Dust aerosol mineralogy retrieved from its infrared optical signature: a laboratory study highlights the potential of infrared remote sensing for aerosol climate studies

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Mineral dust : a global phenomenon with multiple effects on the climate system

A sandstorm over the Sahara desert in Africa seen by ESA astronaut Alexander Gerst from the International Space Station

https://www.esa.int/ESA_Multimedia/

Mineral dust : a global phenomenon with multiple effects on the climate system

A sandstorm seen by ESA astronaut Thomas Pesquet from the International Space Station

Https://www.flickr.com/photos/thom_astro/51277374457/in/photostream/

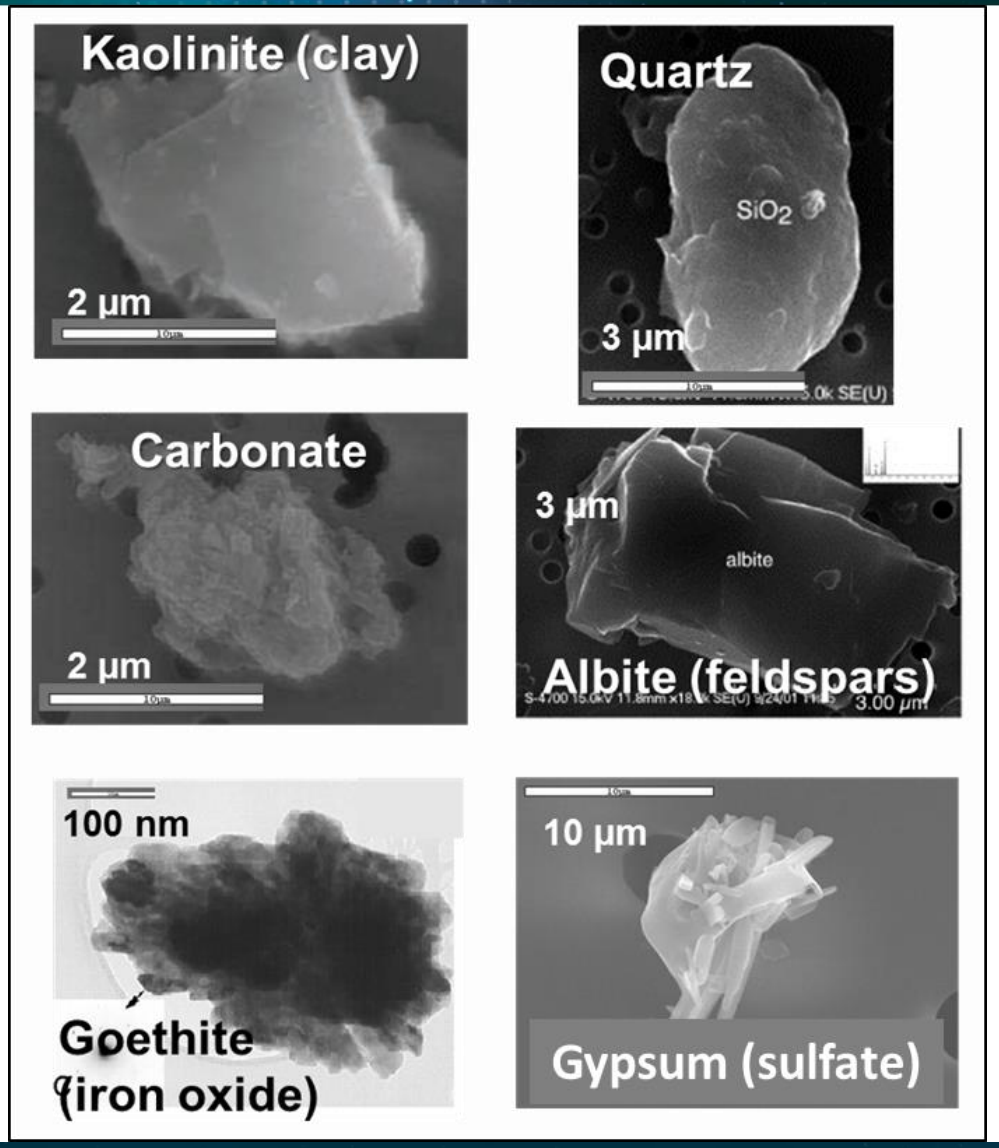
Mineralogy is central in ruling dust effects

Liquid & ice nuclei activity

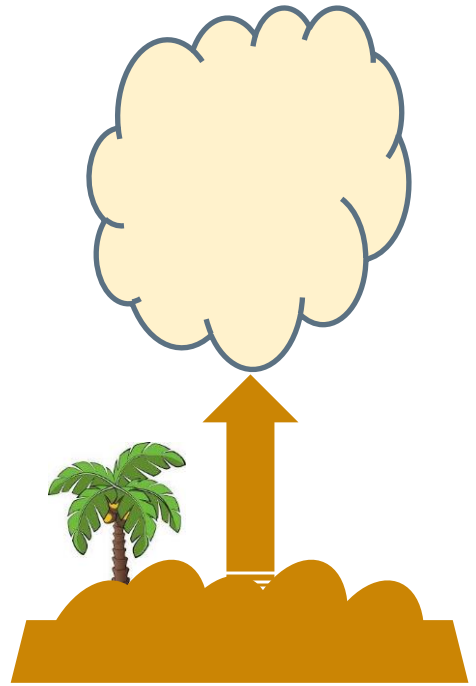
Radiation interactions

Solubility

Chemical reactivity

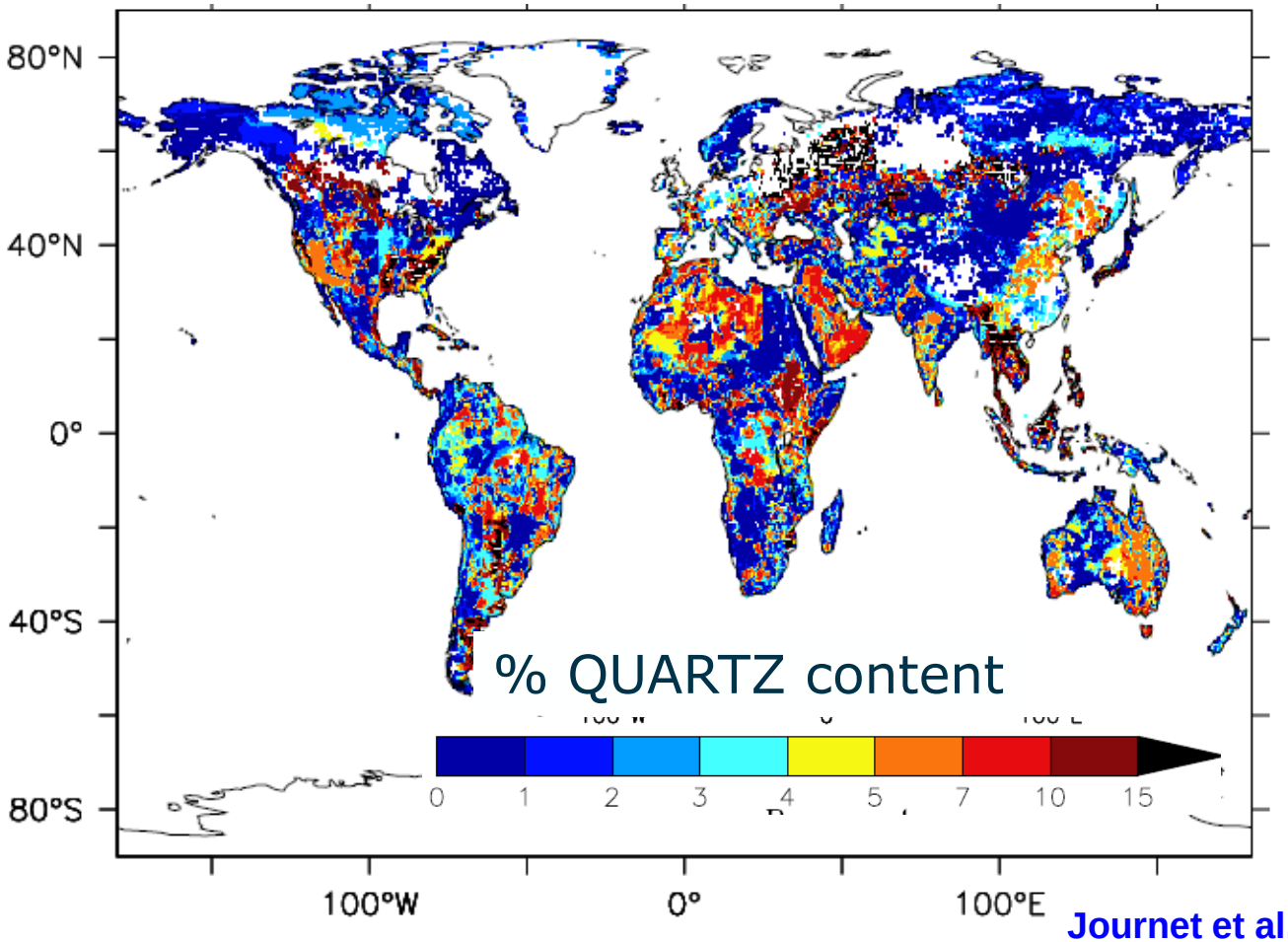


Dust mineralogy varies at the global scale



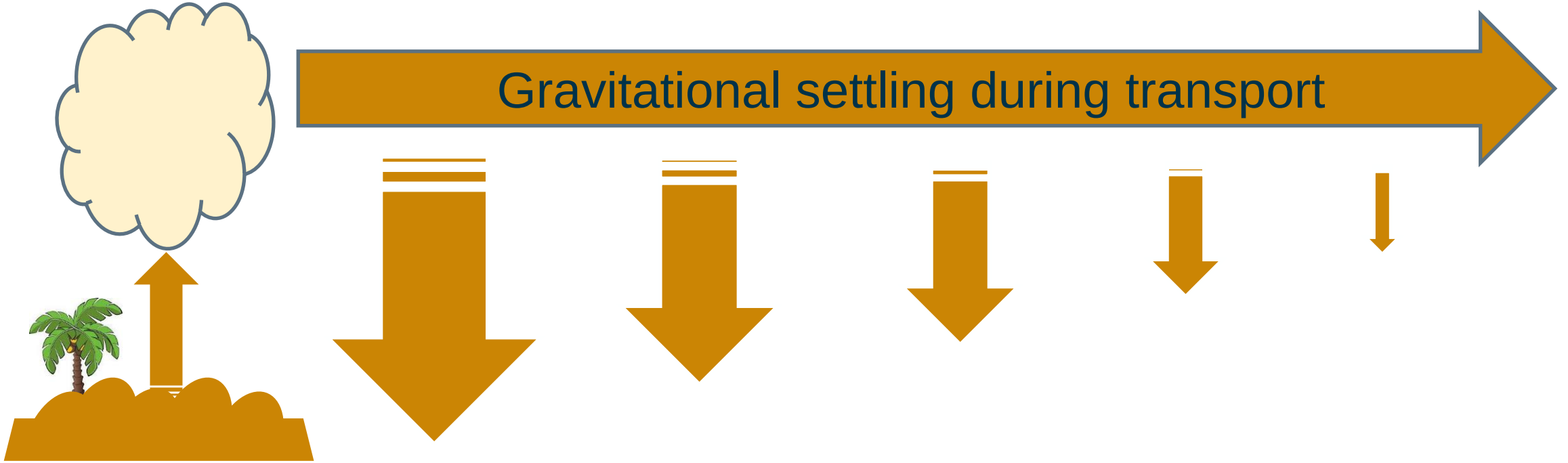
Source variability

Surface soil mineralogy



Journet et al., 2014

Dust mineralogy varies at the global scale



Source variability

Size-dependence → modifications during transport

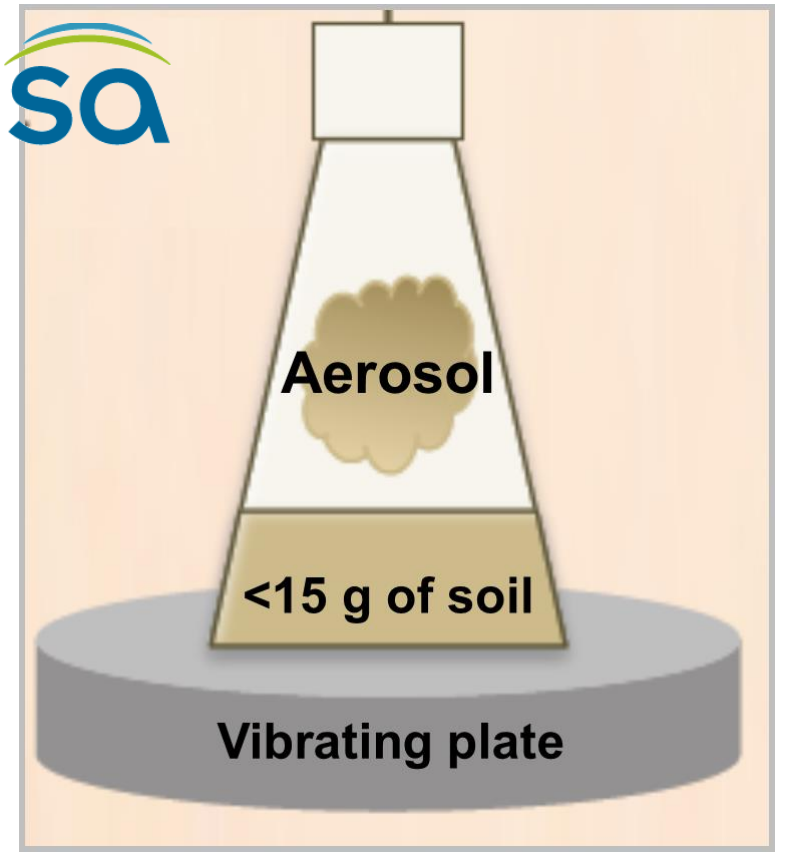
Dust mineralogy varies at the global scale

Dust mineralogy still not measured systematically

regional and global mapping of airborne dust mineralogy is still missing

Simulation chamber experiments on mineral dust

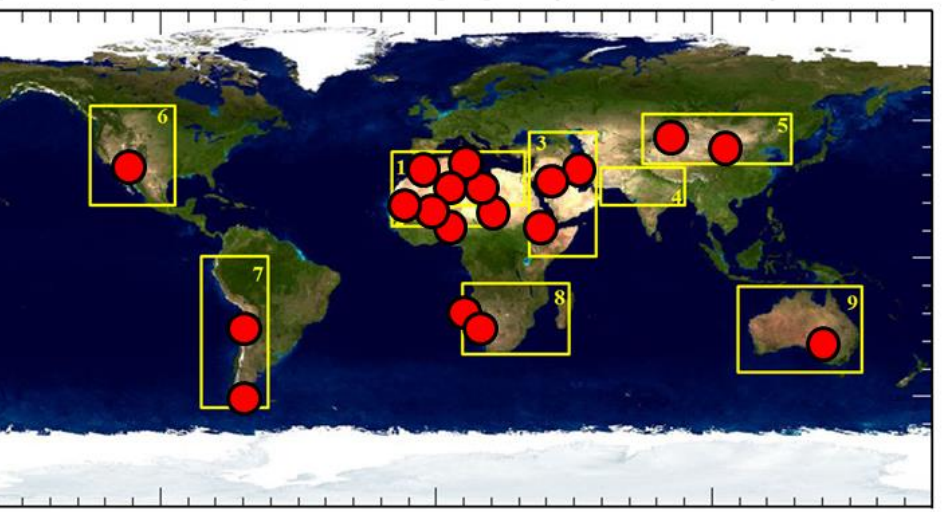
Aerosol resuspension by mechanical shaking of parent soils



Natural soil samples

Di Biagio et al., 2014, 2017, 2019

Experiments on worldwide dust sources



RED-DUST

In situ FTIR
2-16 µm, res 0.5 cm^{-1}

Multireflection white cell

CESAM

Size distribution

SMPS

FTIR

Shortwave optical instruments

WELAS™ OPC

Filter sampling

Natural soil samples

Mineralogical composition

Pressure

Humidity

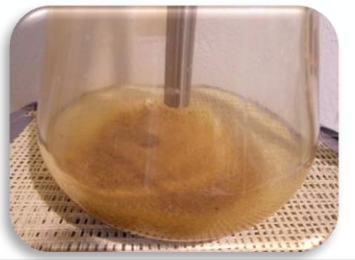
Temperature

Flow

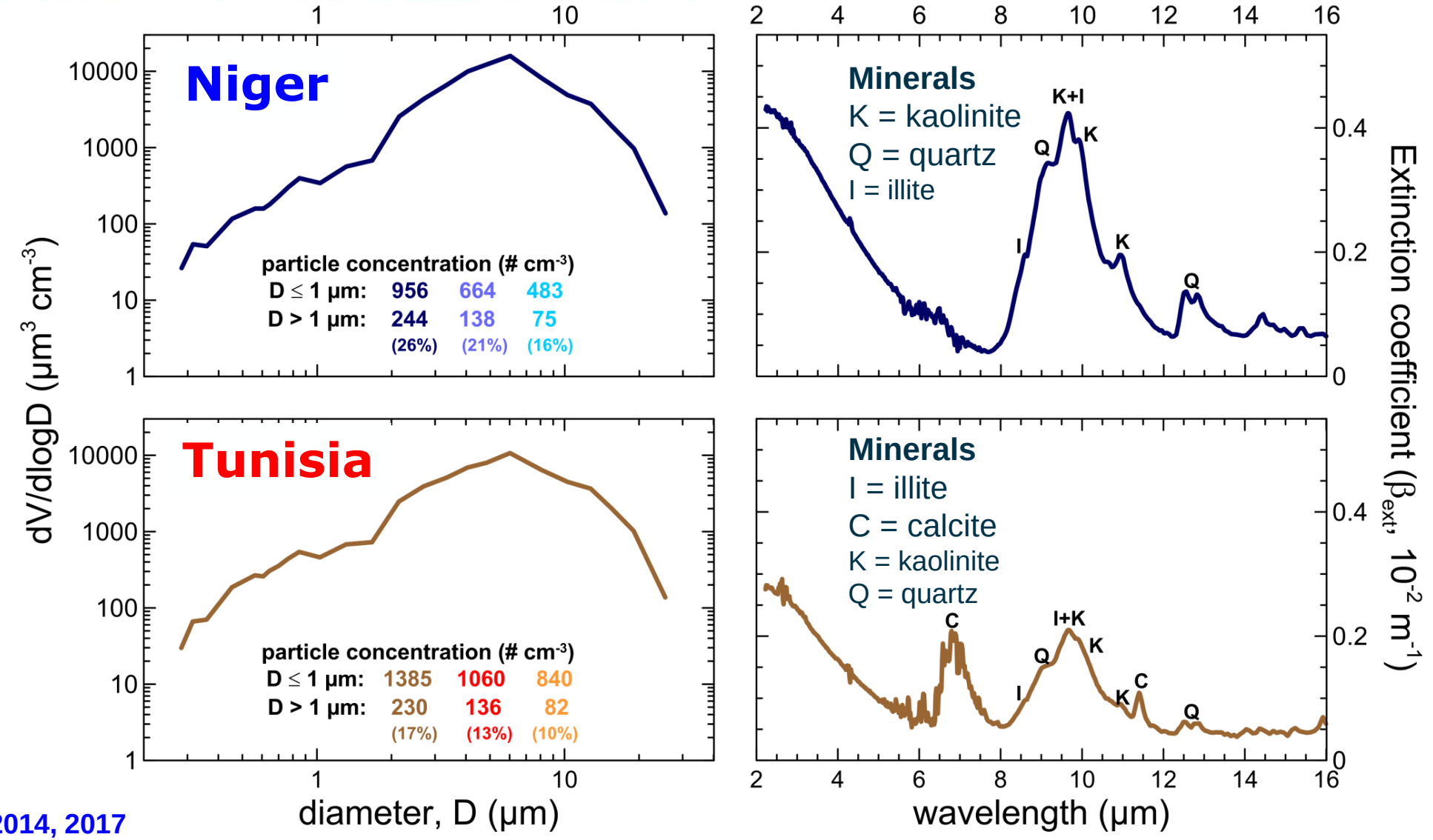
Vacuum system

Stirring fan

Dust generation device



Mineral signatures found in IR extinction spectra



Di Biagio et al., 2014, 2017

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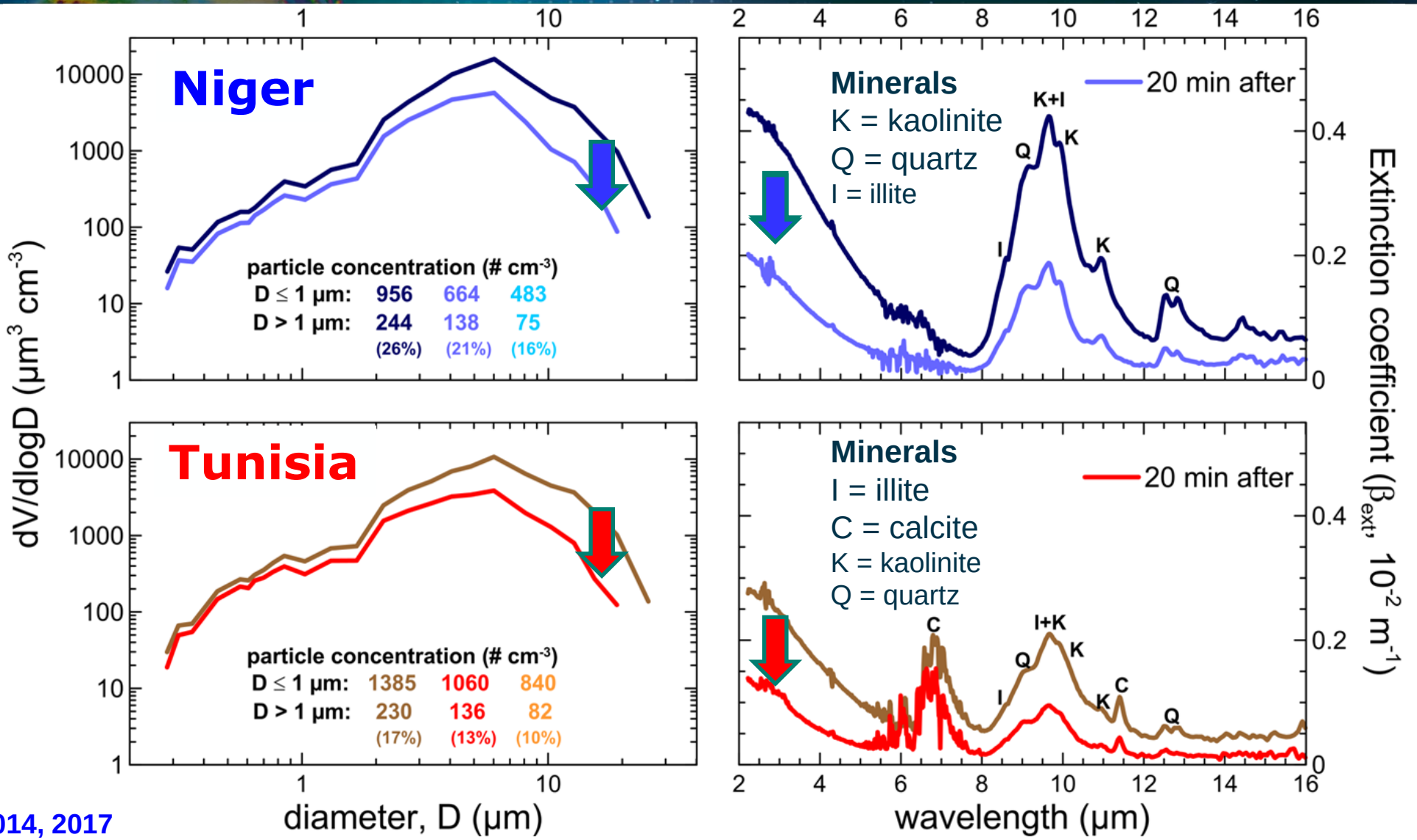
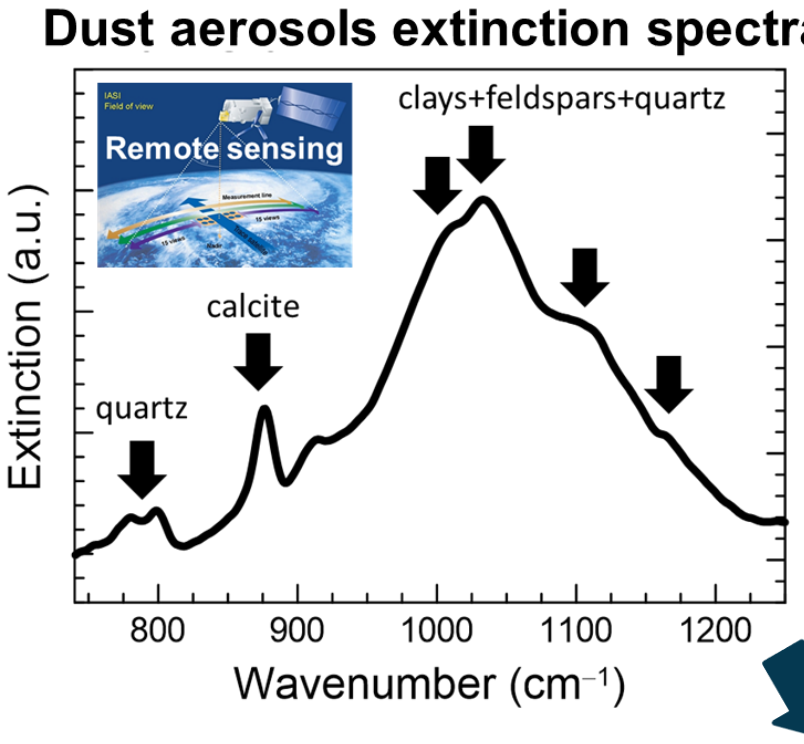
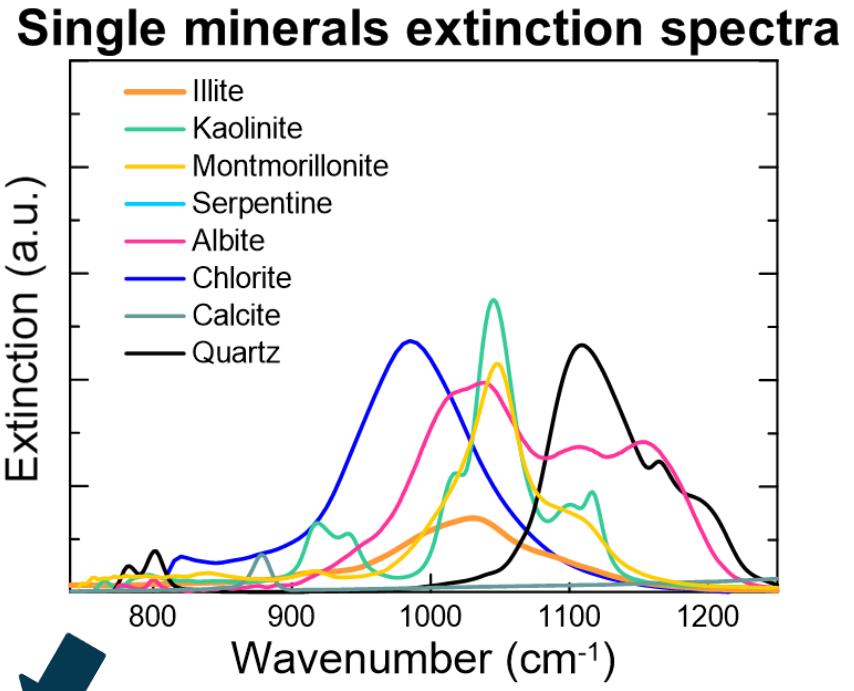


Di Biagio et al., 2014, 2017

Can we retrieve dust mineralogy based on extinction spectra in the 740–1250 cm^{-1} (8 – 12 µm) IR window?





Dust extinction spectra = f_{linear} (single mineral extinction spectra)

Minerals content (quartz, clays, feldspars, calcite, ..)

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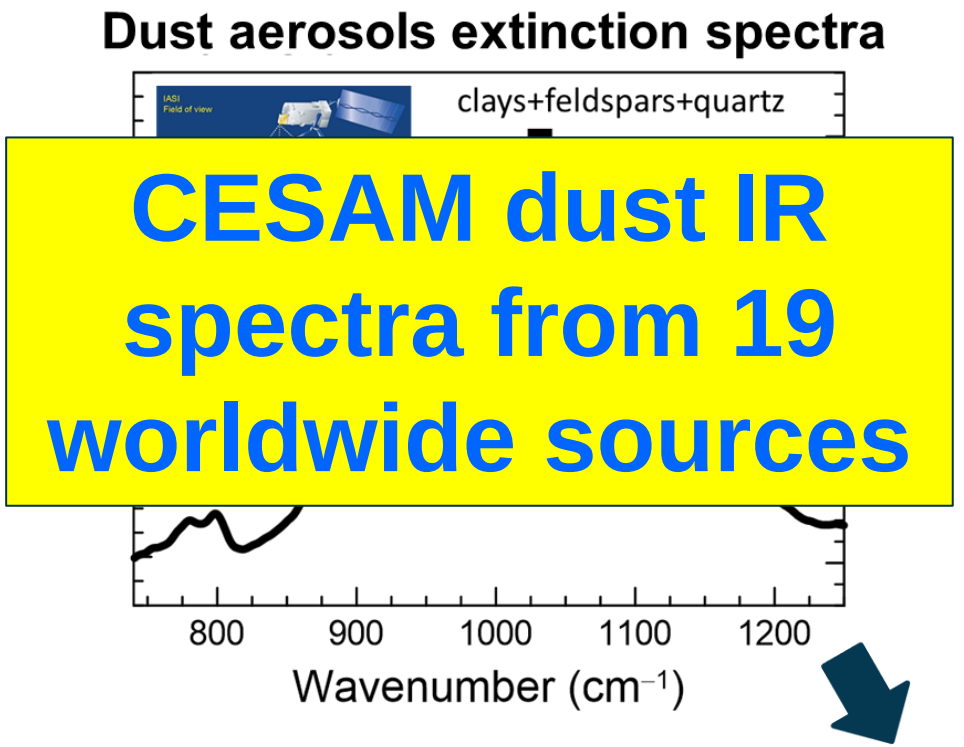
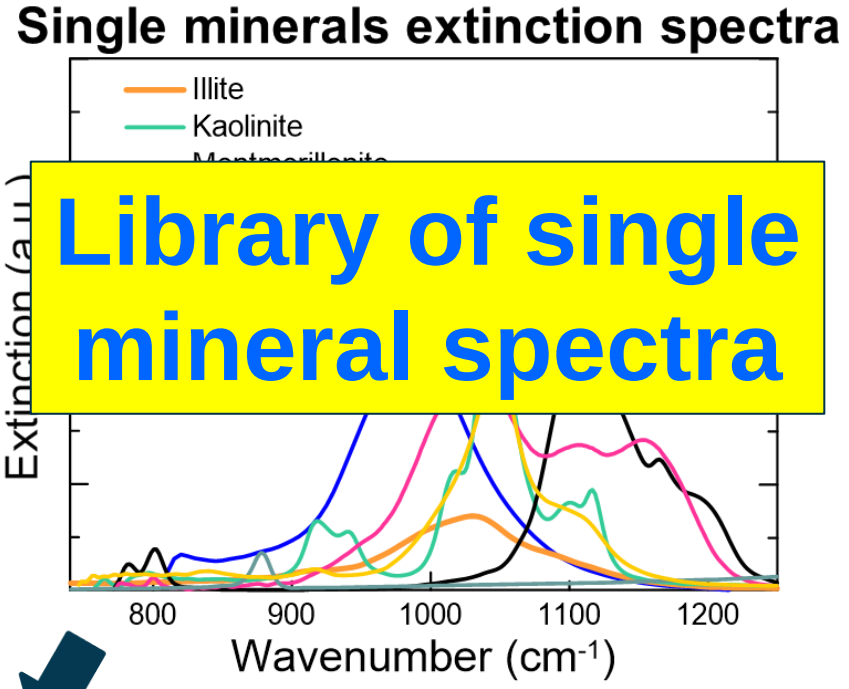


CESAM dust IR spectra from 19 worldwide sources



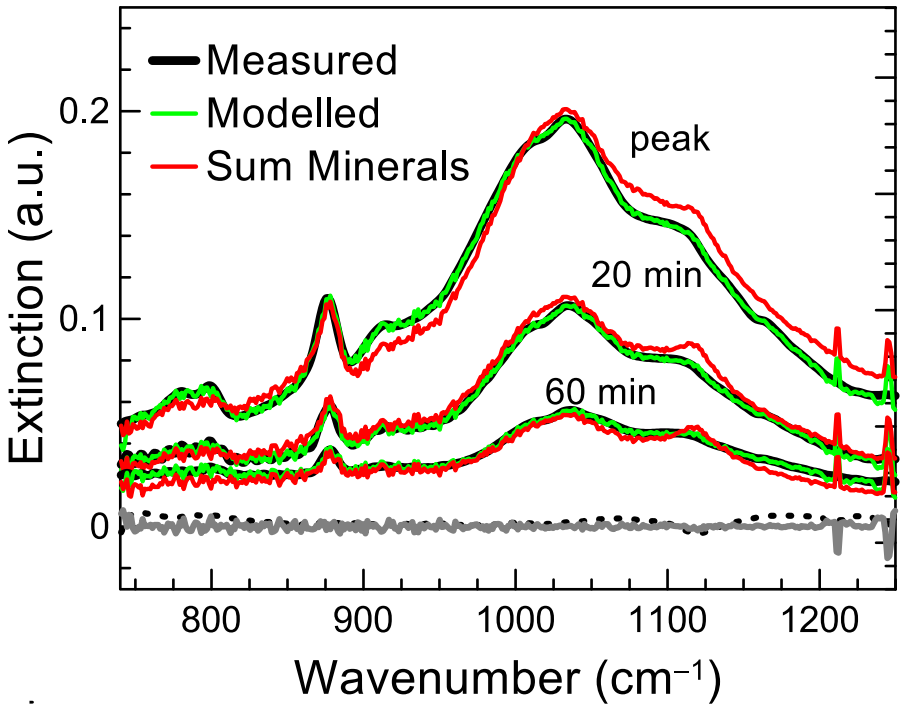
Library of single mineral spectra

Dust extinction spectra = f_{linear} (single mineral extinction spectra)

Minerals content (quartz, clays, feldspars, calcite, ..)

It works! Example of Tunisian dust

Measured extinction as linear combination of single mineral spectra

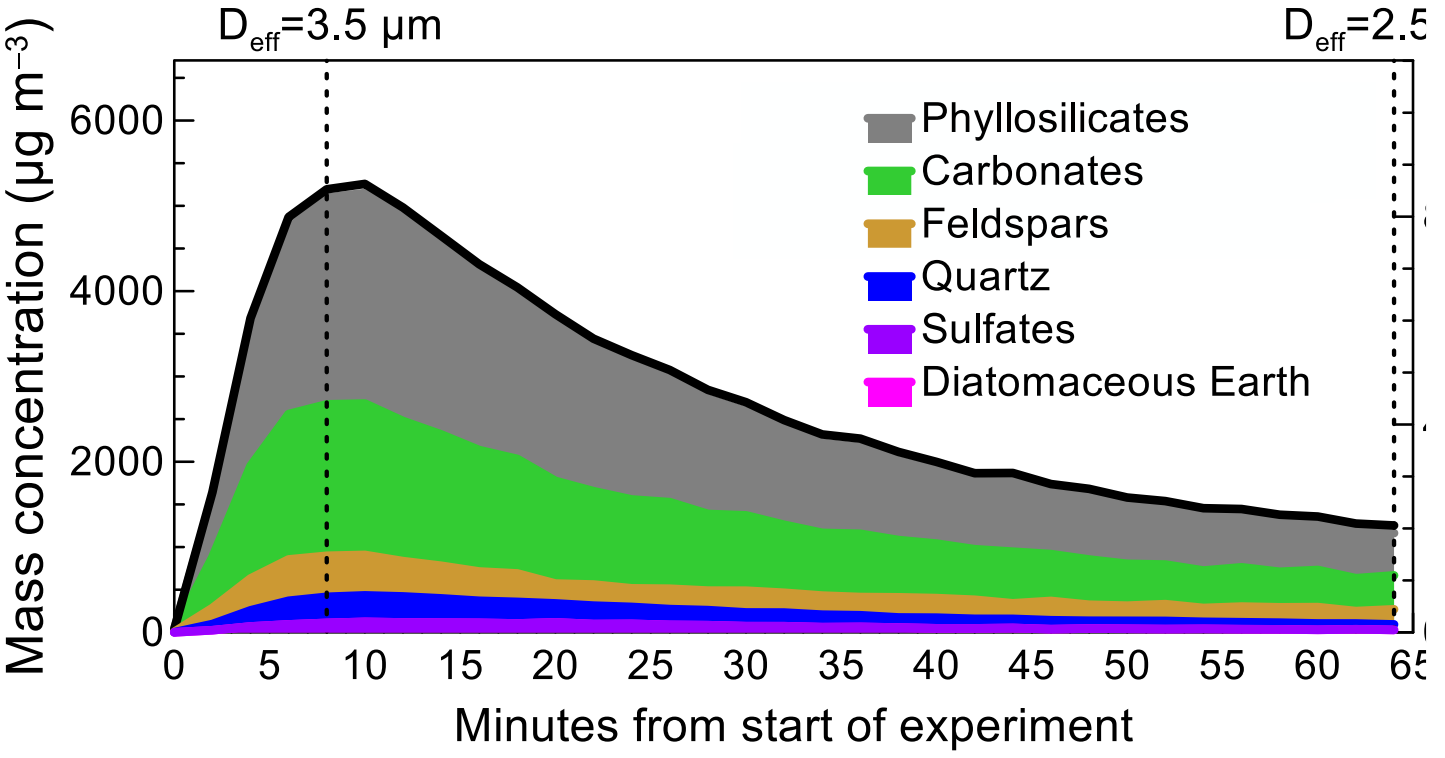


··· Baseline

— Residuals

D_{eff} = Effective diameter

Retrieve mineralogical composition, particularly coarse-size minerals

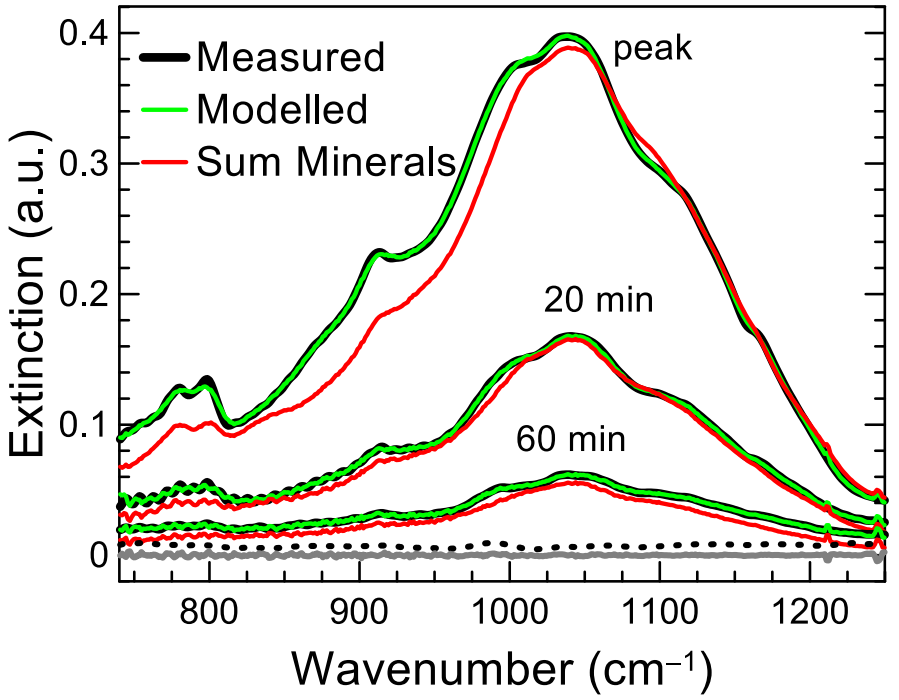


Coarse size depletion by gravitational settling

Di Biagio et al., 2023

It works! Example of Australian dust

Measured extinction as linear combination of single mineral spectra



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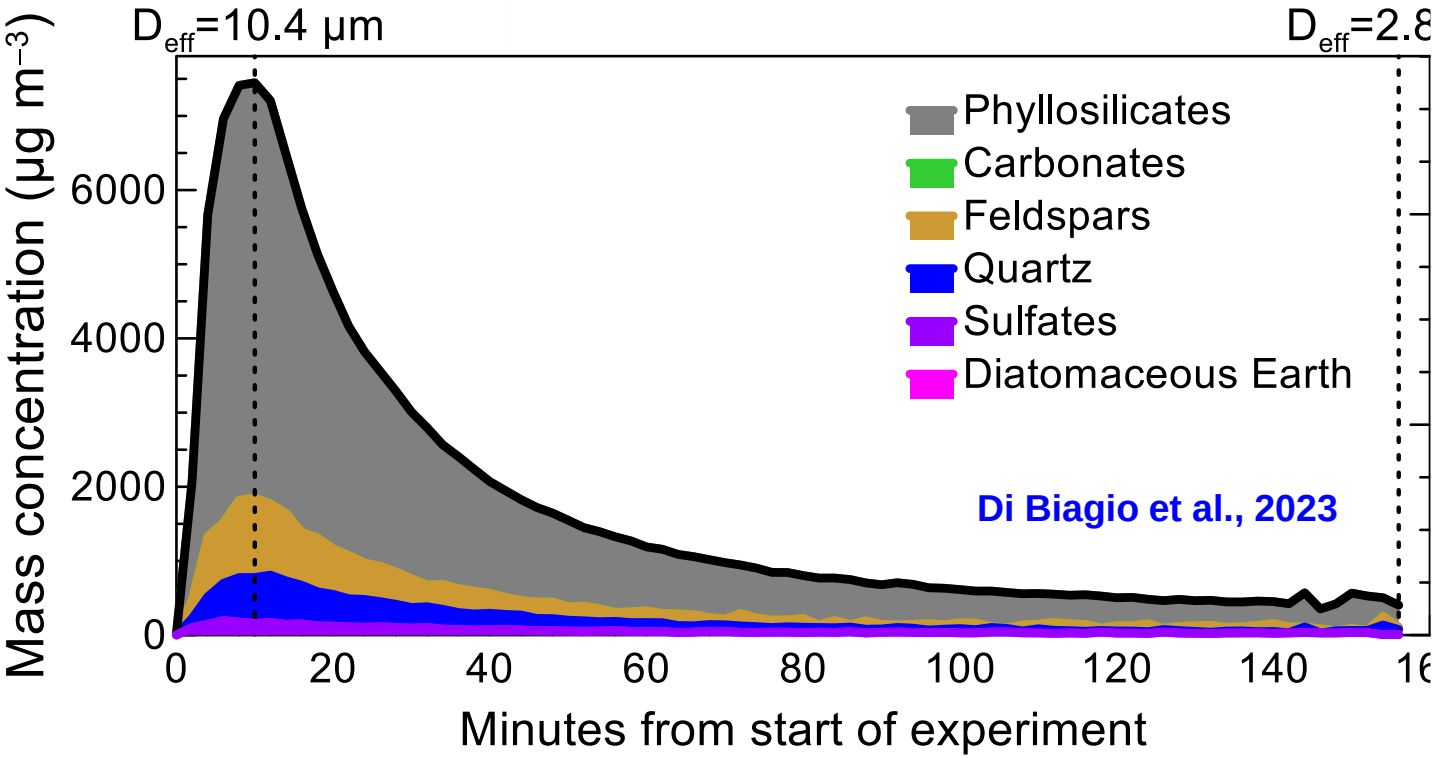
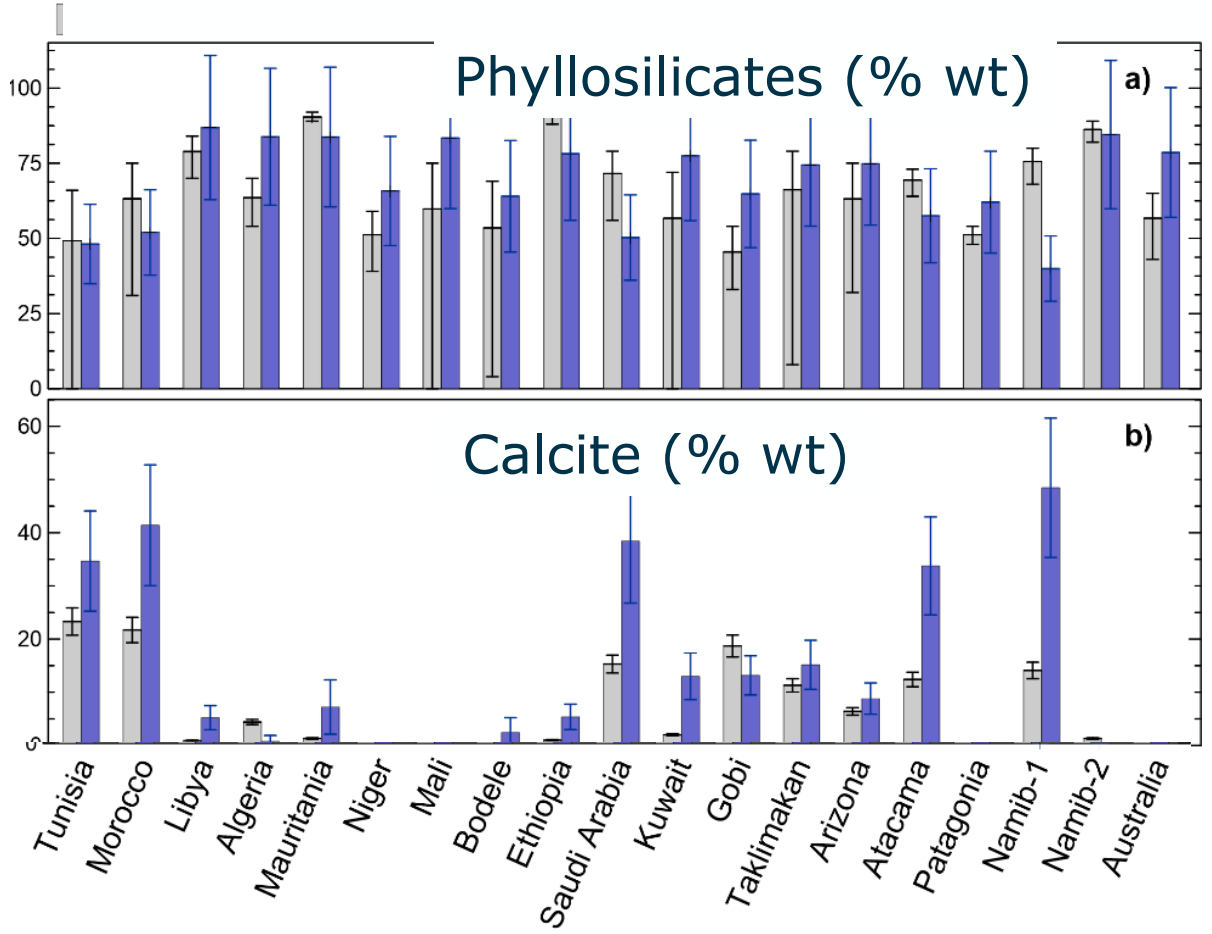


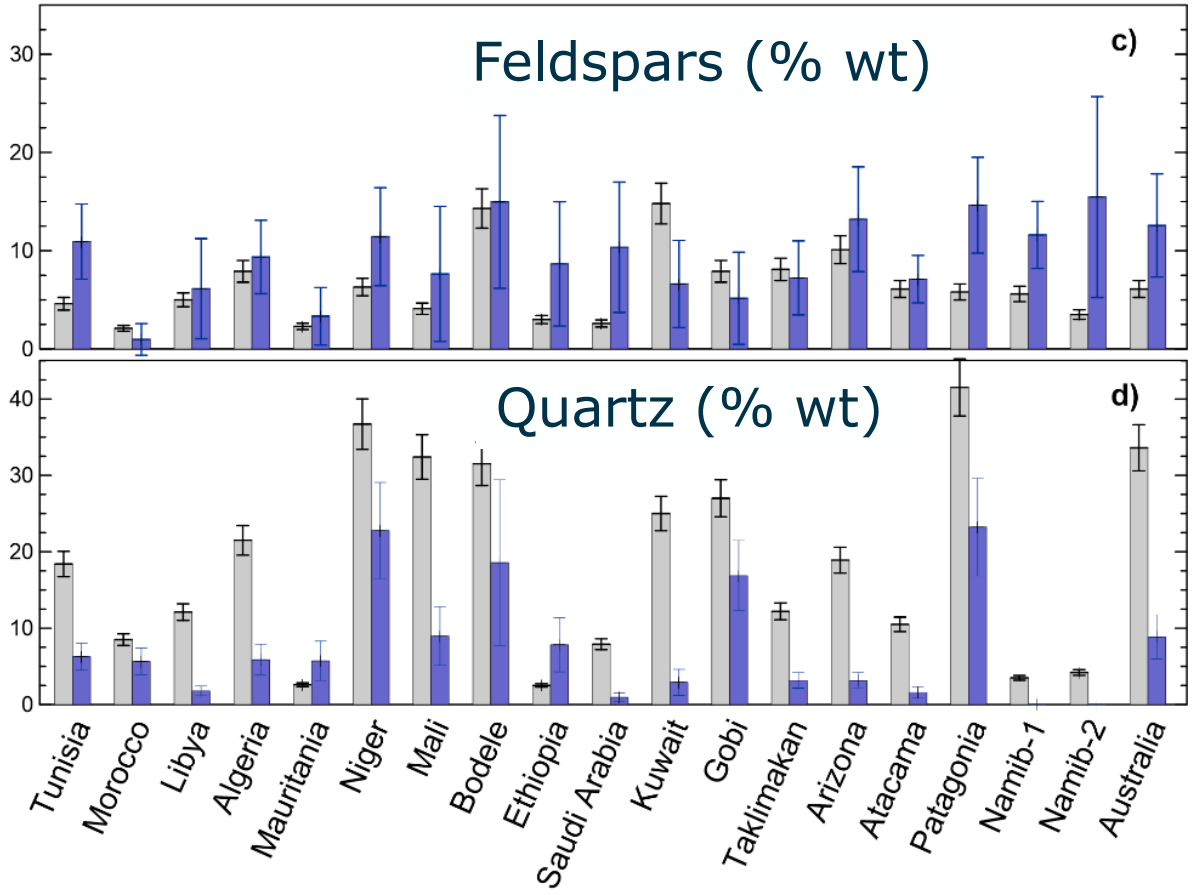
Coarse size depletion by gravitational settling

Agreement of retrieved « optical » mineralogy against X-Ray Diffraction analyses

LSM = Linear Spectral Mixing **XRD = X-Ray Diffraction**

Di Biagio et al., 2023





Conclusions and perspectives

- **IR extinction spectra can be used to retrieve the global-scale features of dust mineralogy, in particular its coarse component (quartz, feldspars, clays, calcite)**
  - Different extinction signatures enable to distinguish dusts with different origins and compositions
  - Modifications of the dust extinction spectra with time can inform on the size-dependent particles mineralogy changes during transport

- **The present analysis supports the use of IR remote sensing spectral and hyperspectral observations (such as those of IASI & IASI-NG & FORUM) to measure the size-segregated mineralogy of global dust**

  - Need further fundamental studies on both natural dust and single minerals!
  - Application of the methodology to real IR remote sensing observations is needed!!

Conclusions and perspectives

IR remote sensing can complement UV-VIS-NIR retrievals from the **EMIT NASA mission** (sensitive only to fine-sized dust components: clays, iron oxides, carbonates)