# Laboratory estimates of the mineral dust shortwave and longwave refractive index from global sources: a new dataset for climate modelling and remote sensing

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# Aerosol direct radiative effect

** Global annual mean at TOA, all-sky*

## Anthropogenic aerosols

**Direct effect* (Wm$^{-2}$)**

**-0.95** **+0.05**

***IPCC, 2013***

## Mineral dust

***IPCC, 2013***

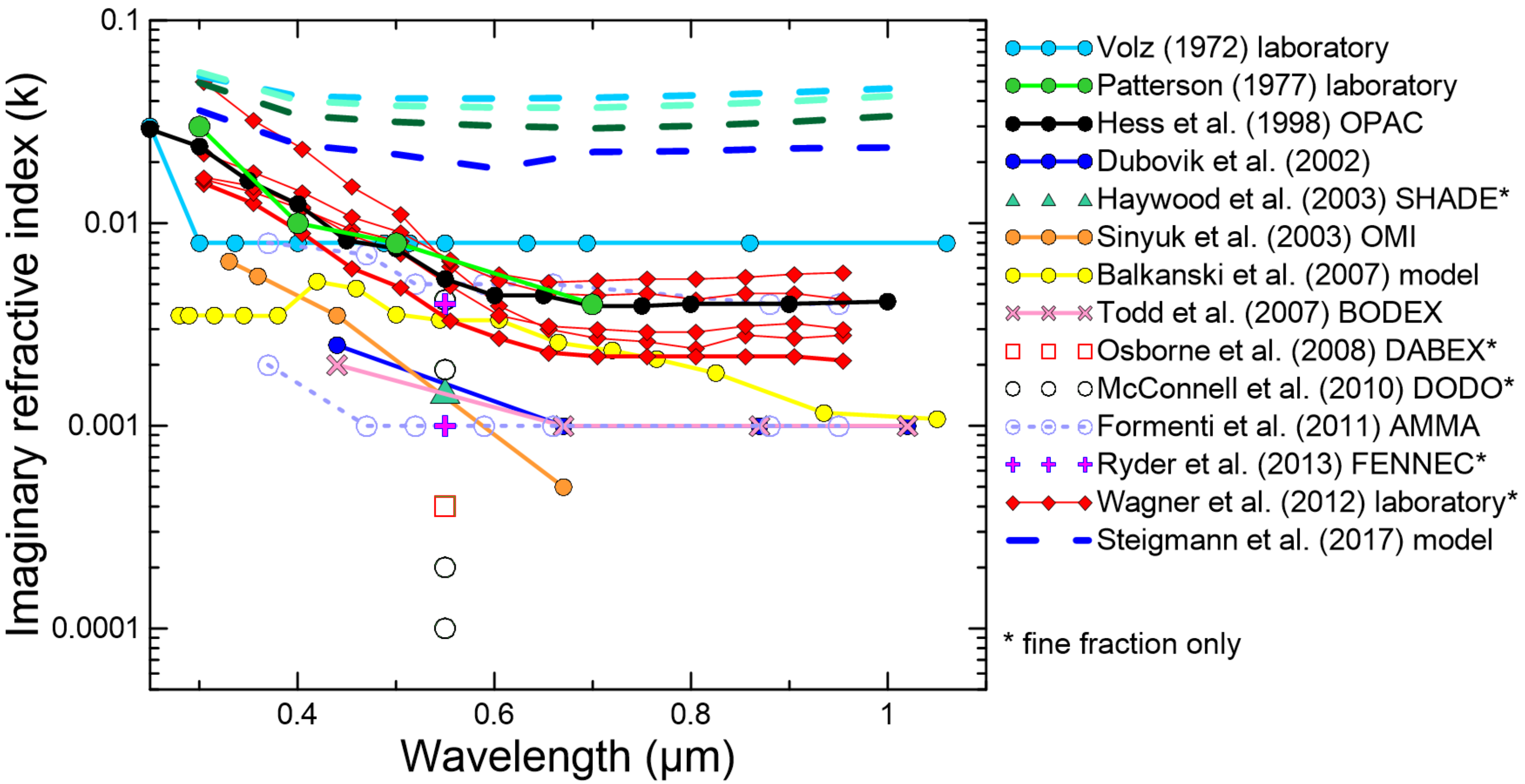
**-0.3** **+0.1**

**-2.2** **Direct effect* (Wm$^{-2}$)** **+0.76**

*Haywood et al., 1999; Woodward, 2001; Miller et al., 2004; Reddy et al., 2005; Balkanski et al., 2007; Zhao et al., 2011; Yue et al., 2010; Rap et al., 2013; Colarco et al. 2014, Kok et al. 2017*

# The absorption properties of mineral dust are a persisting major uncertainty

## Complex refractive index (CRI) = n-ik




Natural variability (size, mineralogy..), sampling artefacts

# The absorption properties of mineral dust are a persisting major uncertainty

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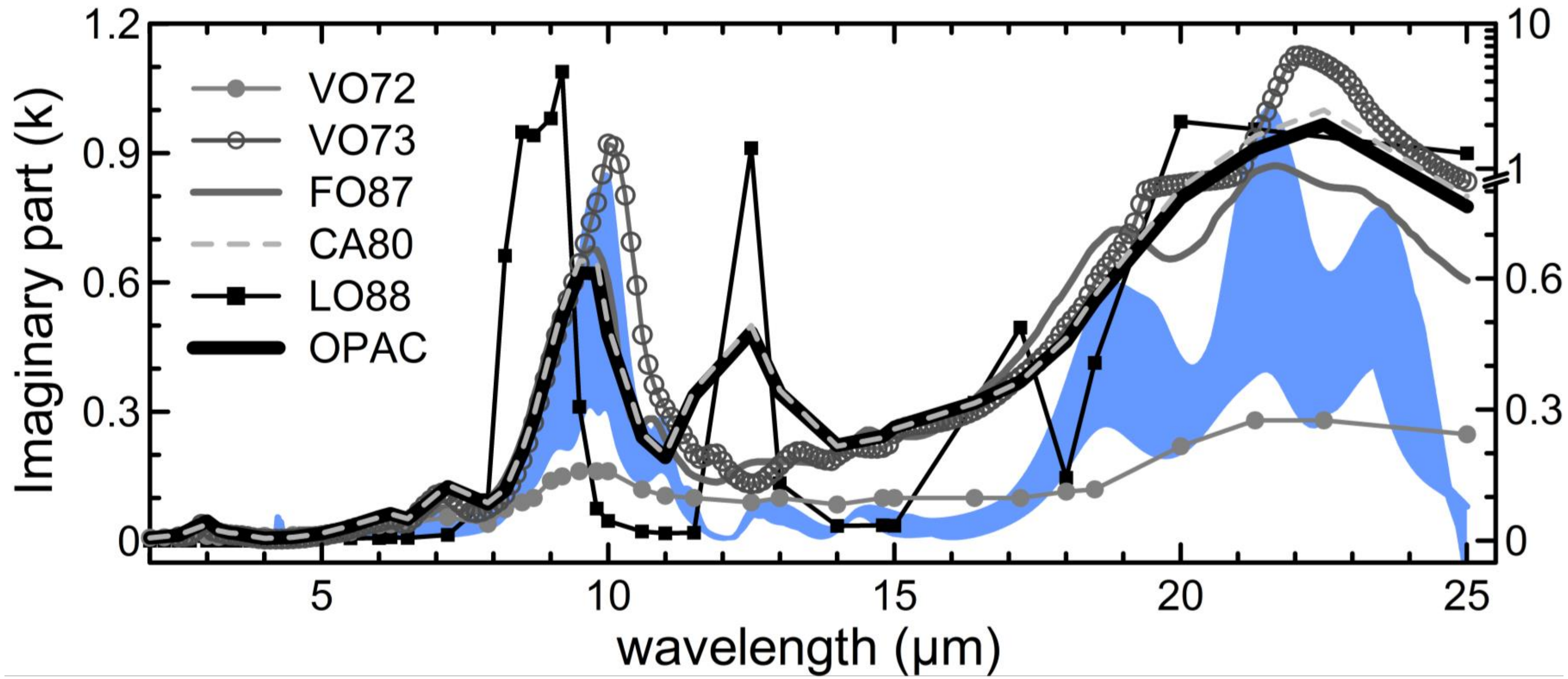



Volz1972 (Germany)
Volz 1973 (Barbados)
Fouquart1987 (Niger)
Carlson1980
Longtin 1988
OPAC
Di Biagio 2014 (Niger, Algeria)

Natural variability (size, mineralogy..), sampling artefacts

**Climate models and remote sensing retrievals use a spatially invariant generic refractive index**

In 2014 the LABEX-IPSL supported a new laboratory chamber activity to investigate the climate–relevant spectral optical properties of mineral dust

# RED-DUST

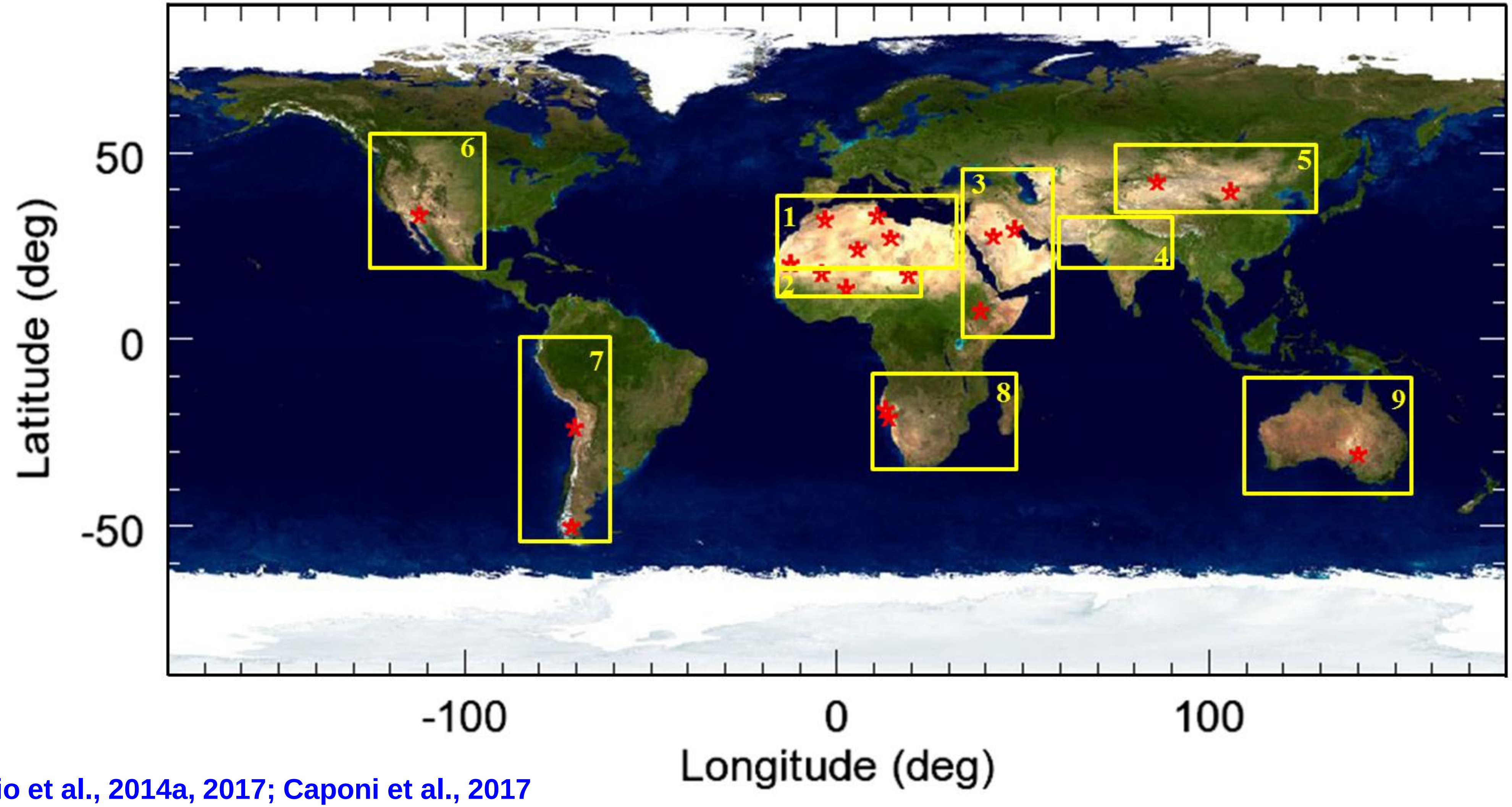
**A laboratory-based project targeting the absorption optical properties of mineral dust according to…**

**wavelength (UV/visible/IR)**
**soil mineralogy**
**size distribution**
**atmospheric ageing**

RED-DUST

# Soil sample databank (>150 soils)

19 selected soils worldwide




Di Biagio et al., 2014a, 2017; Caponi et al., 2017



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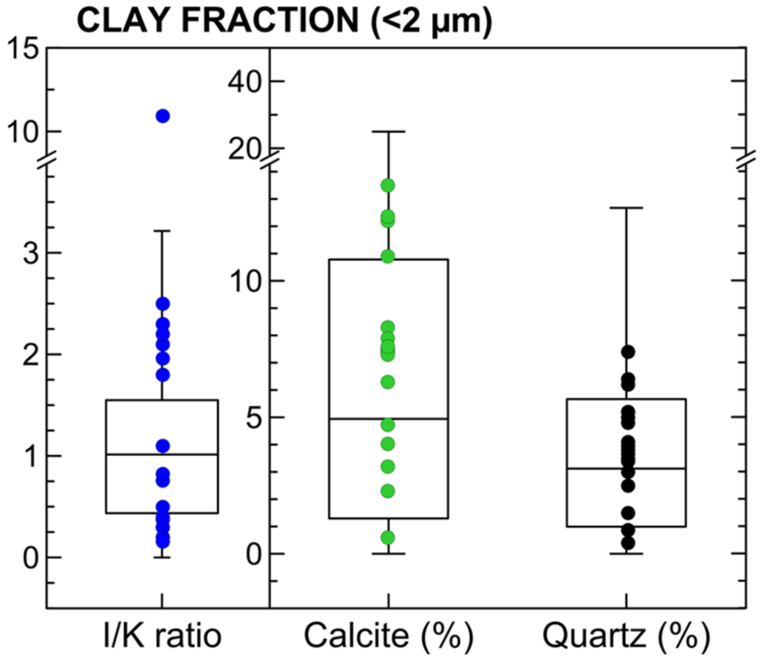
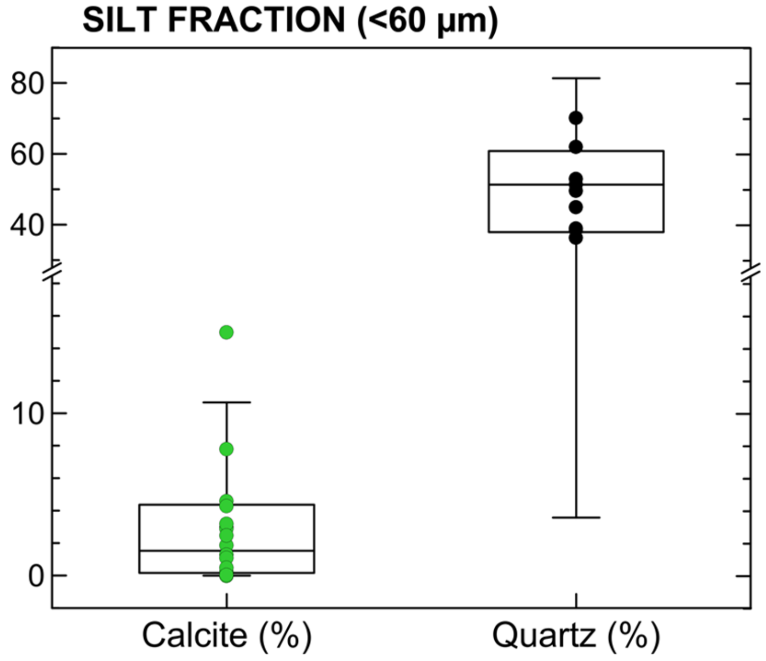
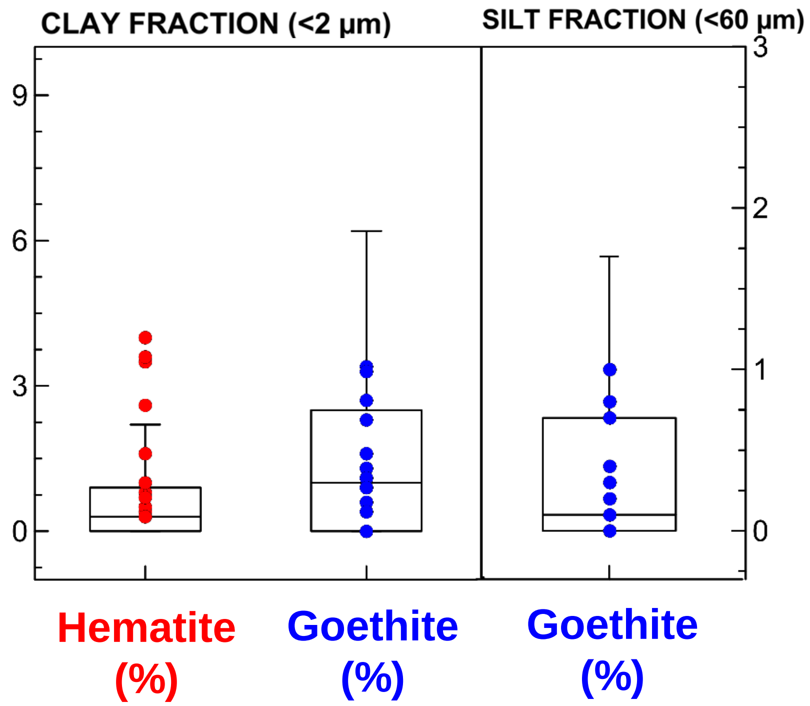
# Mineralogy of selected vs global soils

**Samples selected to represent the natural mineralogical variability of the global soils according to the soil database by Journet al al. (2014)**

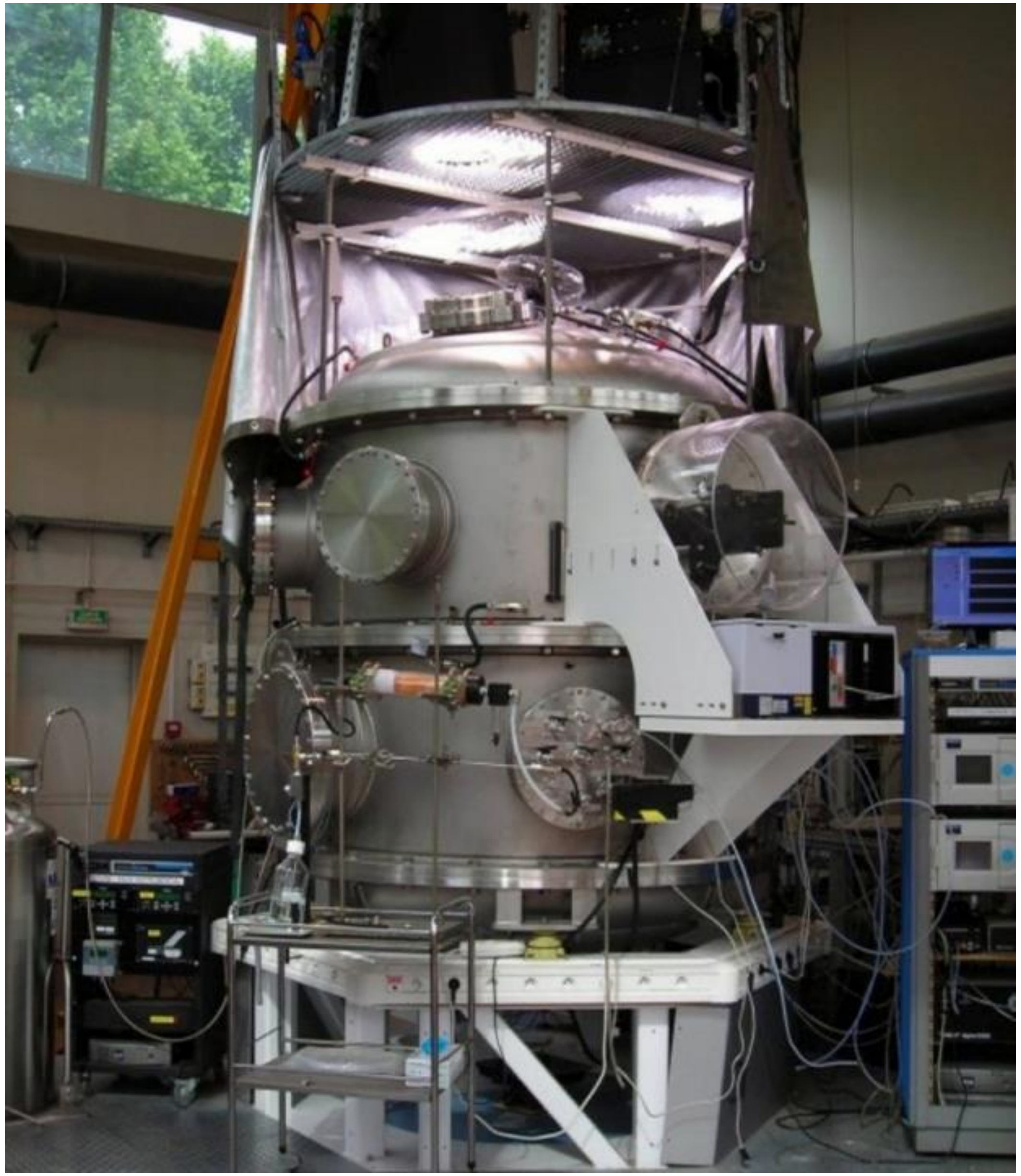



Di Biagio et al., 2014a, 2017; Caponi et al., 2017

# The CESAM simulation chamber

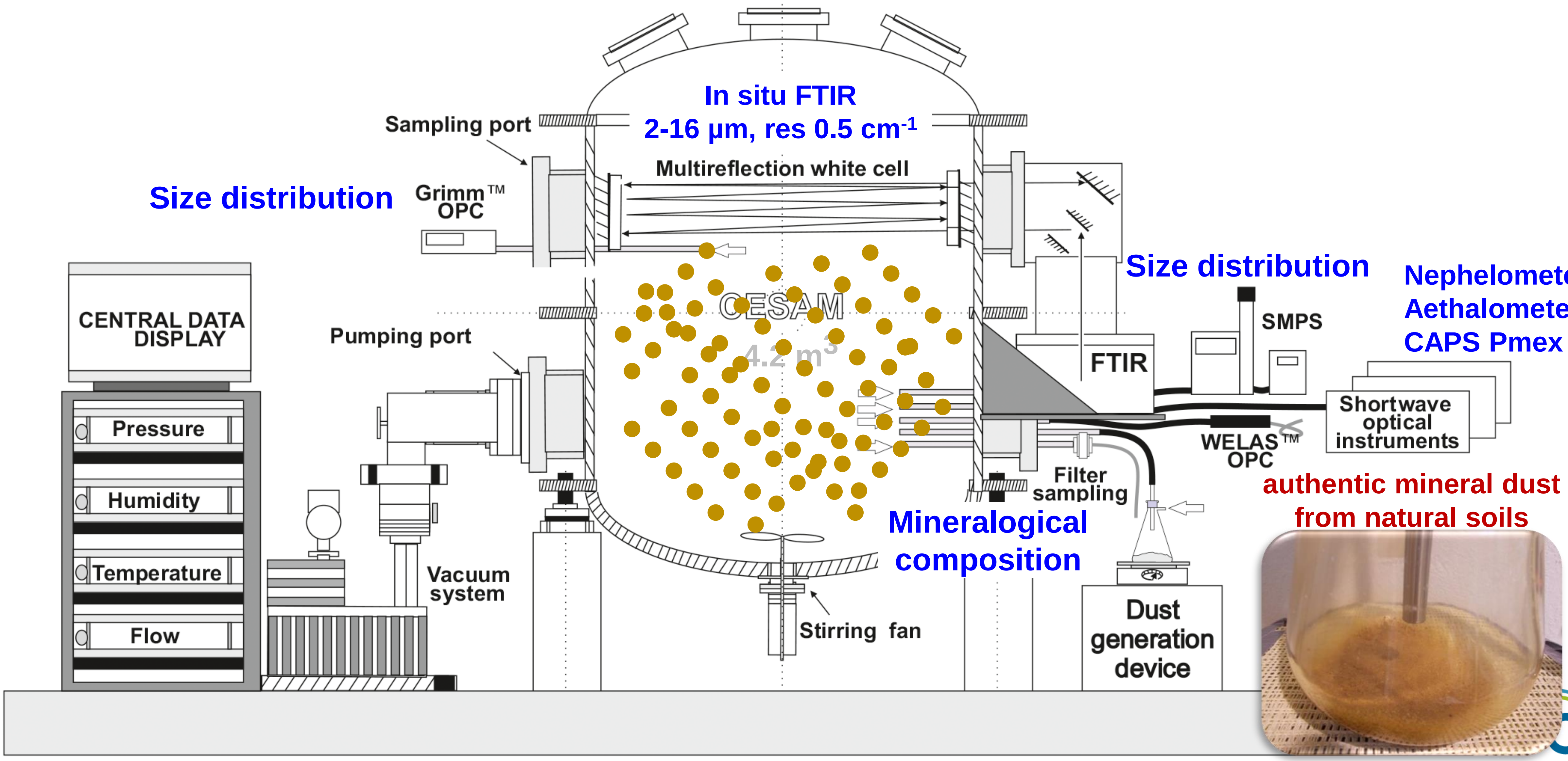


- Stainless-steel, 4.2 $m^3$ volume
- Generating aerosols under controlled conditions
- Long lifetime (> 24h for submicron aerosols)
- Simultaneous measurements of physico-chemical and optical properties

**www.cesam.cnrs.fr**

# Laboratory simulations - simultaneous measurements of physico-chemical and spectral optical properties

RED-DUST




authentic mineral dust from natural soils

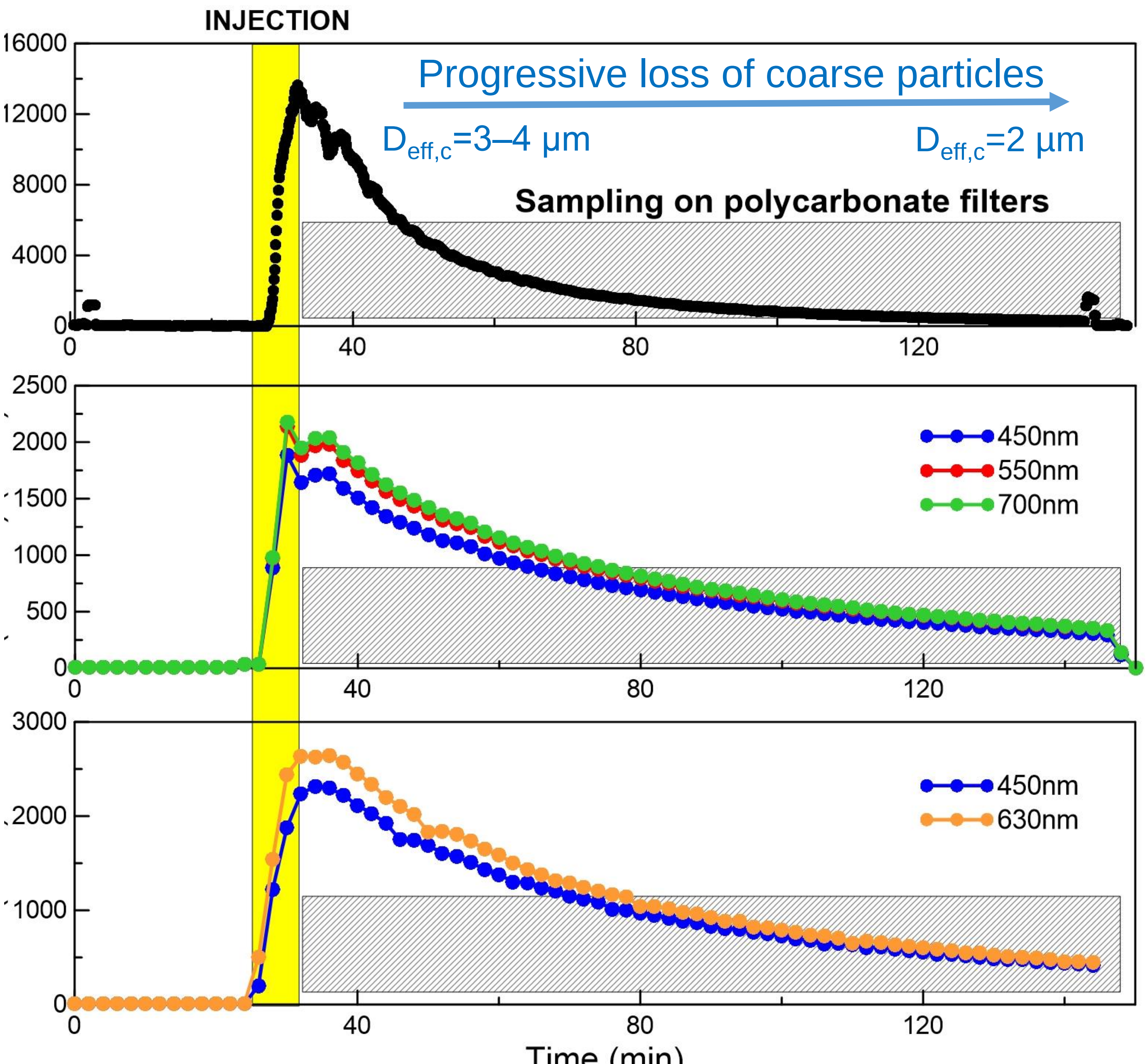
# Experiments

RED-DUST

Mass concentration (µg m$^{-3}$)

Scattering coefficient (7°-170°) (Mm$^{-1}$)

Extinction coefficient (Mm$^{-1}$)




**Mineralogical composition integrated over the whole experiment**

Morocco dust

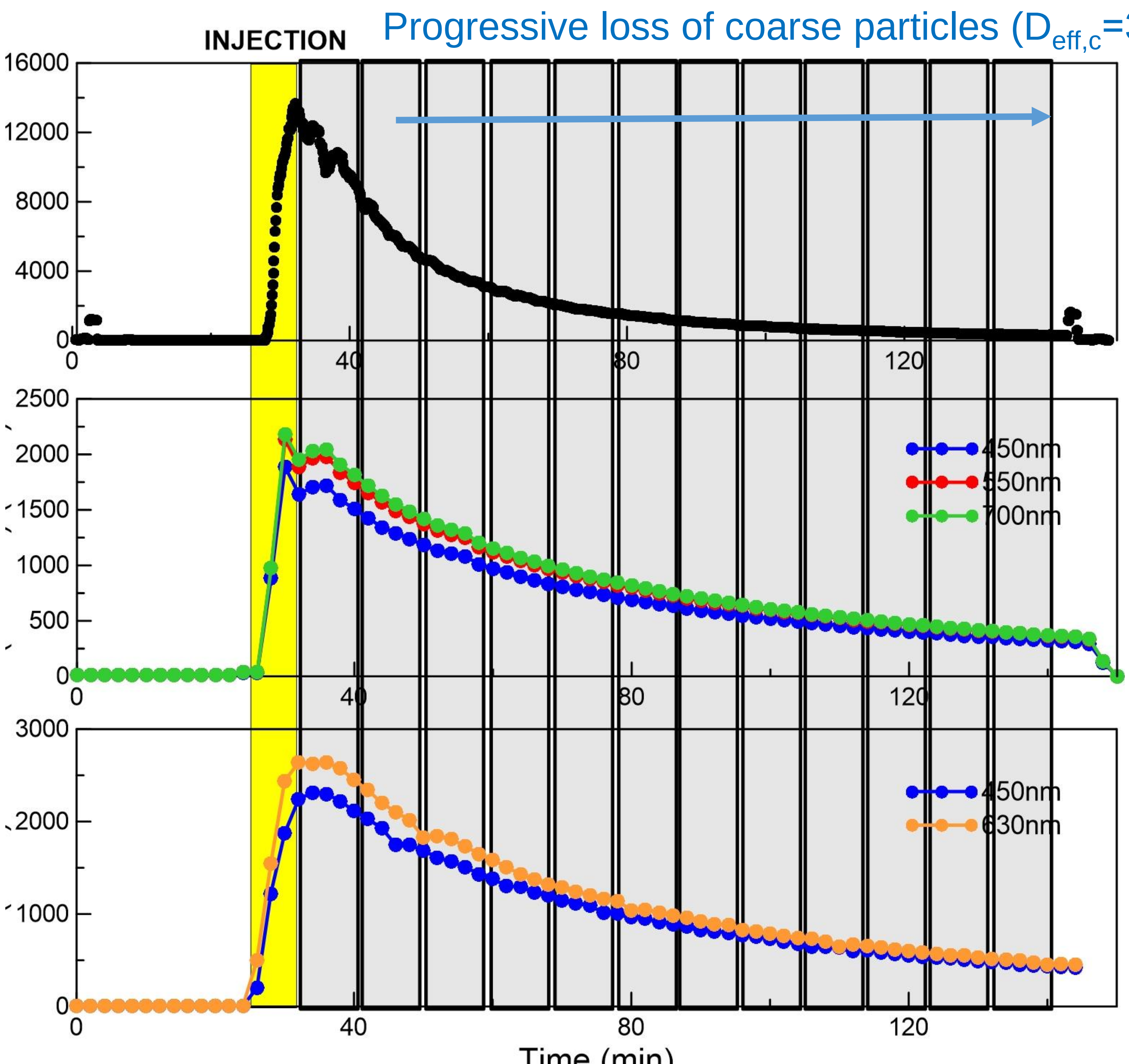
# Experiments

RED-DUST

Mass concentration (µg m$^{-3}$)

Scattering coefficient (7°-170°) (Mm$^{-1}$)

Extinction coefficient (Mm$^{-1}$)




**CRI and SSA retrieved at 10-min temporal resolution**

**Same on LW extinction**

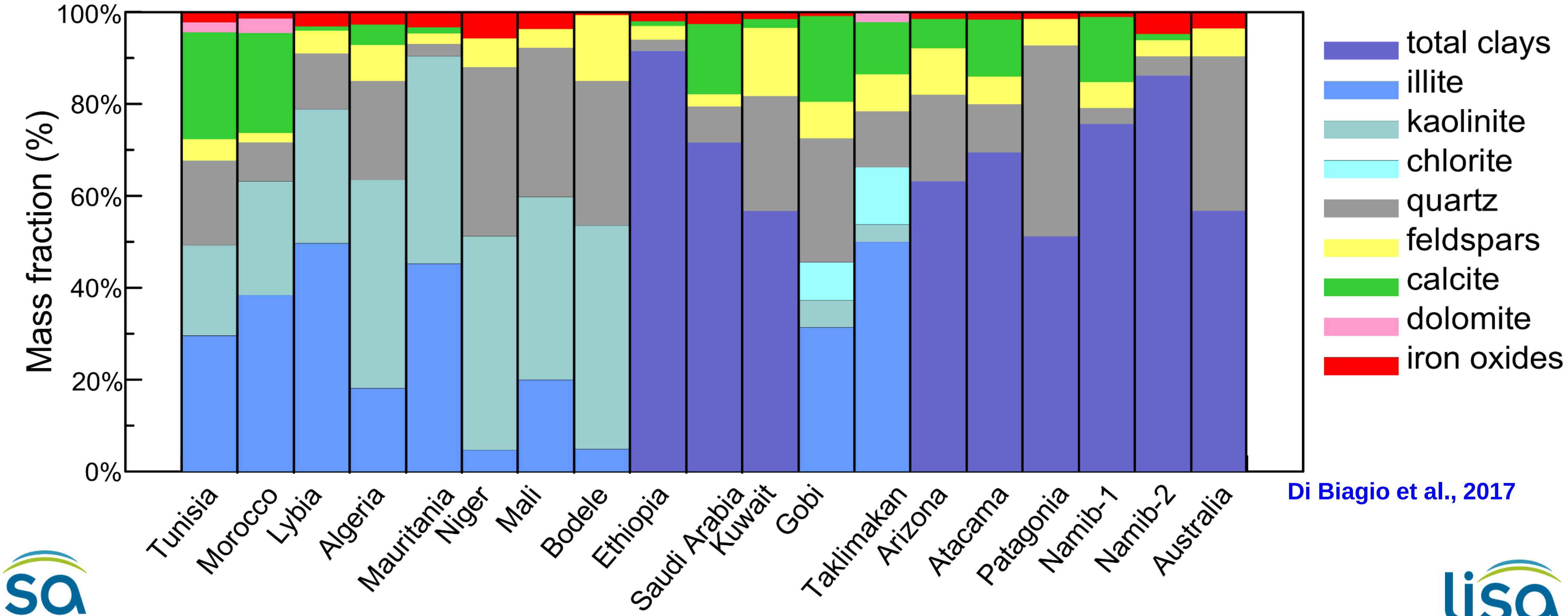
Morocco dust

RED-DUST

# Generated dust aerosols: variable and realistic mineralogy

**Iron oxides < 5.8%**

**Total elemental iron 2.4 – 10.6%**

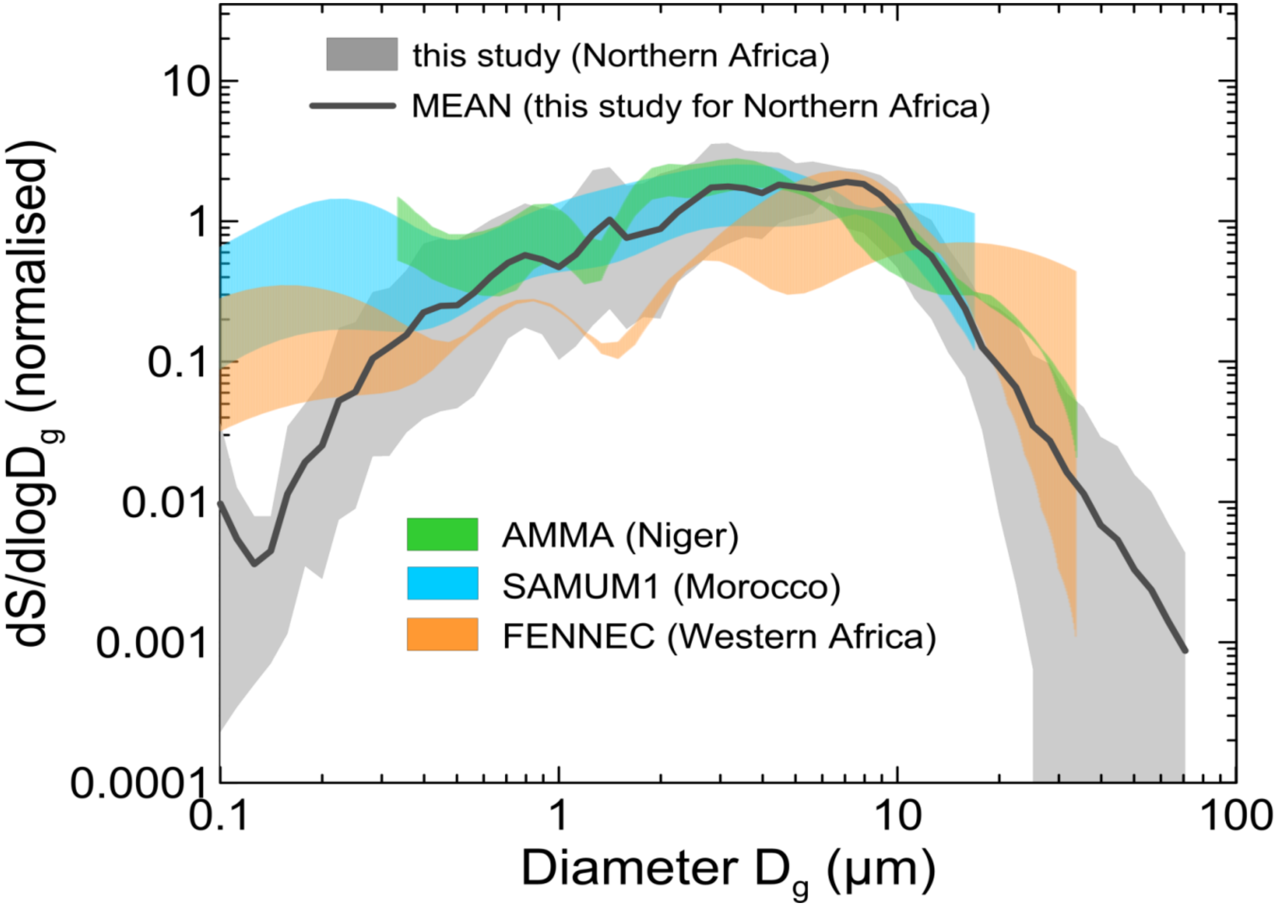



Di Biagio et al., 2017

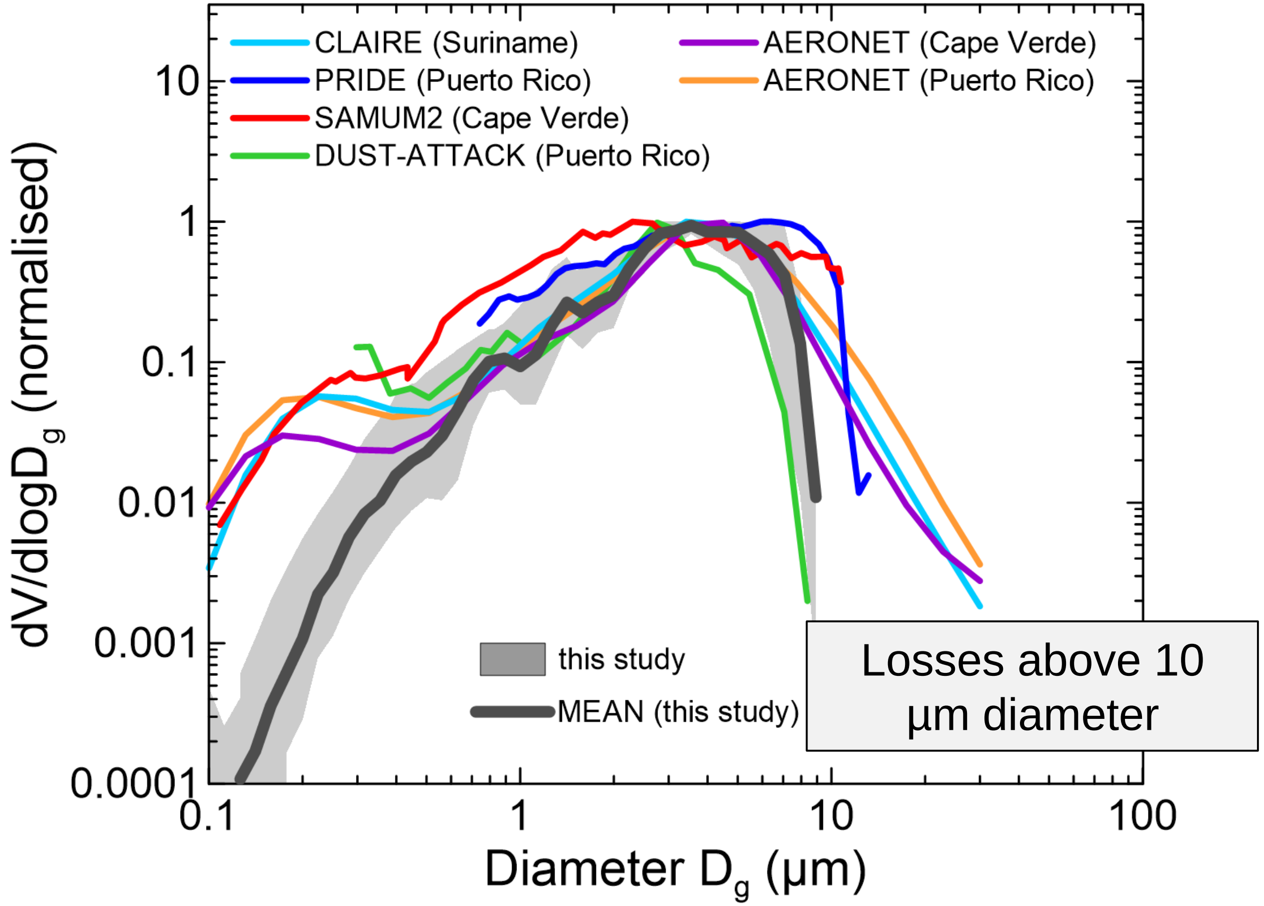
RED-DUST

# Generated dust aerosols: realistic size distribution

Injected in CESAM
(mimic **source dust**)



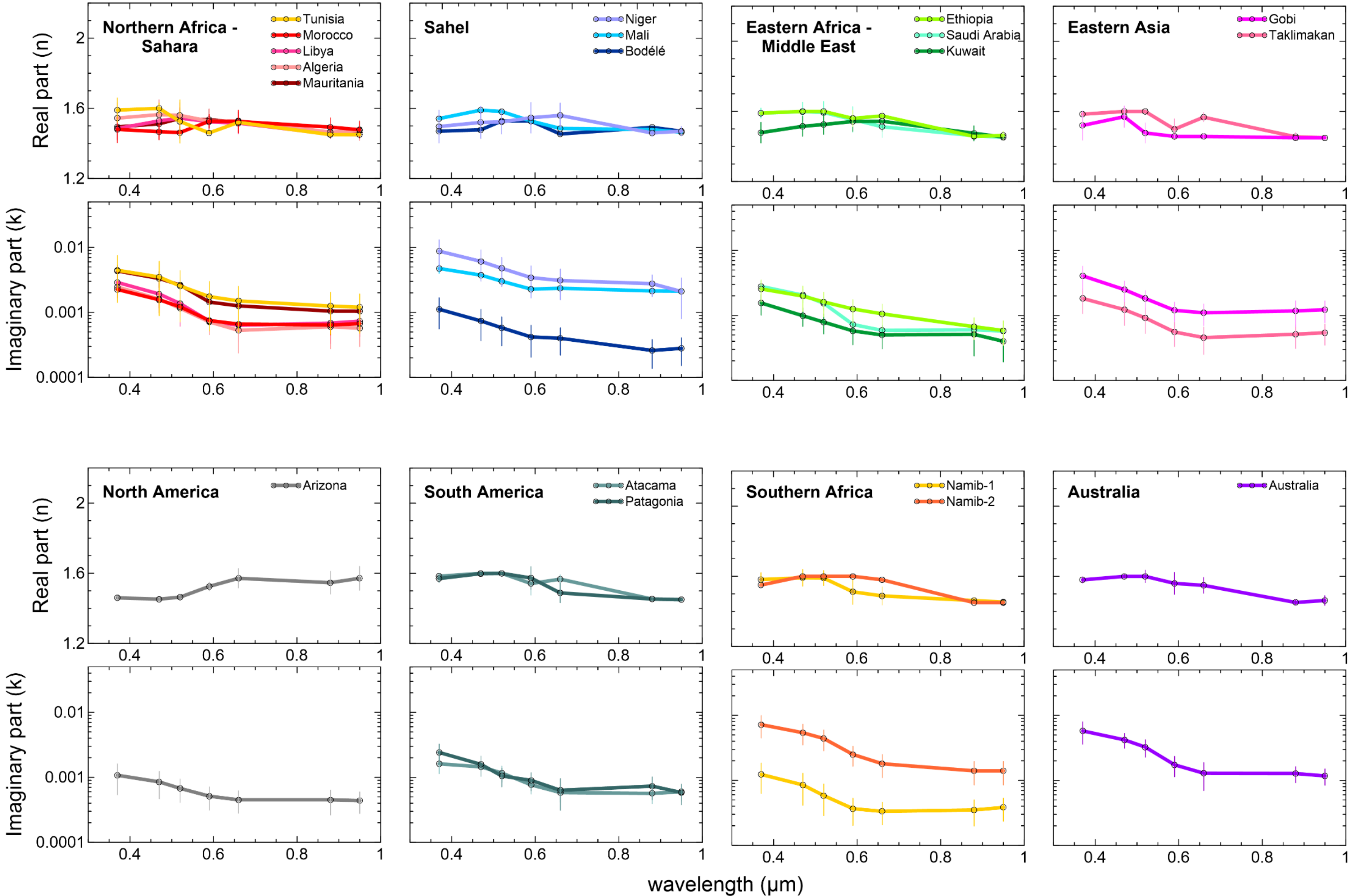

Seen by the instruments
(mimic **transported dust**)




Di Biagio et al., 2017

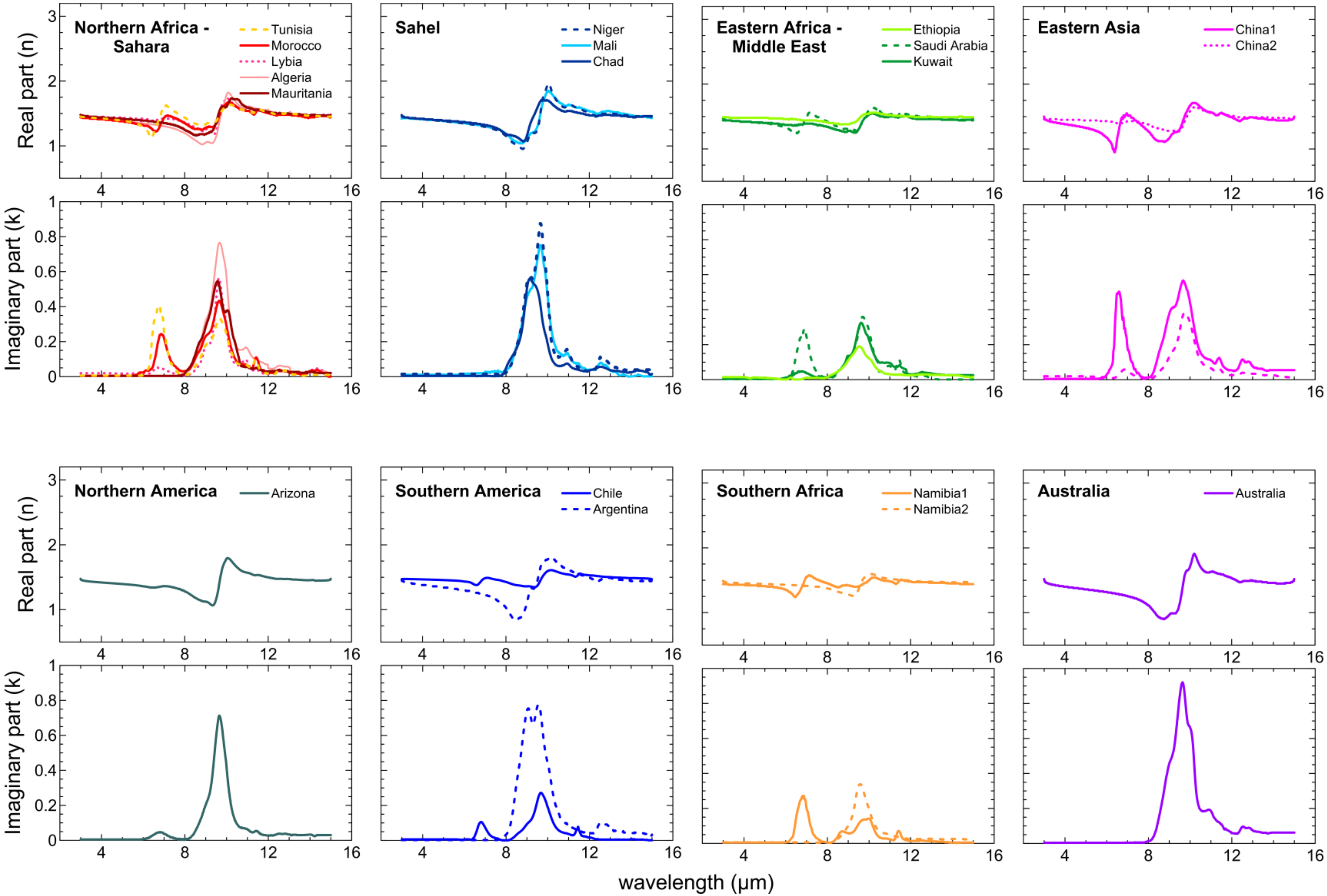
# Dust SW refractive index: regional scale variability

RED-DUST



# Dust LW refractive index: regional scale variability

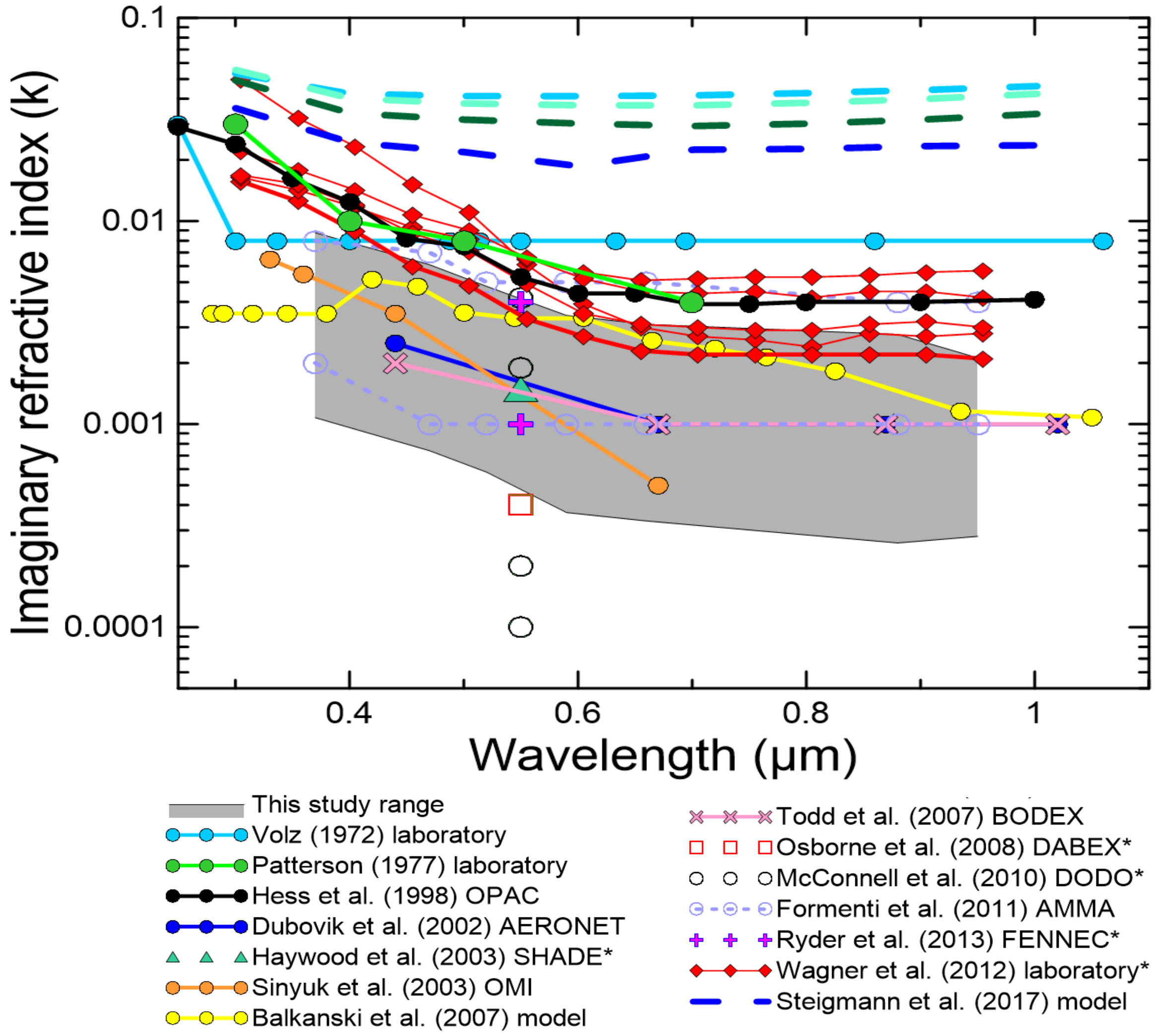
RED-DUST



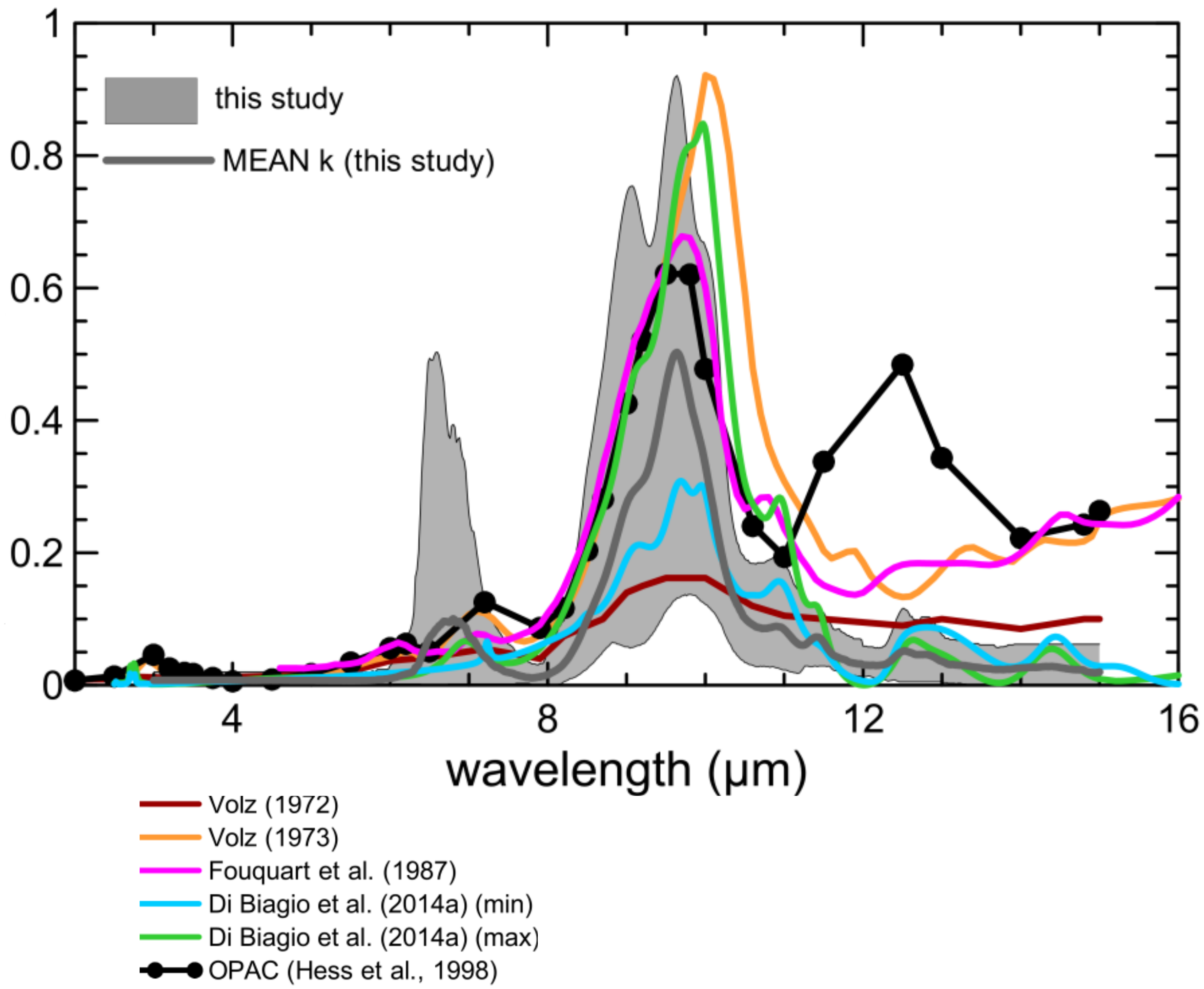
# Comparison with previous results

RED-DUST

## UV-VIS




## IR




**….how to translate this variability for models?**



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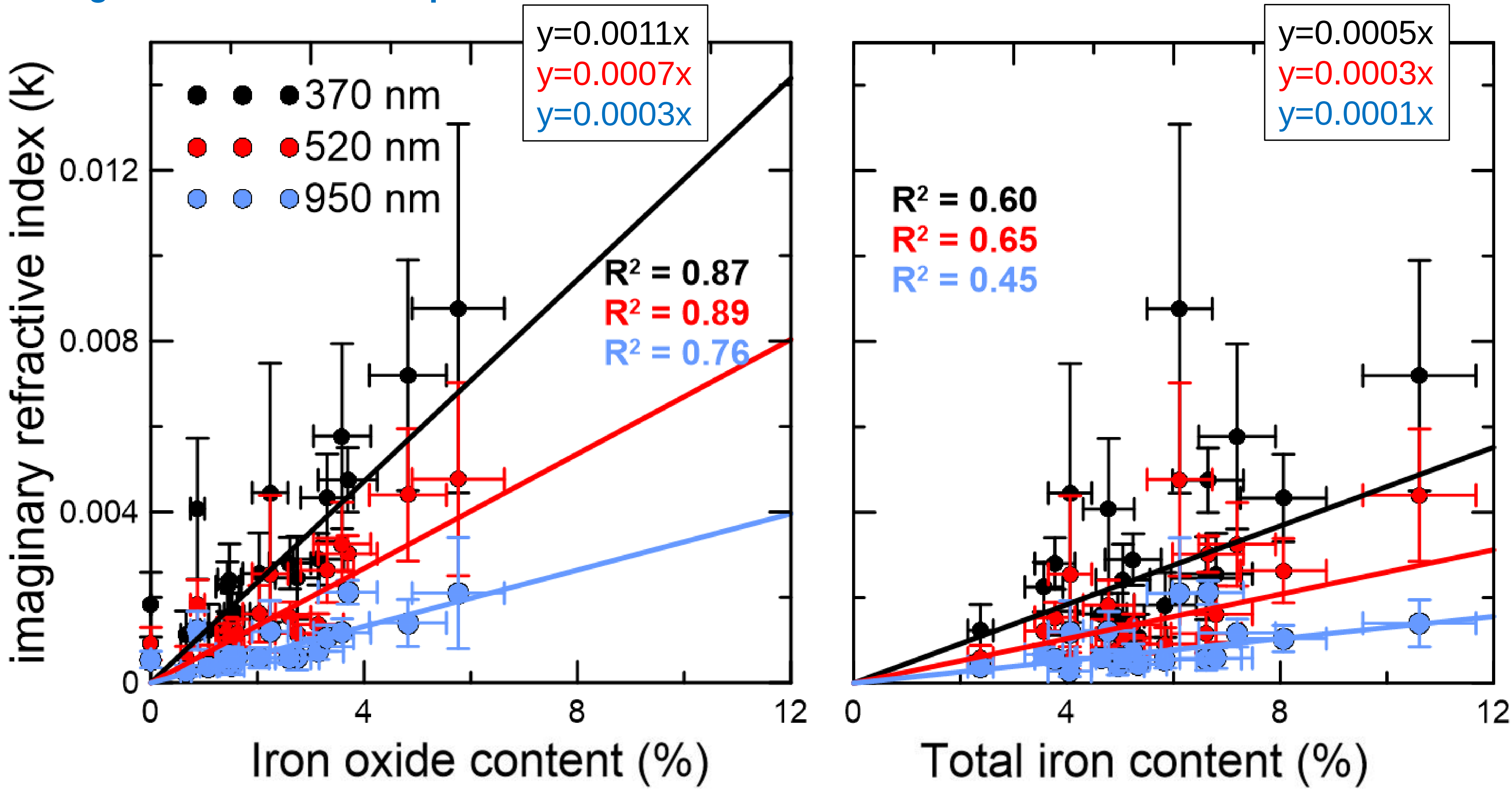
# Relationship between CRI and iron and iron oxide content

## Average values for each experiment

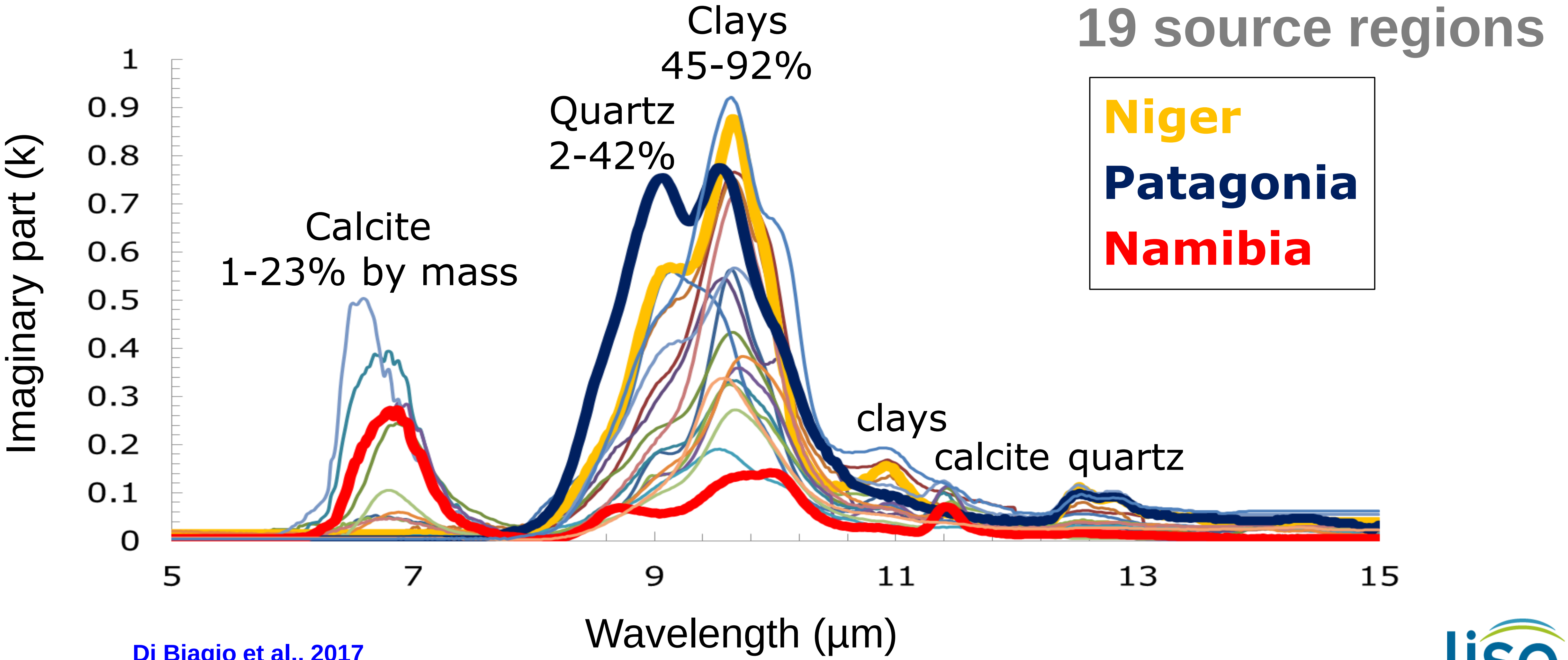



Consistent with previous work by Moosmüller et al. (2012) and Engelbrecht et al. (2016), PM2.5 dust

# Relationship between LW CRI and clays, calcite, and quartz content

RED-DUST

**Average values for each experiment**




Di Biagio et al., 2017

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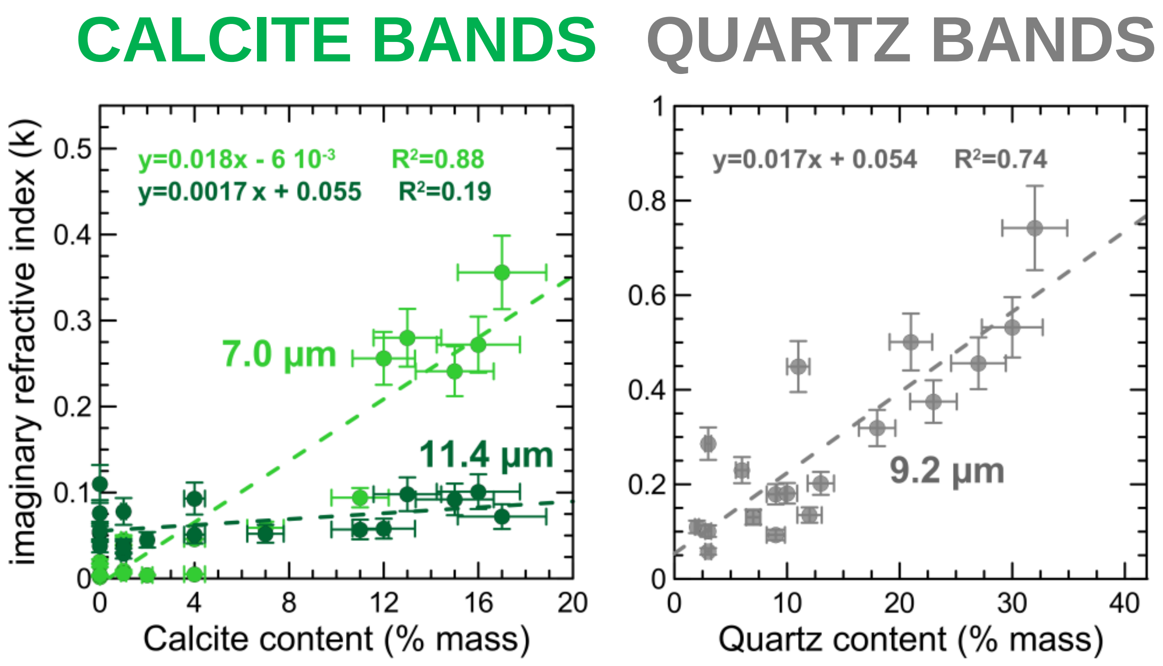
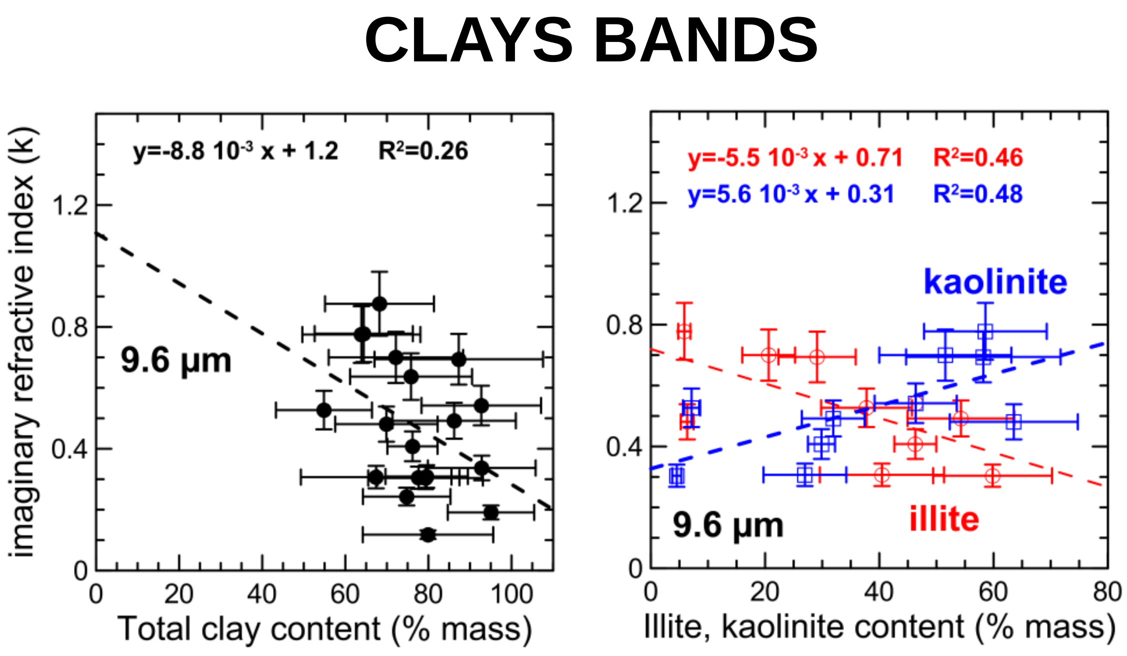
# Relationship between LW CRI and clays, calcite, and quartz content

RED-DUST



# Summary

- Systematic laboratory measurements of the CRI at UV-VIS-IR wavelengths on **natural dust aerosol samples** representing the global mineralogy of particles smaller than 10 µm

- The **real part of the refractive index don't change regionally**, suggesting that a source-invariant spectral n can be used in models and remote sensing applications

- **Conversely the imaginary part of CRI (absorption) shows a clear spectral dependence and a regional variability that mostly depends on mineralogy**
  - **In the UV-VIS:** linear with the iron oxide and the total iron content (even better when particles are smaller than 2.5 µm (not shown)
  - **At selected bands in the LW**: linear with the content of calcite, quartz and clays (more tricky)
- **Same for the UV-VIS single scattering albedo (not shown)**

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