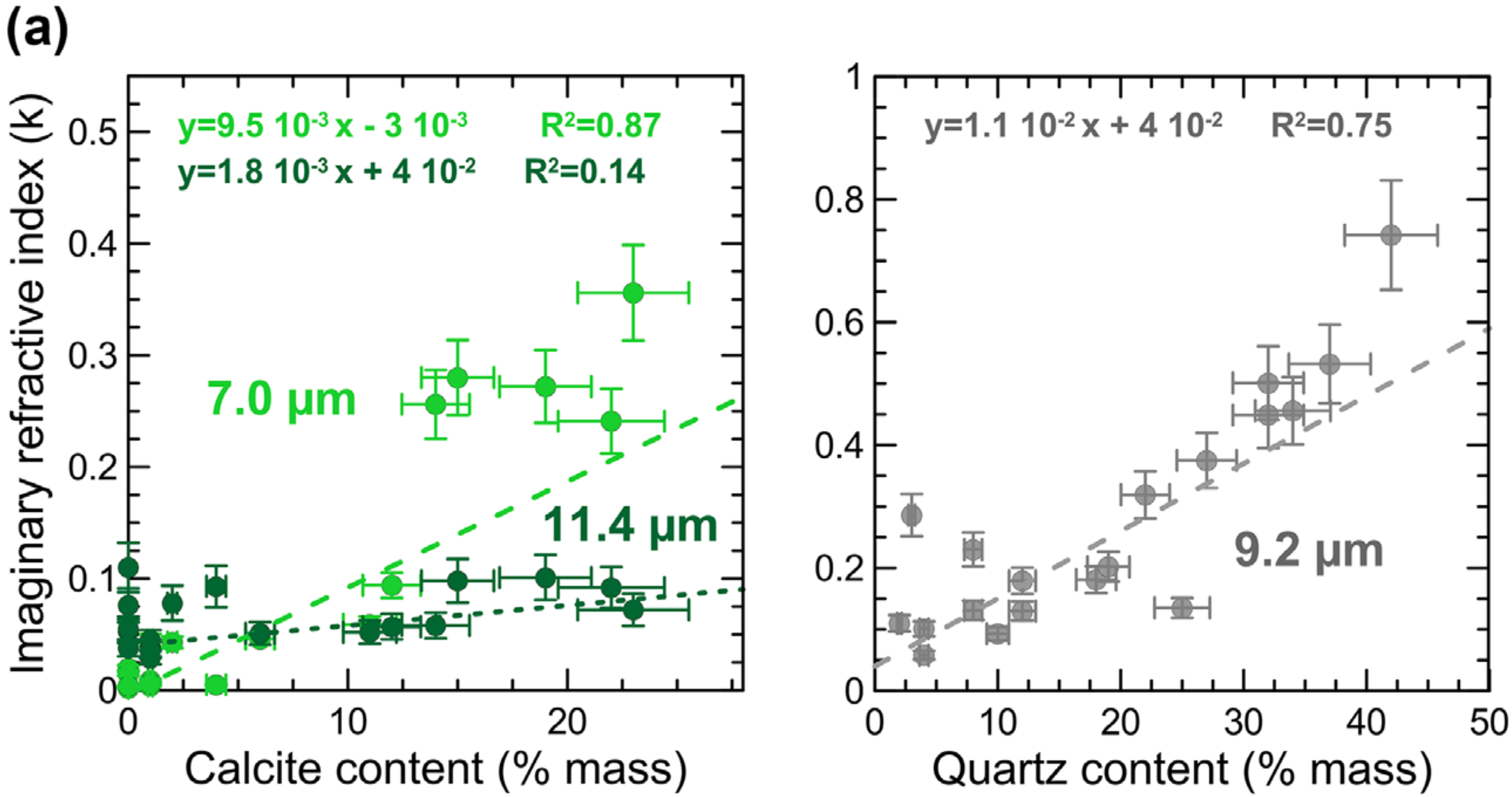
Shortwave forcing



Moosmüller et al. (2012)

Iron oxides
Hematite

Longwave forcing



Di Biagio et al. (2017)

Calcite

Quartz

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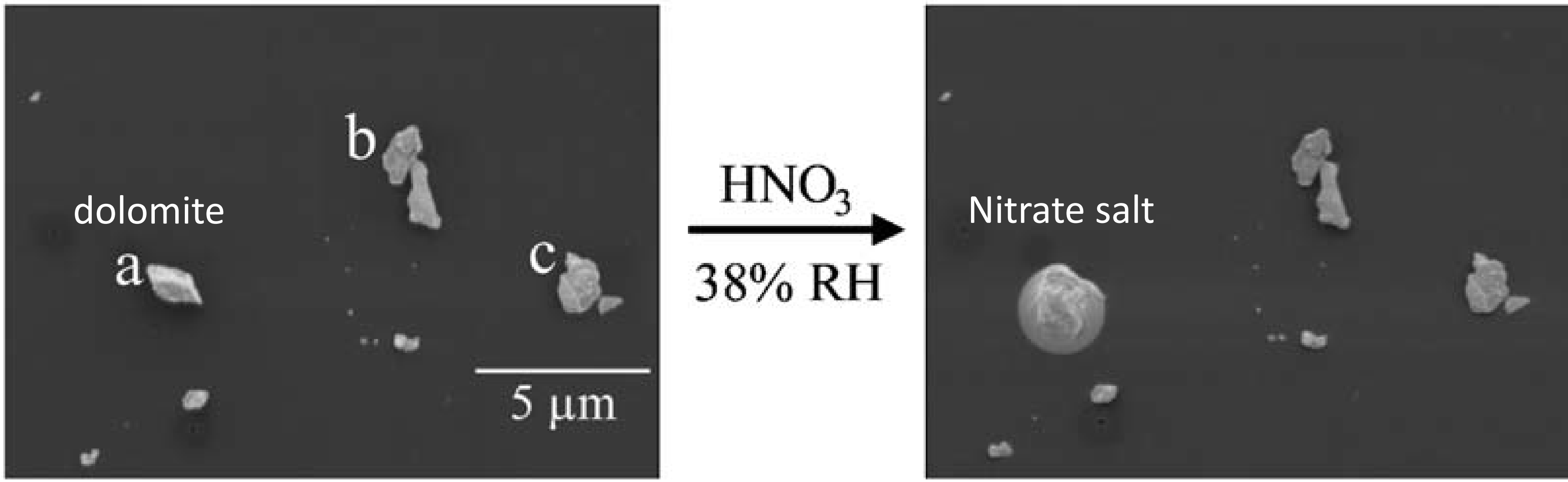
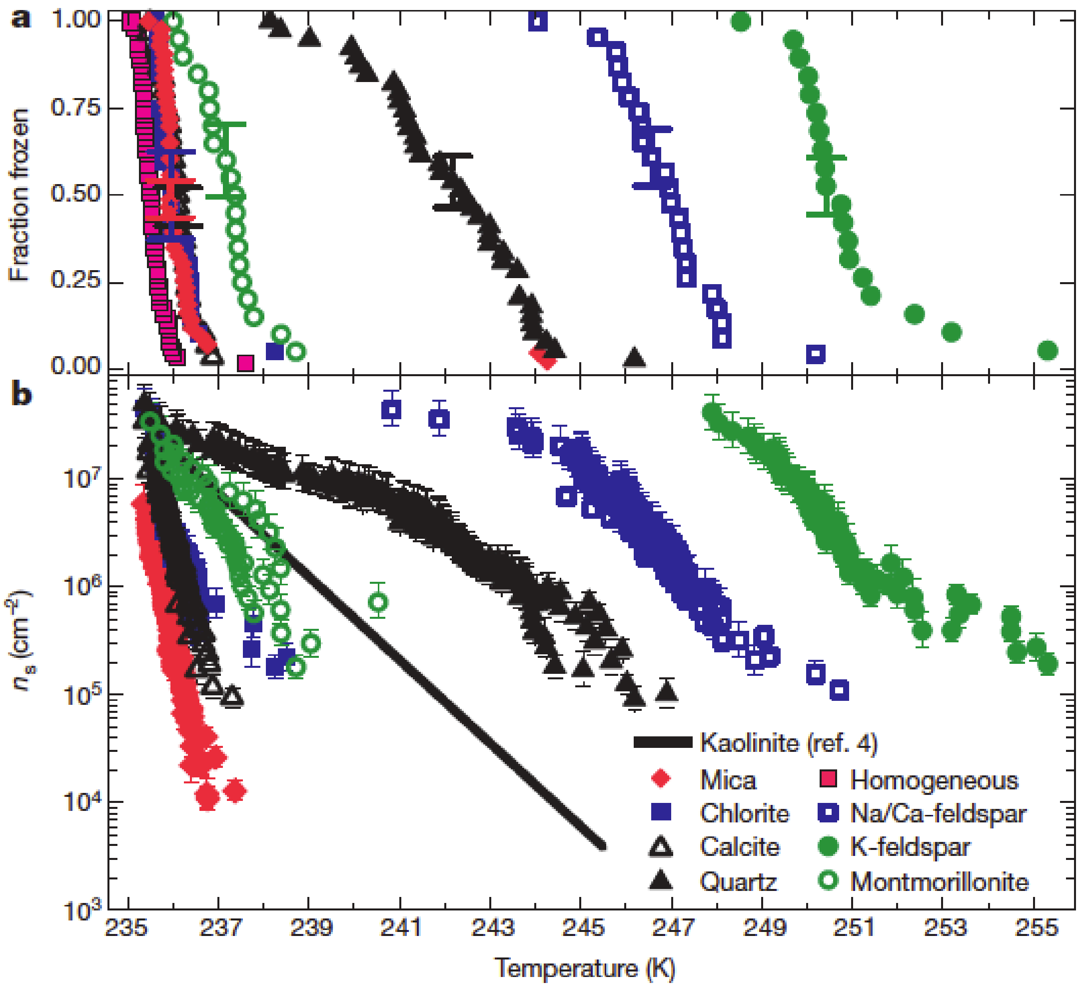
Heterogeneous chemistry



Krueger et al. (2004)

Ice nucleation and mixed-phase clouds



Atkinson et al. (2017)

K-Feldspar

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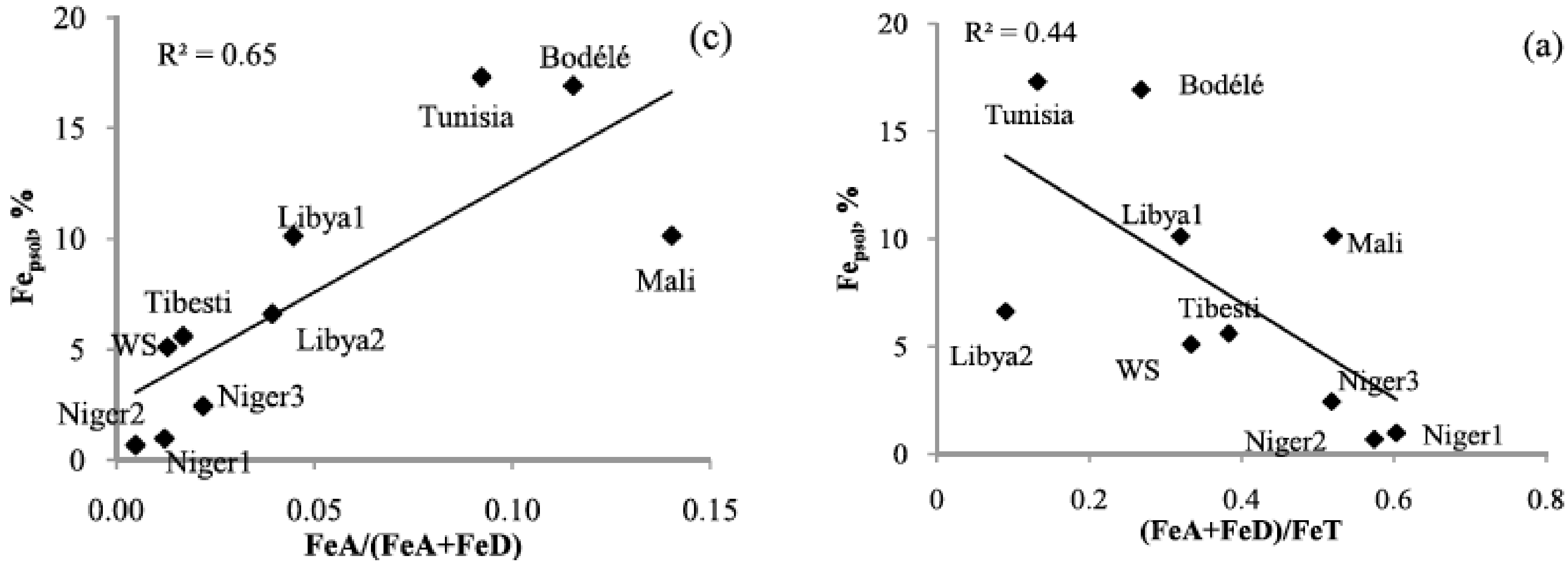
Iron mineralogy and solubility



FeA: amorphous and/or poorly crystalline and nanoparticulate Fe (ascorbate Fe)
FeD: crystalline Fe(III) oxides, mainly goethite and hematite (dithionite Fe)
FeT: Total Fe including Structural Fe (FeSt)

Shi et al. (2011)

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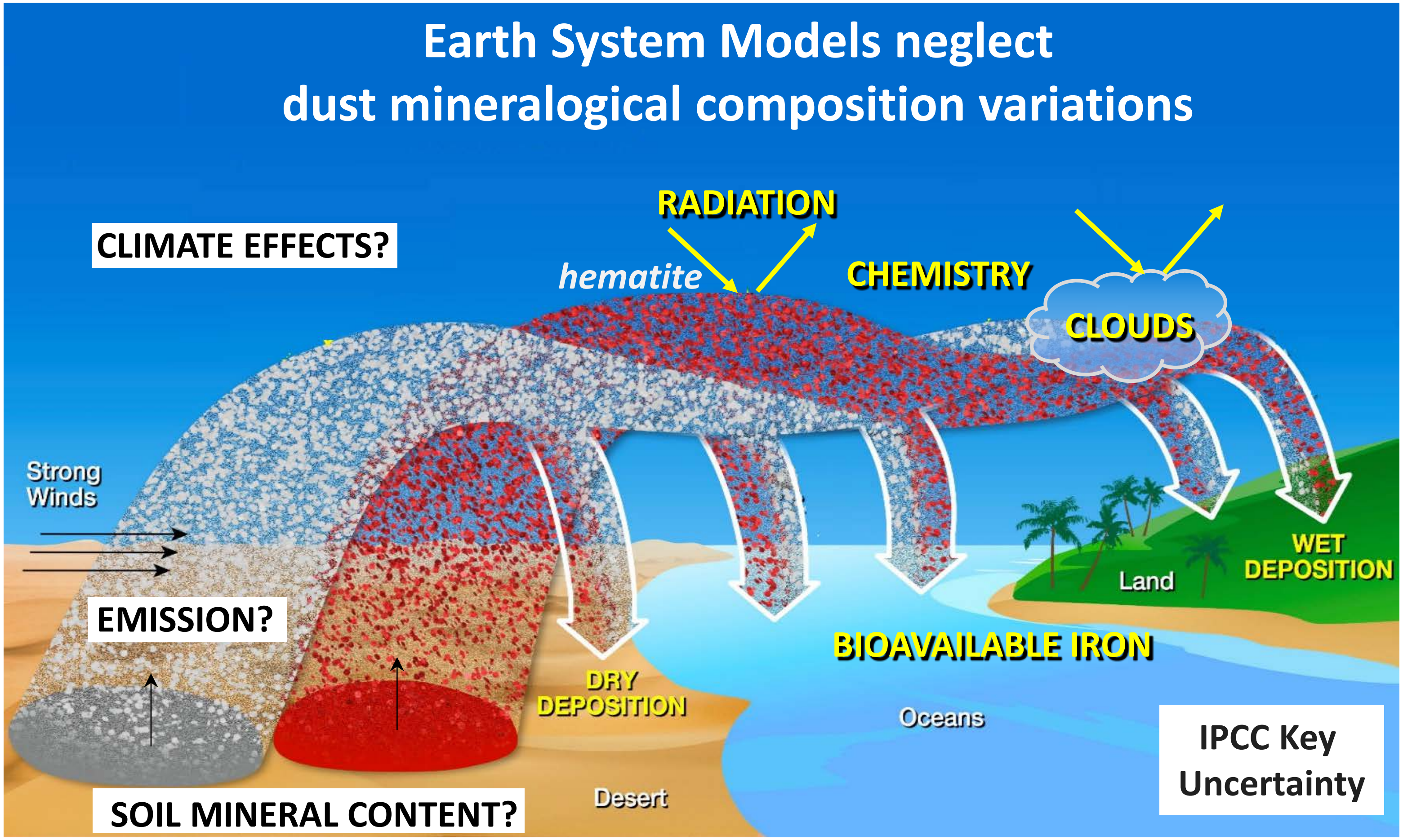
Motivation



- Constrain the global dust mineralogical composition
- Understand and calculate its effects upon climate

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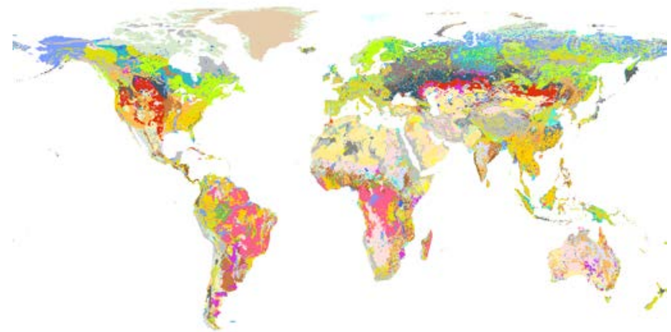
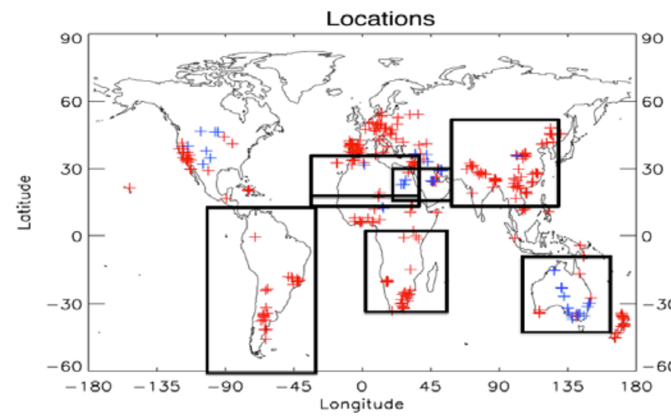
Mapping of soil-surface mineralogy

- Claquin et al., 1999; Journet et al., 2014
- Currently 12 key minerals estimated
- 700 soil descriptions sampling 55 % of FAO soil units
- Many regions including prolific sources not sampled
- Massive extrapolation based on soil unit/type
- A number of assumptions to overcome the lack of data: for example on hematite and goethite size
- Soil analysis based on *wet sedimentation* ("*wet sieving*"), which breaks the aggregates found in undispersed soils subject to wind erosion.



FAO soil types or units

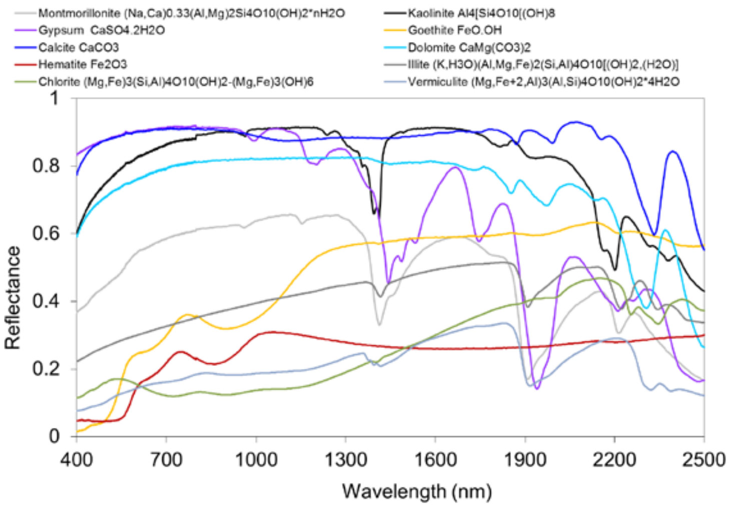


Sieves for mechanical analysis

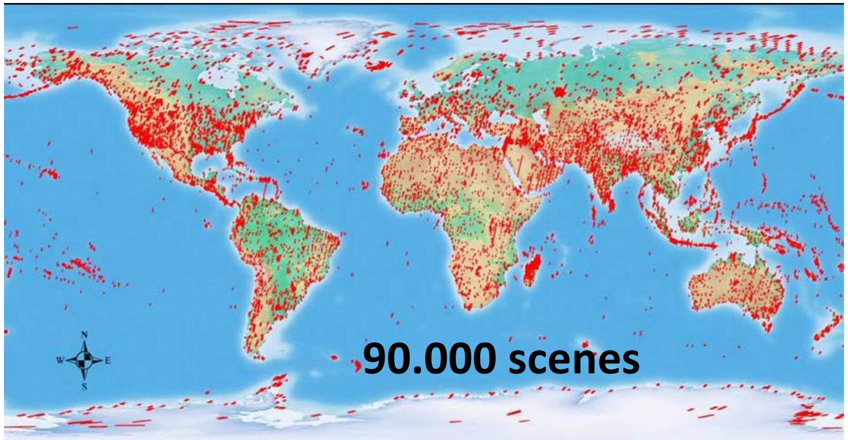
Soil Hydrometer apparatus

Space borne hyperspectral imaging spectroscopy

VSWIR Spectra of Dust Source Minerals

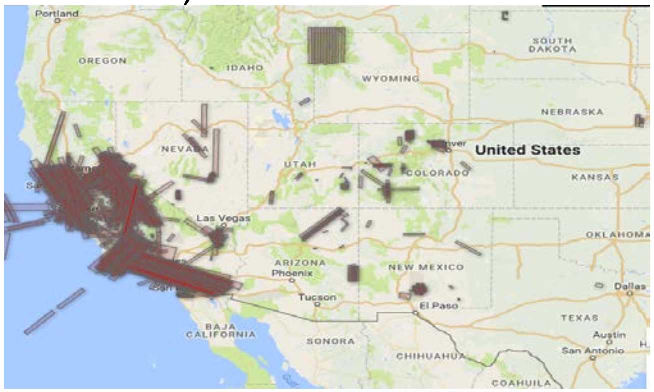


Hyperion: satellite hyperspectral sensor 0.4 to 2.5 µm, 242 spectral bands, 10nm spectral resolution, 30 m spatial with a SNR of ~50:1



AVIRIS airborne scenes

0.4–2.5 µm, 224 bands, 10 nm spectral resolution, SNR of ~500:1



Coming soon (2021)!!!

NASA FUNDED

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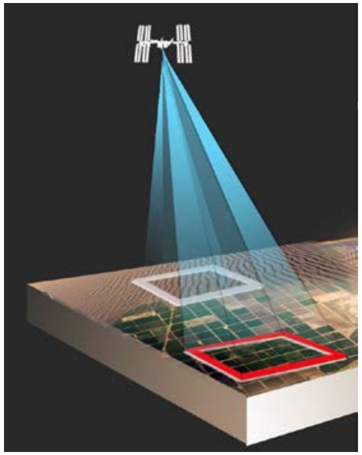
Earth Surface

Mineral Dust Source

Investigation



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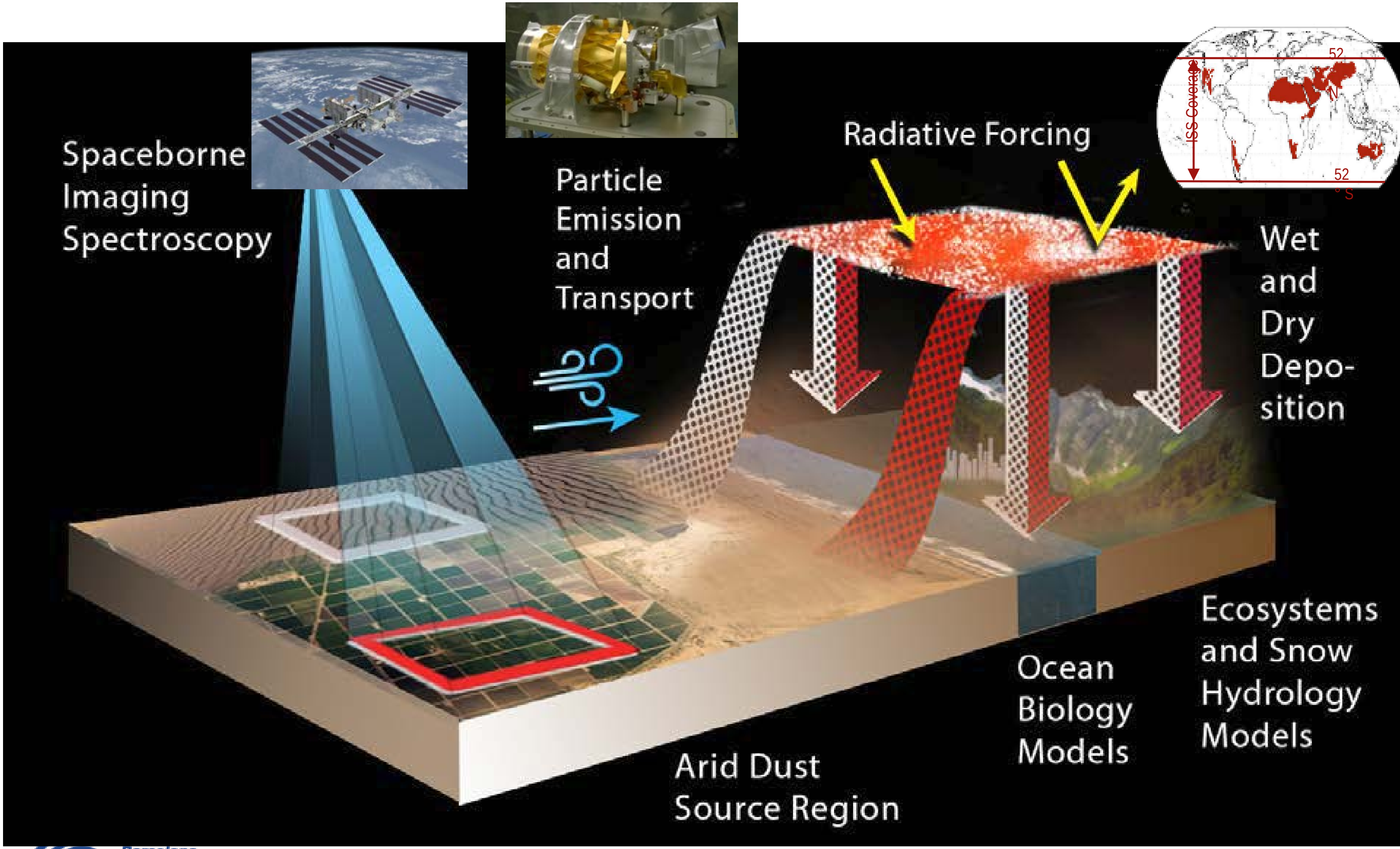
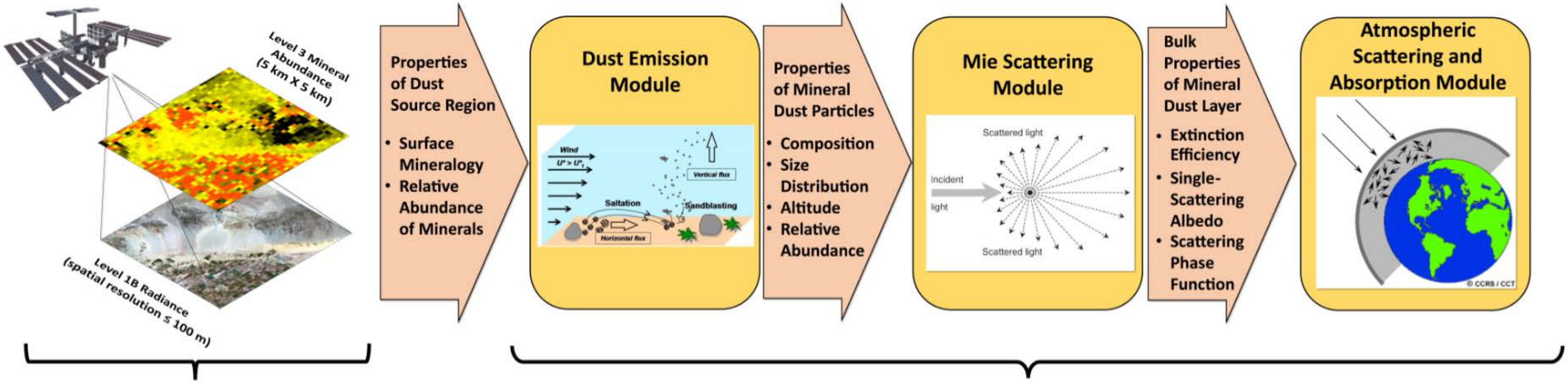


Spaceborne
Imaging
Spectroscopy
Particle
Emission
and
Transport
Radiative Forcing
52
N
ISS Coverage
52
S
Wet
and
Dry
Depo-
sition
Ecosystems
and Snow
Hydrology
Models
Ocean
Biology
Models
Arid Dust
Source Region

EMIT



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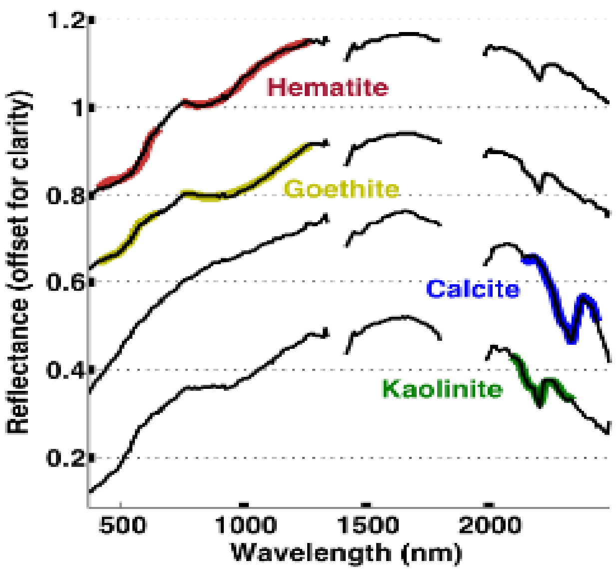
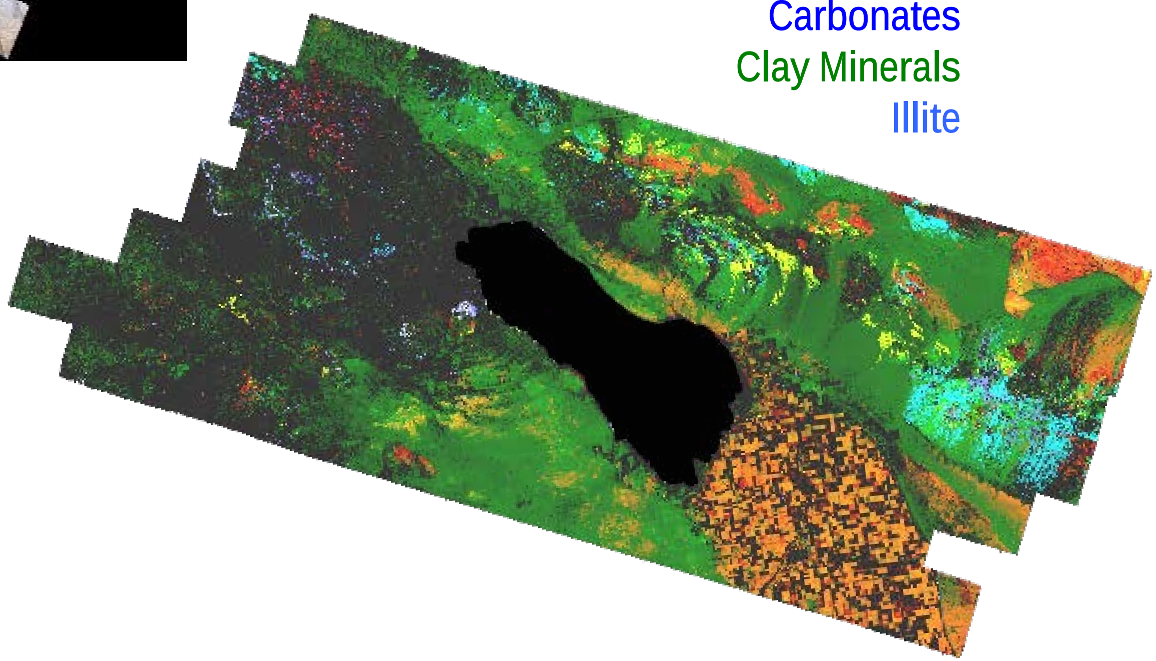
Earth System Model

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

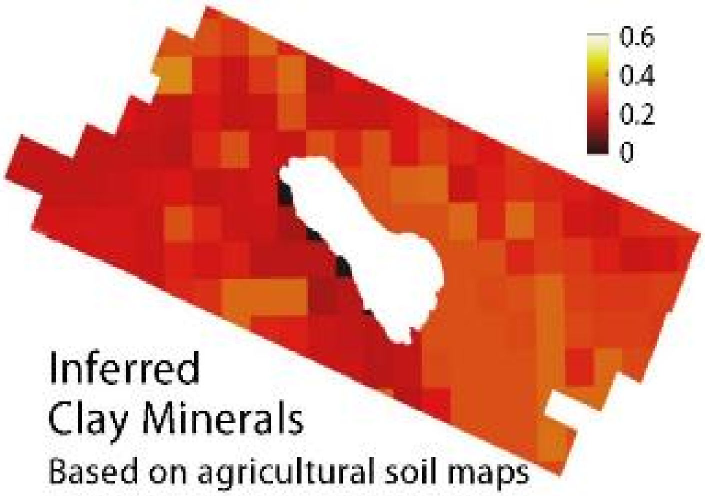
AVIRIS imaging spectroscopy measurements of the Salton Sea region in Southern California acquired as part of the 2014 NASA HyspIRI airborne campaign.



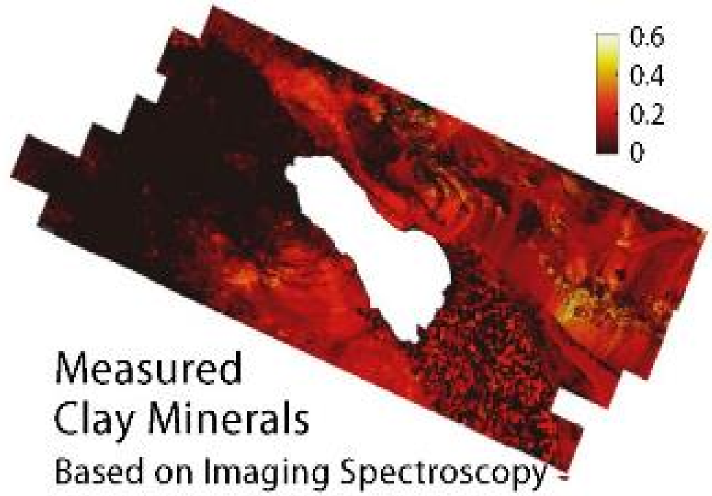


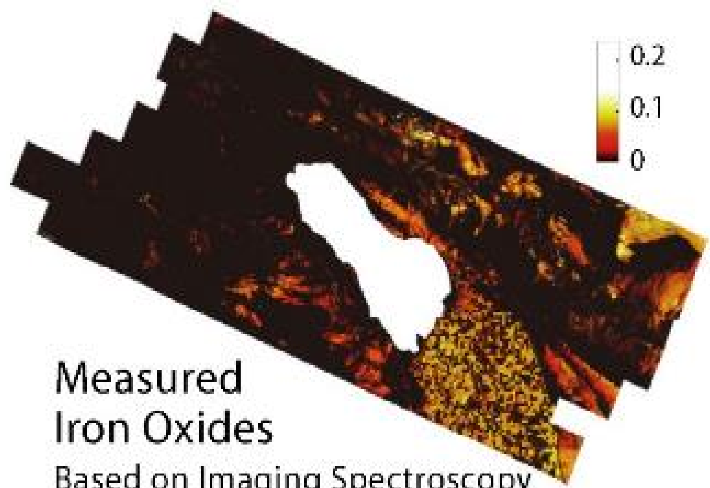
Existing FAO Mineralogy versus Imaging Spectroscopy

FAO Based Minerals

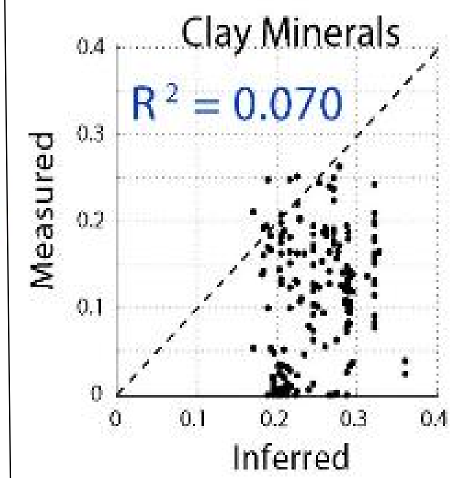


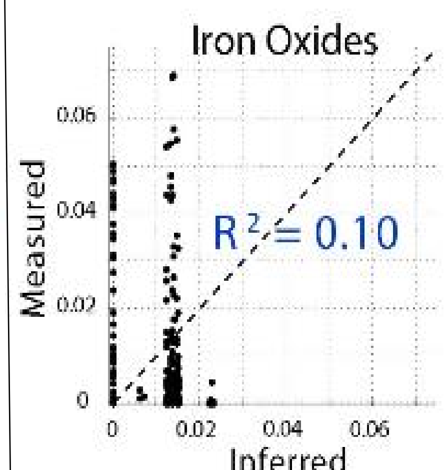
VSWIR Spectroscopy





Comparison





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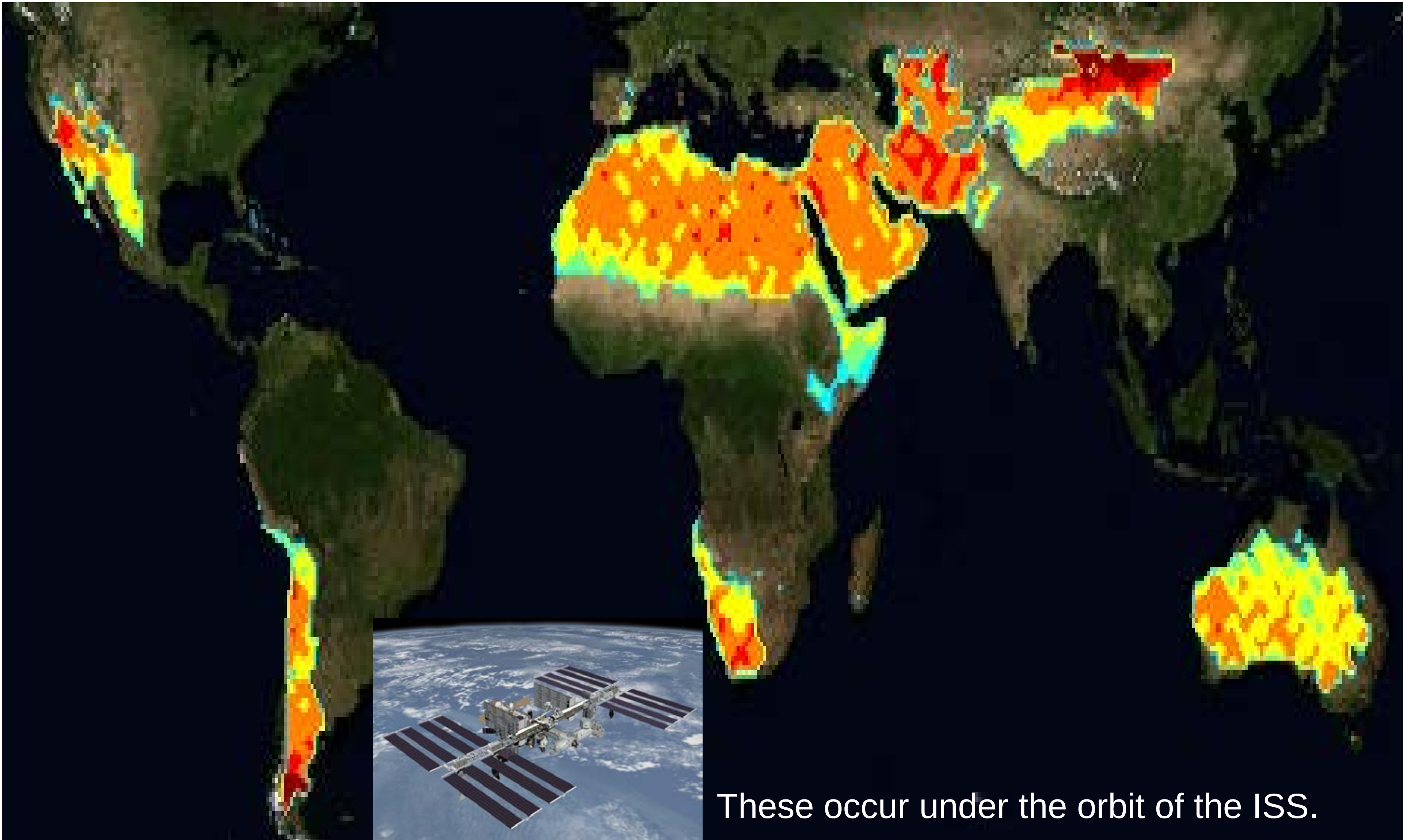
EMIT Target Areas are focused in the Arid Land Regions

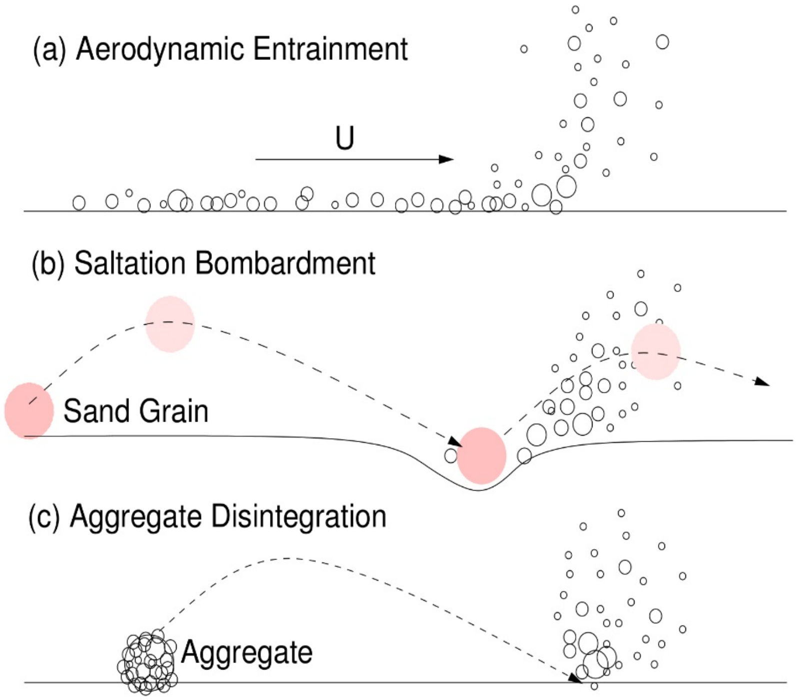


Emission of dust minerals

Emitted PSD of dust minerals is key to quantifying their climate effect

Without consideration of mineralogy:

- Incomplete understanding of the physics
- Paucity and incompleteness of measurements
- Lack of (realiable) input data at global scale (e.g. soil PSDs)



Dust emission mechanisms (Shao et al. 2008)

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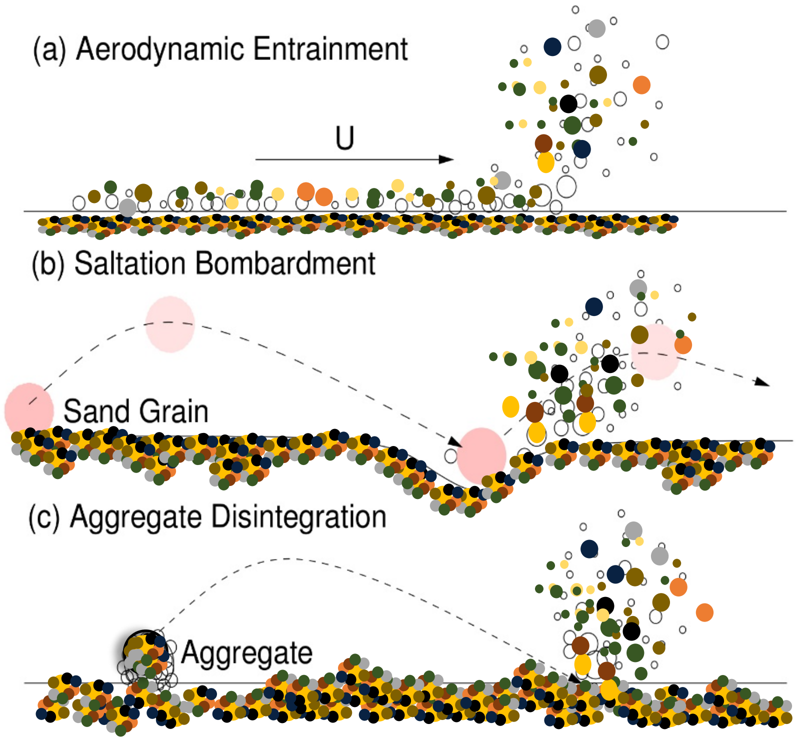
Emission of dust minerals

Emitted PSD of dust minerals is key to quantifying their climate effect

With consideration of mineralogy:

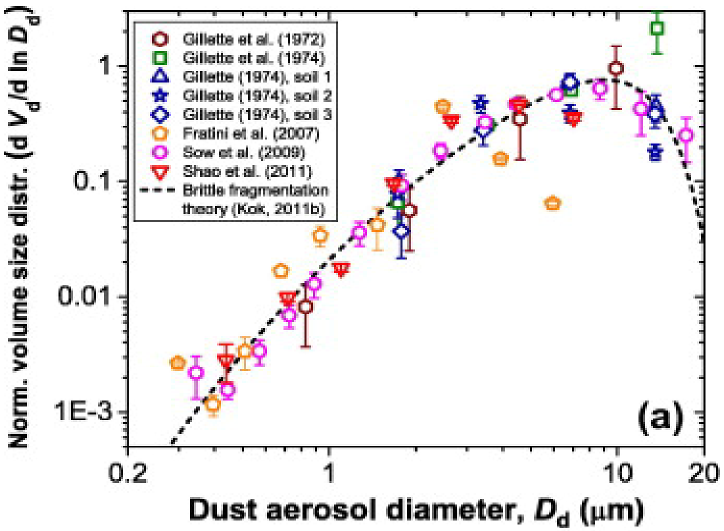
- Incomplete understanding of the physics
- Paucity and incompleteness of measurements
- Lack of (realiable) input data at global scale (e.g. soil PSDs)
- Complete lack of experimental studies tackling the relationship of the emitted PSD and soil-surface mineralogy
- Internal and external mixtures of different minerals important for climate impacts



Dust emission mechanisms (Shao et al. 2008)

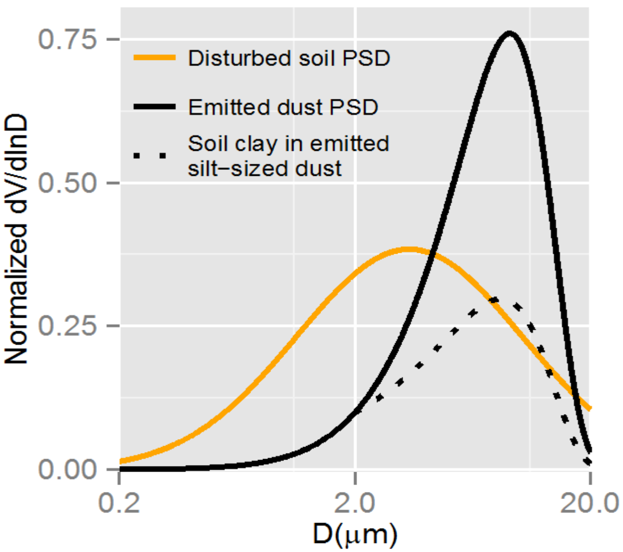
Emitted PSD and mineralogy in models

Brittle Fragmentation Theory auspicious for mineralogy as it is based on the soil dispersed PSD



Kok (2011)

$$\frac{dV}{d\ln D} = \frac{D}{C_V} u(D) \exp\left[- \left(\frac{D}{\lambda} \right)^3 \right]$$



Scanza et al. (2015)

Perlwitz et al., 2015 (a,b)
Pérez García-Pando et al., (2016)

Pérez García-Pando et al., in prep

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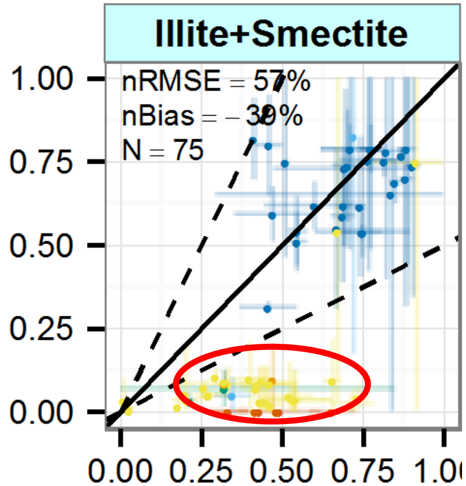
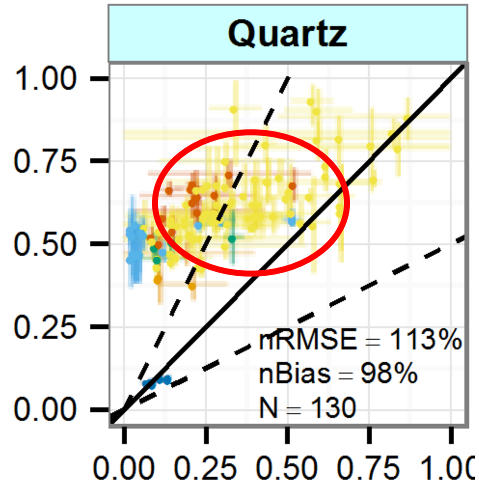
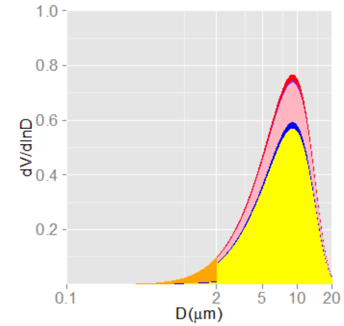
Realistic dust size Distribution

No aggregate reconstruction

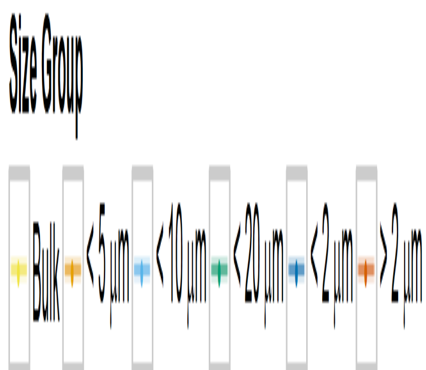


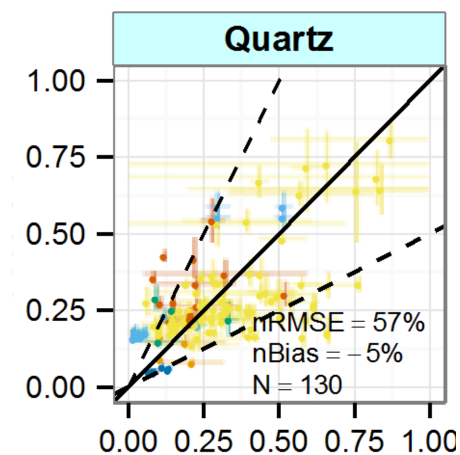


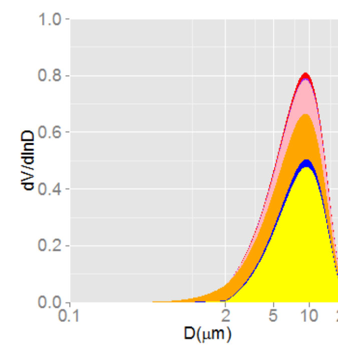


Estimating mineral size Distributions

Aggregate reconstruction and fragmentation





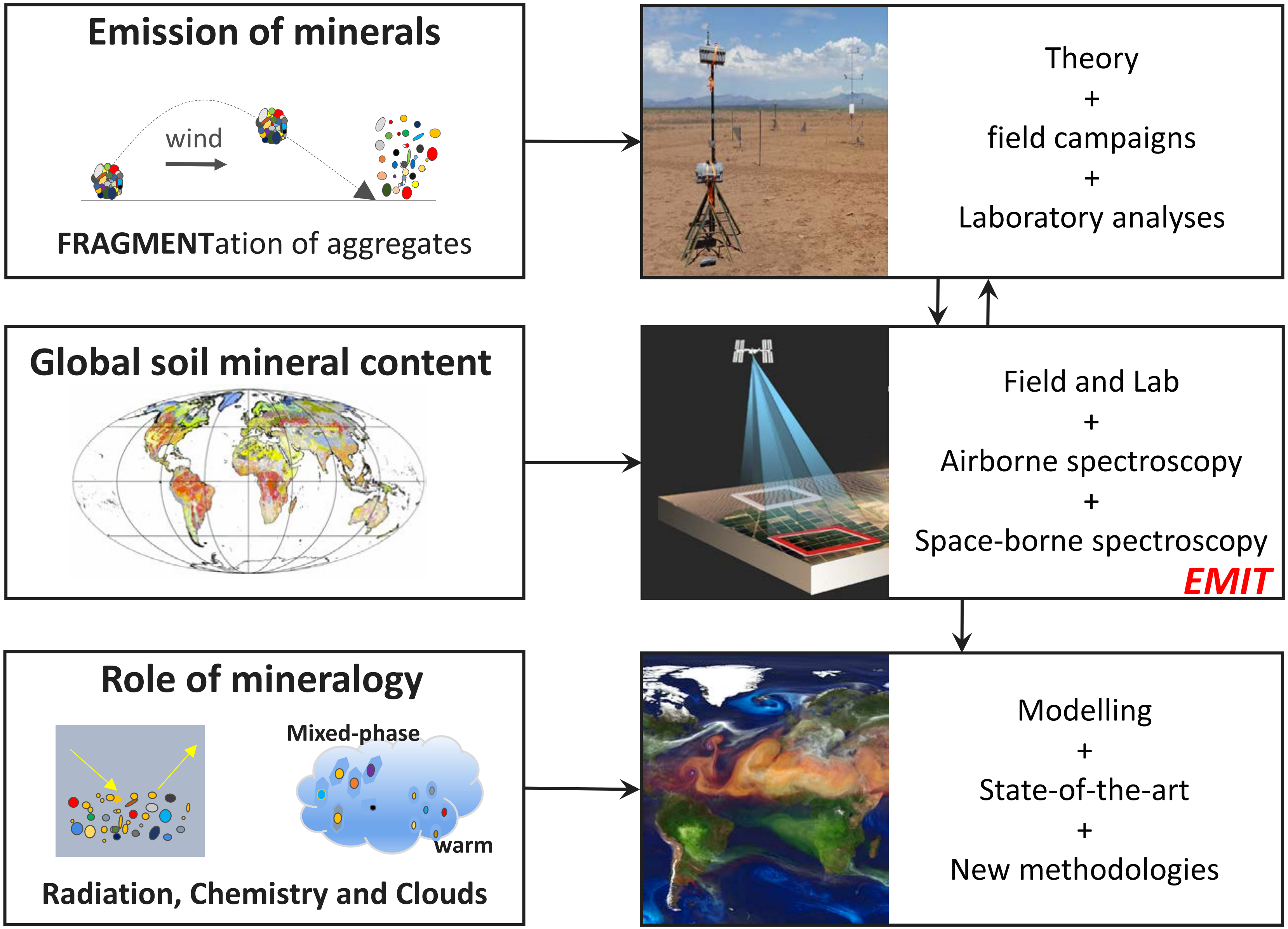


Observations

Size Group

Bulk, < 5 μm, < 10 μm, < 20 μm, < 2 μm, > 2 μm

FRAGMENT: FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe

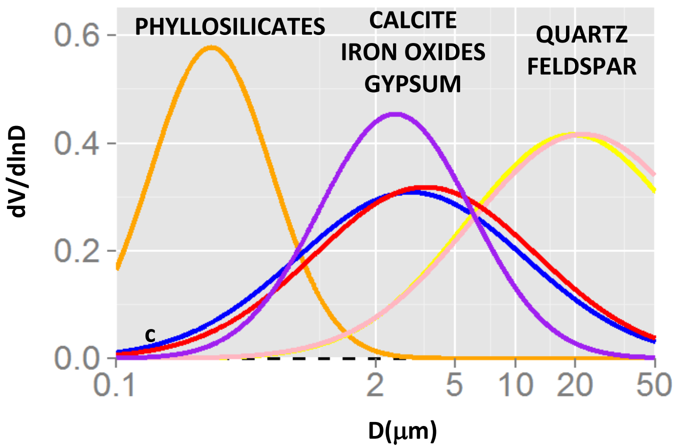


Emitted PSD of minerals

Understand emitted PSD of minerals and relationship with parent soil
Extend theoretical framework(s) and produce global model scheme

Field campaigns

Laboratory



Theory

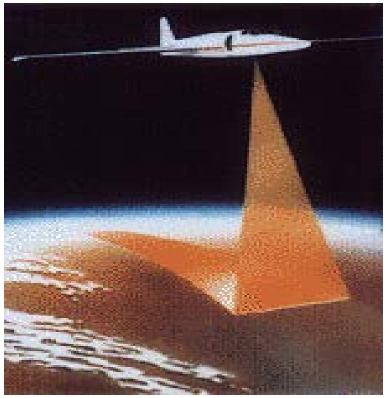
- Atmospheric Forcing
- Size-segregated and composition resolved dust fluxes
- Size-segregated and composition resolved dry and wet soil

Global soil-surface mineralogy

Constrain global soil-surface mineralogy
Link spectroscopy of soil-surface to dust emission

Field and lab spectroscopy

AVIRIS (US)



Airborne Spectroscopy

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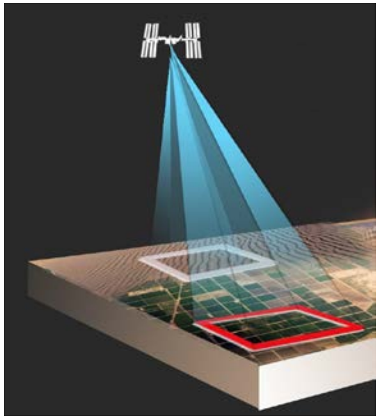

Space-borne Spectroscopy

- Point and field spectrometers
- Lab spectroscopy of soil and Aeolian samples
- Tetracorder Spectral Identification and Mapping
- Linking to size and composition resolved measurements relevant to theories of dust PSD

SUPPORT and TIMELY IMPACT EMIT

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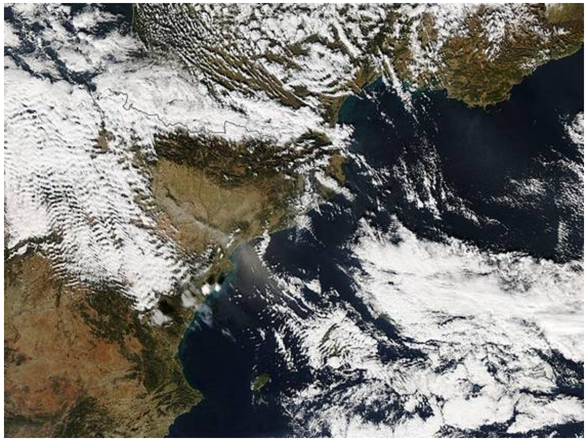
Field Campaigns: Where, Why and When?

Testing in Aragón, Spain 2019



M´Hamid, Zagora, Morocco 2019 (ONGOING)

Salton Sea and surroundings, US 2020

Icelandic sources (HiLDA!) 2020

……Erfoud, Morocco in 2021

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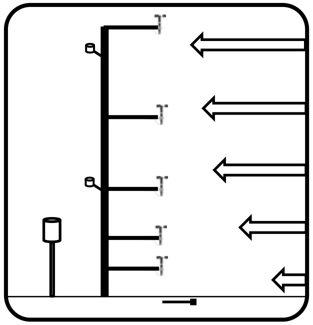
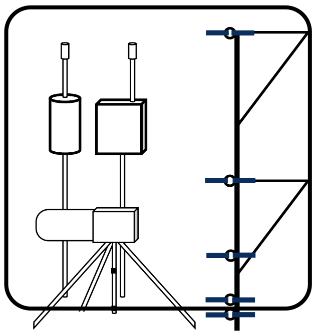
Field Campaigns: What?



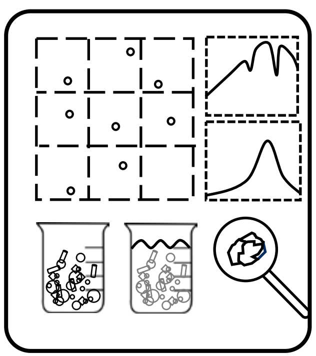
Atmospheric forcing

- 2D wind and temp profiles, 3D wind, turbulence, pressure
- Radiative fluxes
- Soil-surface humidity
- RH close to the ground
- Precipitation



Sand and Dust

- Time- and size-resolved vertical number and mass fluxes
- Size-segregated samples of suspended dust (compositional fluxes)
- Saltation flux (time/size resolved and bulk) – active and passive
- Absorption and scattering

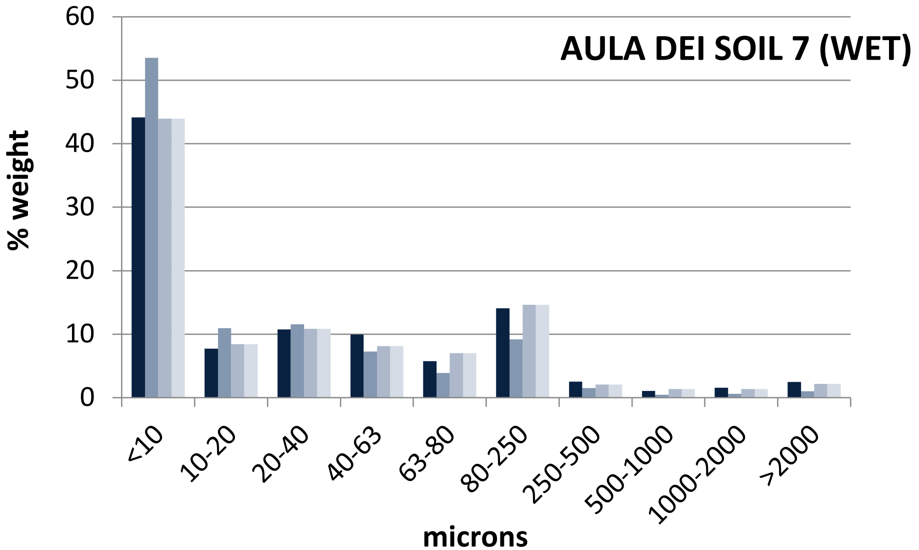


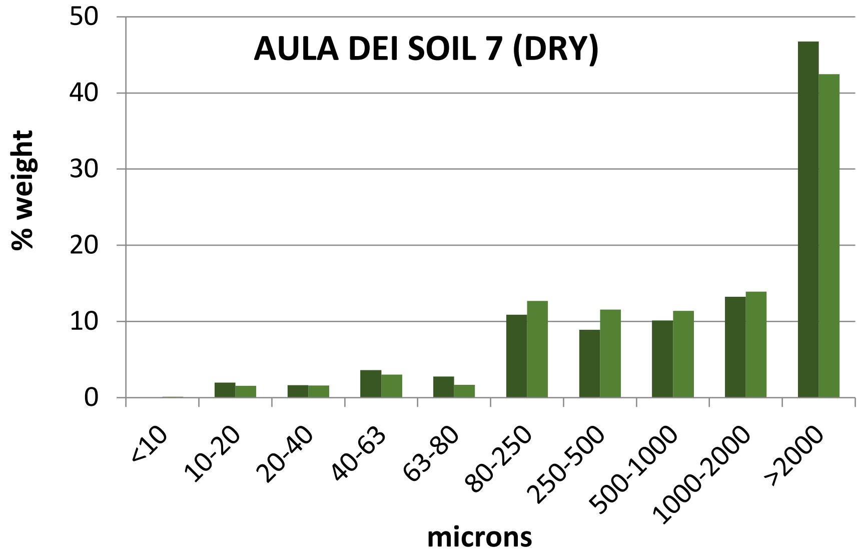
Soil sampling, surface spectroscopy and lab analyses

- Soil-surface sampling
- Surface composition (based on reflectance spectra + tetracorder)
- Dry soil aggregate stability, crust strength

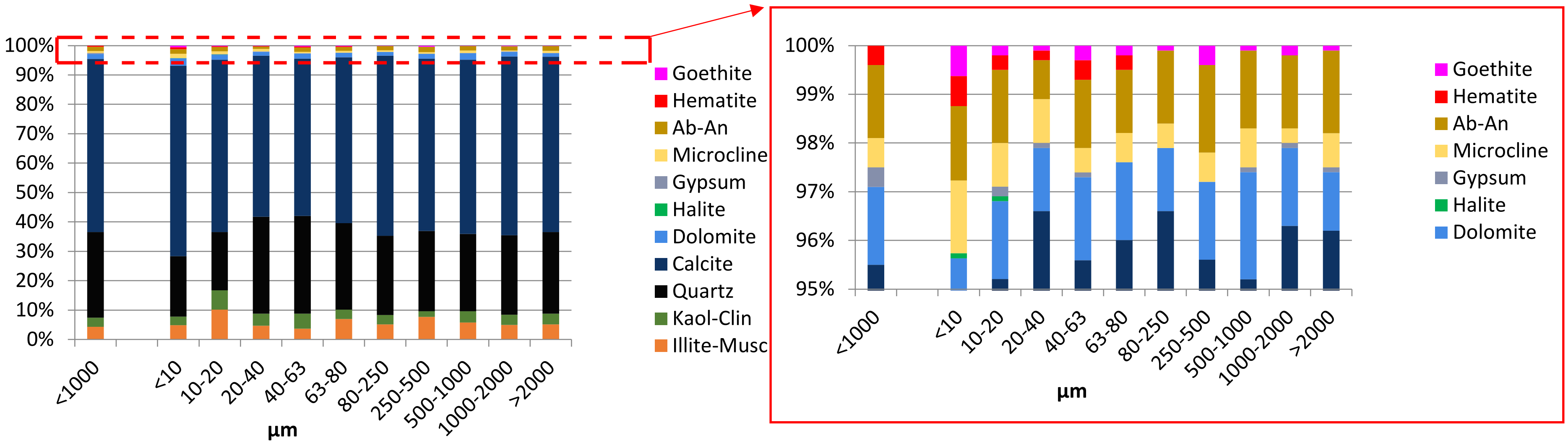
- PSD in wet and dry dispersion of soil and saltation samples
- Size-resolved mineralogy, chemistry, morphology and mixing state of soil, saltation and dust samples (XRD, TEM, BSED,..)
- Composition of soil and aeolian samples and sub samples based on spectroscopy

Results of ultrasound sieving in Zaragoza

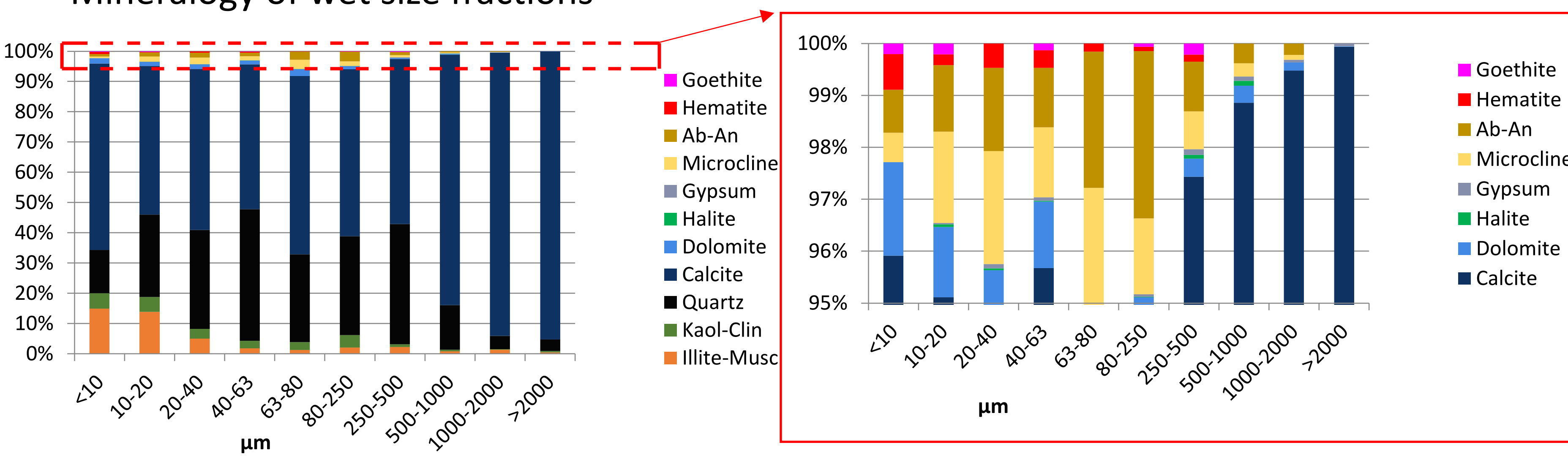


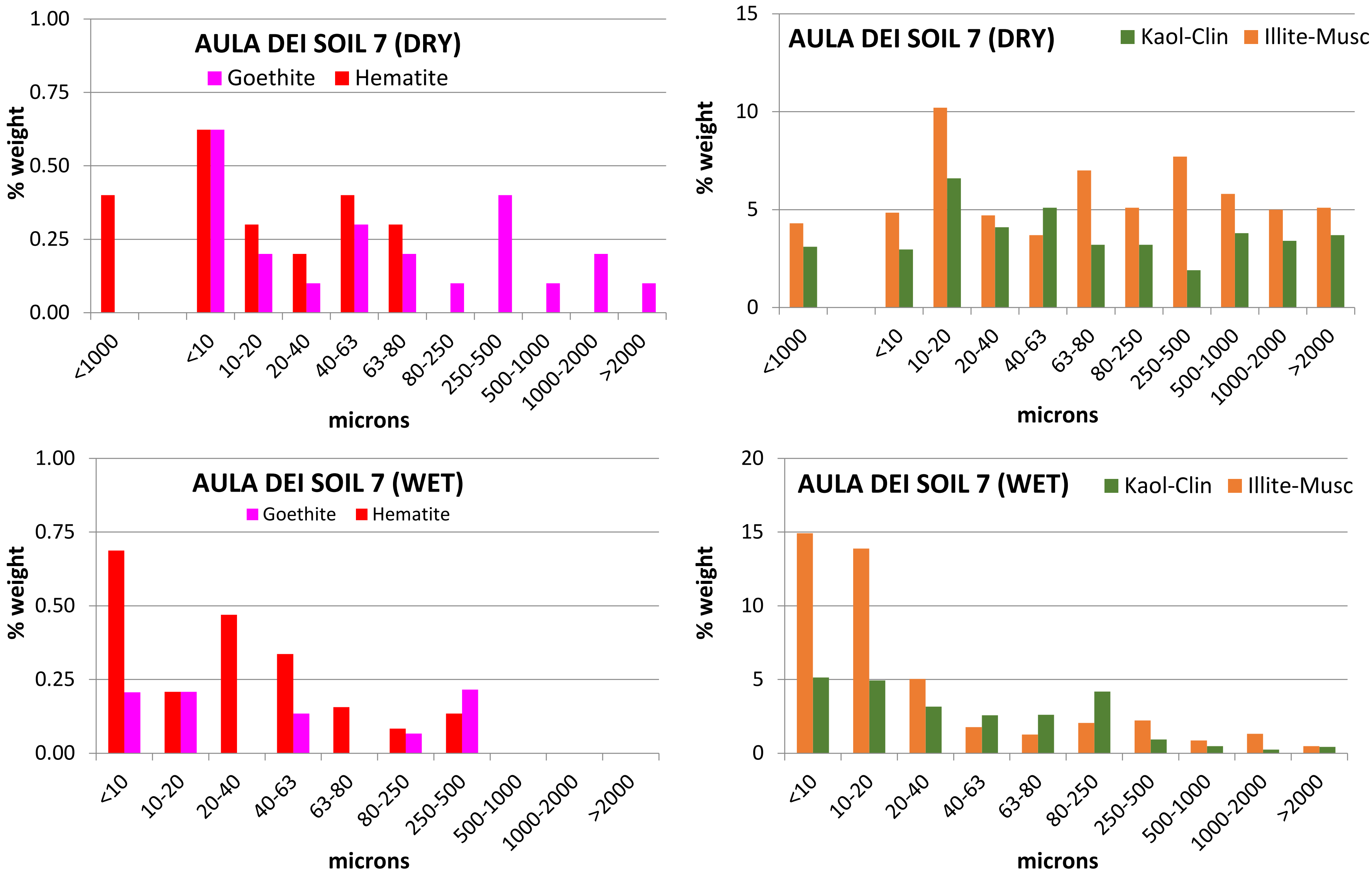


Mineralogy of dry size fractions

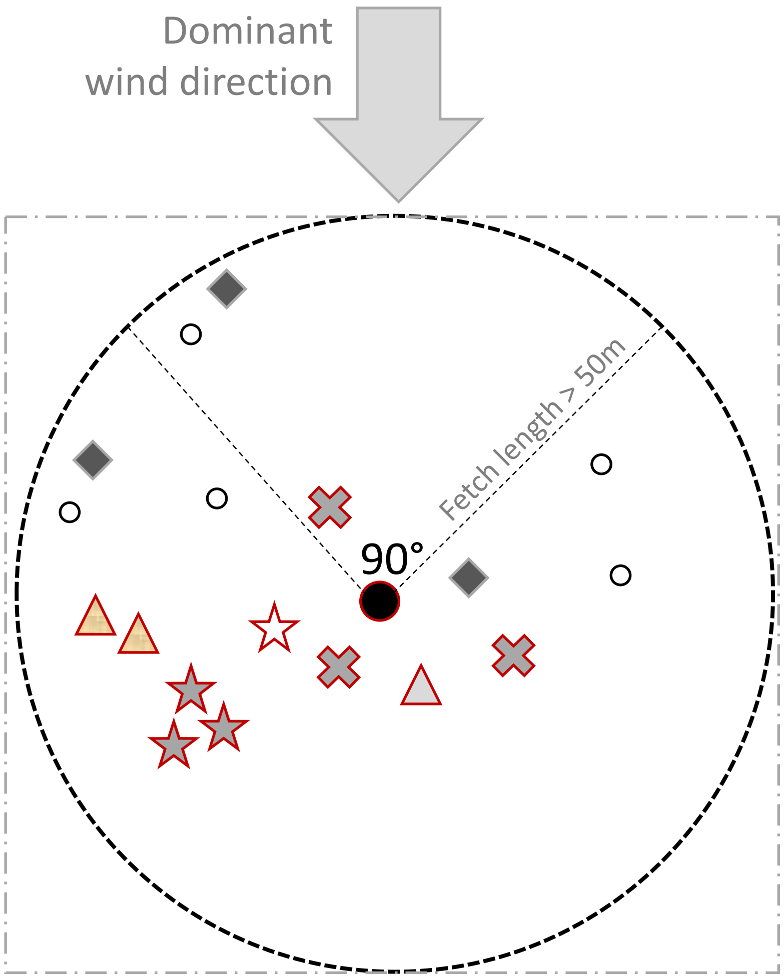


Mineralogy of wet size fractions




AULA DEI SOIL 7 (DRY)
Goethite
Hematite
% weight
1.00
0.75
0.50
0.25
0.00
<1000
<10
10-20
20-40
40-63
63-80
80-250
250-500
500-1000
1000-2000
>2000
microns
AULA DEI SOIL 7 (DRY)
Kaol-Clin
Illite-Musc
% weight
15
10
5
0
<1000
<10
10-20
20-40
40-63
63-80
80-250
250-500
500-1000
1000-2000
>2000
microns
AULA DEI SOIL 7 (WET)
Goethite
Hematite
% weight
1.00
0.75
0.50
0.25
0.00
<10
10-20
20-40
40-63
63-80
80-250
250-500
500-1000
1000-2000
>2000
microns
AULA DEI SOIL 7 (WET)
Kaol-Clin
Illite-Musc
% weight
20
15
10
5
0
<10
10-20
20-40
40-63
63-80
80-250
250-500
500-1000
1000-2000
>2000
microns

Field setup



	10m tower: 5 2D sonic anemometers, 4 temp sensors with aspirated shield, 1 RH/T sensor, P sensor, 2 3D sonic anemometers, 1 Wellas optical counter
	2 FIDAS Optical counters at 2 m and 4 m 2 MOUDI Multistage Cascade impactors Polar nephelometer and aethalometer
	3 SANTRIS Saltation sensors, 3 heights each
	5 MWAC masts (4 heights: 0.1, 0.2, 0.5, 1)
	Radiometer and pluviometer
	Soil-surface moisture sensors
	PM2.5/PM10 low volume samplers
	3 Free wing impactors

M´Hamid (24 Aug – 6 Oct)

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EMIT Science team

Science Team
The EMIT investigation, led by **Robert O. Green (JPL),** brings together leaders in mineral measurements, soil science, surface property retrievals, Earth System modeling, and imaging spectroscopy.

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Roger Clark (PSI)
Bethany Ehlmann (Caltech)
Paul Ginoux (NOAA)

Olga Kalashnikova (JPL)
Ron Miller (GISS)
Greg Okin (UCLA)
Thomas Painter (JPL)

Carlos Perez (BSC)
Vincent Realmuto (JPL)
Gregg Swayze (USGS)
David R. Thompson (JPL)

<u>Science Collaborators:</u>
Luis Gaunter (GFZ)
Eyal Ben Dor (UTA)
Elizabeth Middleton (GSFC)

FRAGMENT Team

Research Team:
FRAGMENT, led by **Carlos Pérez García-Pando*** from the Barcelona Supercomputing Center, involves world-class experts on modelling, aerosol campaigns and analyses, mineralogy, and spectroscopy.

Martina Klose (BSC)
Cristina González (BSC)
Adolfo González (BSC-CSIC)
Oriol Jorba (BSC)
Maria Gonçalves (BSC)
+ other members of BSC

Xavier Querol (IDAEA-CSIC)
Andrés Alastuey (IDAEA-CSIC)
+ other members of IDAEA-CSIC

Konrad Kandler (TUDA)
Agnesh Panta (TUDA)

Ron Miller (NASA GISS)*
Robert Green (JPL)**
Bethany Ehlmann (Caltech)*
Roger Clark (PSI)*

** PI of EMIT
* Part of EMIT´s Science Team

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EXCELENCIA SEVERO OCHOA

Thank you

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