Inaugural dust and climate model simulations with the new EMIT global mineral abundance maps.

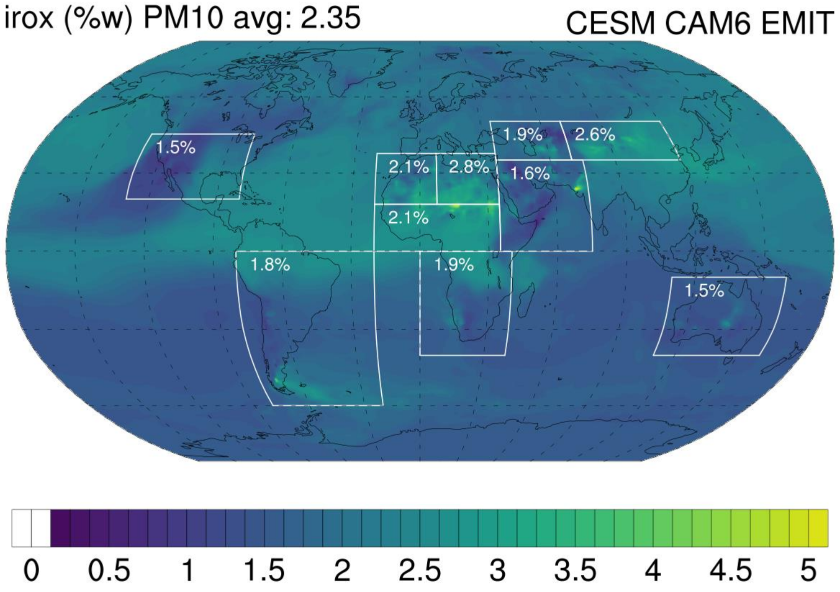
M. Gonçalves Ageitos and the EMIT science team.

Dust mineralogy has multiple impacts in the Earth System (e.g., iron oxides affect SW radiation absorption).

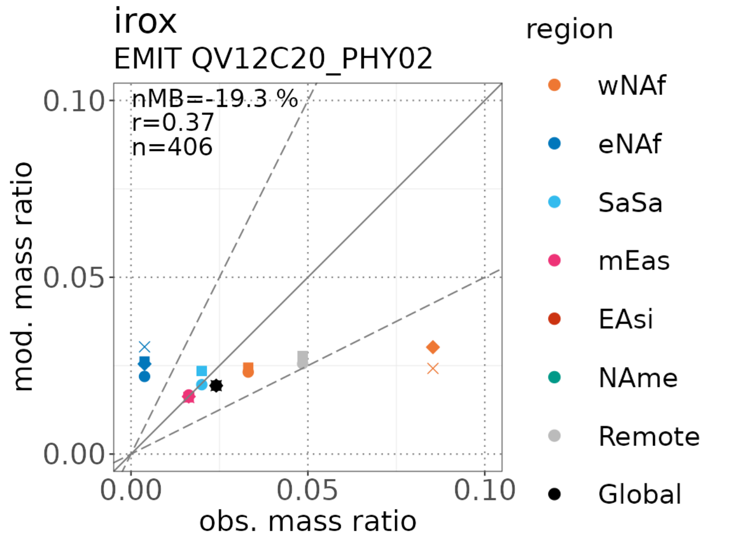
New insights on **the global soil mineral** abundance through **EMIT**.

PICO SCREEN 5.7

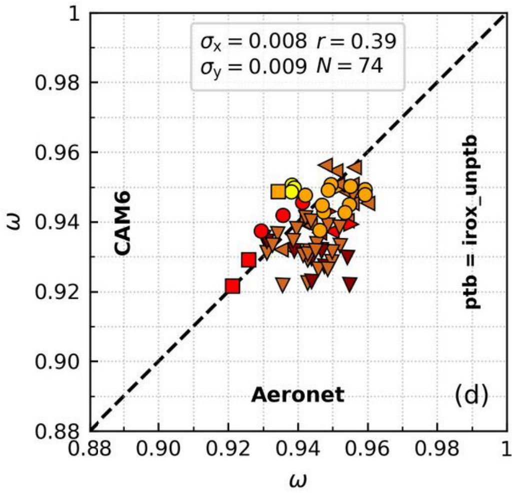
Multi-model assessment
EMIT map vs. baseline



Evaluation of mineral mass fractions



Effect on single scattering albedo



AS3.9 **Aeolian dust: initiator, player, and recorder of environmental change.** EGU24-17044

EGU General Assembly 2024
Vienna, 18/04/2024

European Geosciences Union

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Inaugural dust and climate model simulations with the new EMIT global mineral abundance maps

María Gonçalves Ageitos

Vincenzo Obiso, Ron L. Miller, Oriol Jorba, Martina Klose, Jerónimo Escribano, Luka Ilić, Longlei Li, Natalie M. Mahowald, Paul Ginoux, Qianqian Song, Philip G. Brodrick, David R. Thompson, Robert O. Green, Carlos Pérez García-Pando

and the EMIT science team

EMIT Earth Surface Mineral Dust Source Investigation

FRAGMENT

erc European Research Council Established by the European Commission

CERTAINTY Cloud-aerosol interactions & their impacts in the Earth system

FORCeS

FOCI

AXA Research Fund

Gobierno de España Ministerio de Economía y Competitividad

ICREA

EGU24-17044 - **Aeolian dust: initiator, player, and recorder of environmental change**

Radiation interaction

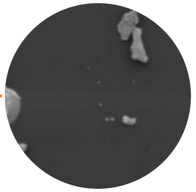
Iron oxides

Cloud formation

Quartz
Feldspar

Biogeochemical cycles

Iron containing minerals

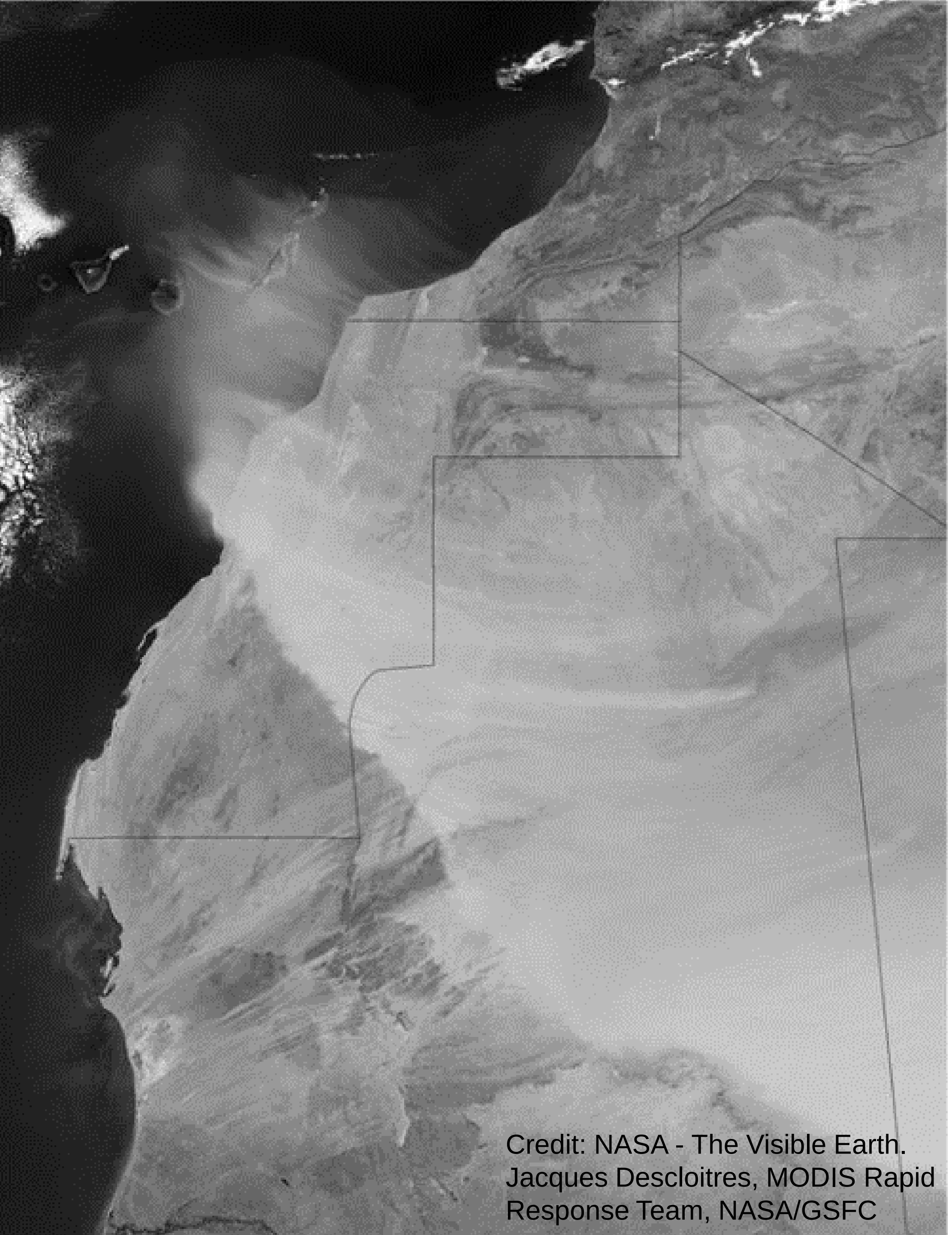


Atmospheric chemistry

Calcite

… these impacts are modulated by mineralogy.

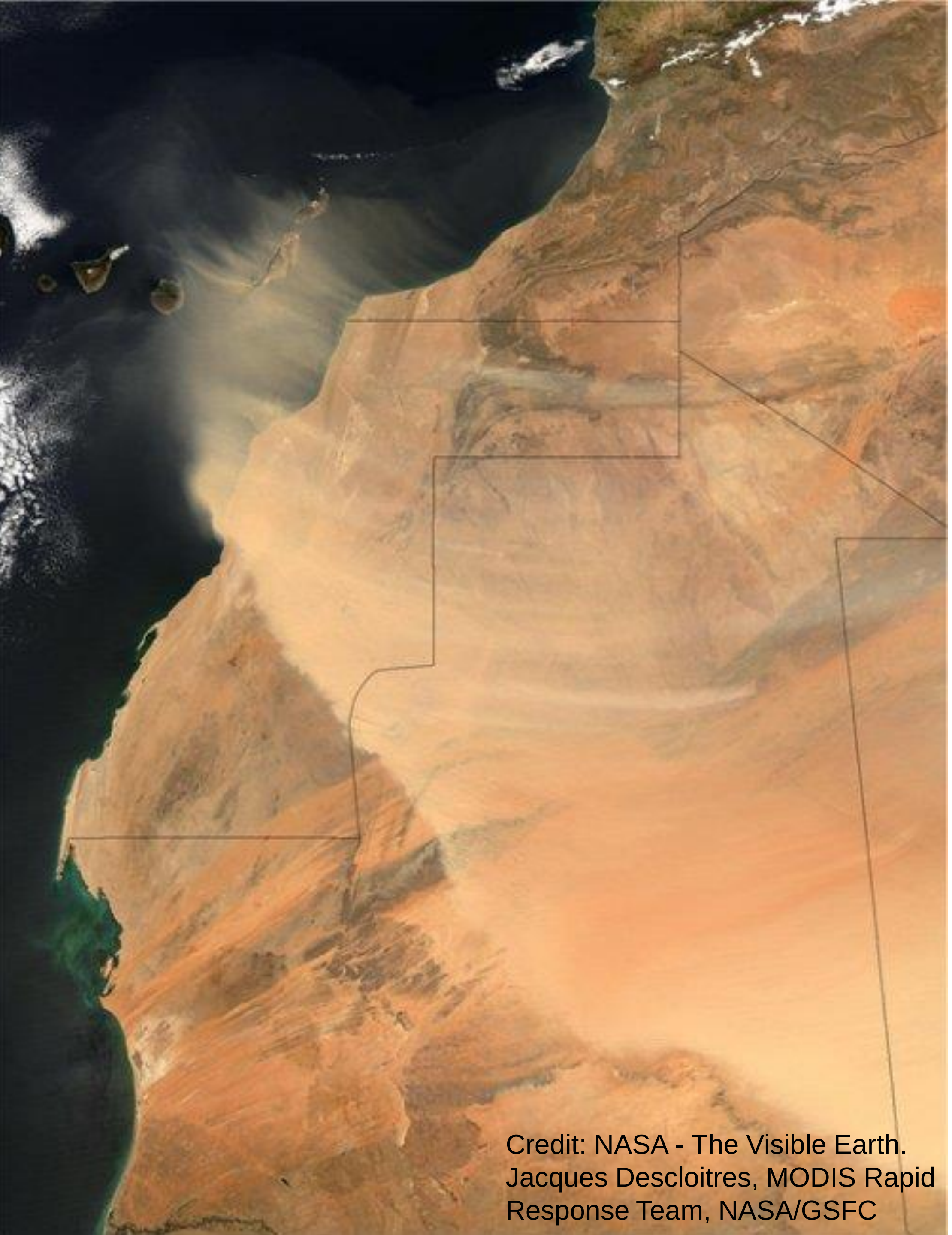
Image credits: NASA, NOAA, Krueger et al. (2004)



Challenges to represent mineralogy in Earth System Models:

… limited knowledge of the composition of parent soils

… and the resulting size-distributed mineralogy at emission



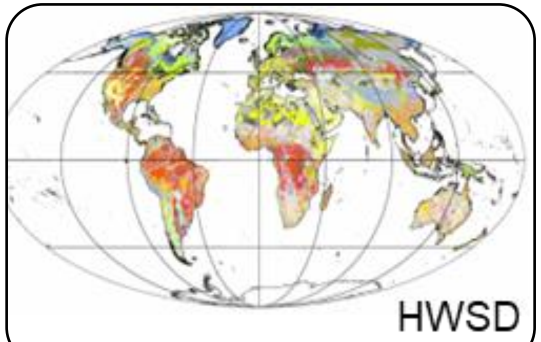
Credit: NASA - The Visible Earth.
Jacques Descloitres, MODIS Rapid
Response Team, NASA/GSFC

Challenges to represent mineralogy in Earth System Models:

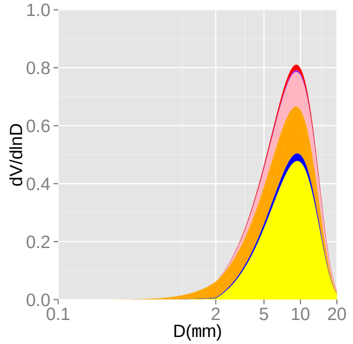
… limited knowledge of the composition of parent soils

… and the resulting size-distributed mineralogy at emission

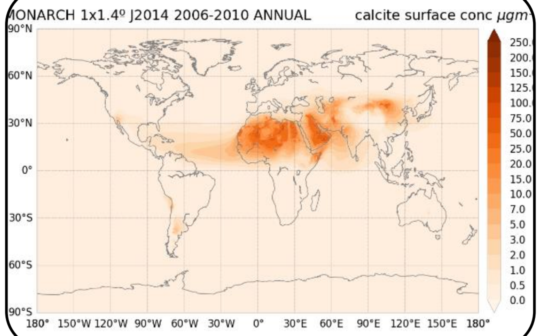
Modelling dust mineralogy



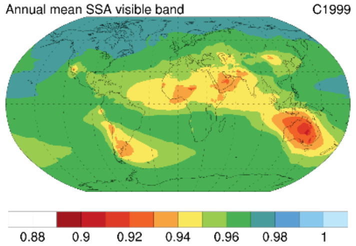
Soil mineralogy maps



Emitted size-resolved mineral fractions



Minerals' atmospheric cycle



Dust single scattering albedo

Soil mineralogy maps

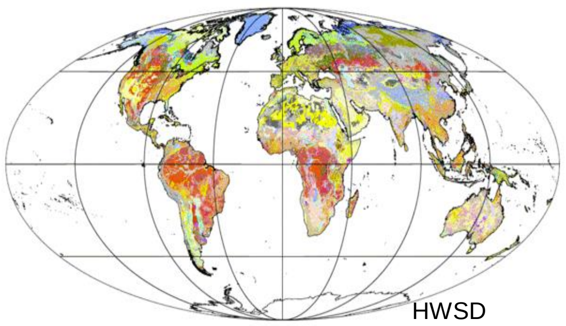
Global soil mineralogy atlases (pre-EMIT)

- **Claquin et al. 1999, Nickovic et al. 2012**: 8 minerals.

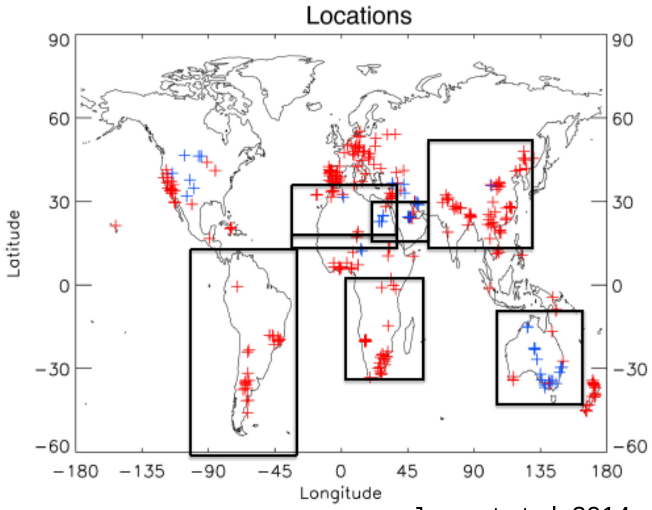
Illite, smectite, kaolinite, quartz, feldspars, calcite, gypsum and hematite (iron oxides).

- **Journet et al. 2014**: 12 minerals.

Illite, smectite, kaolinite, vermiculite, chlorite, mica, quartz, feldspars, calcite, gypsum, hematite and goethite.

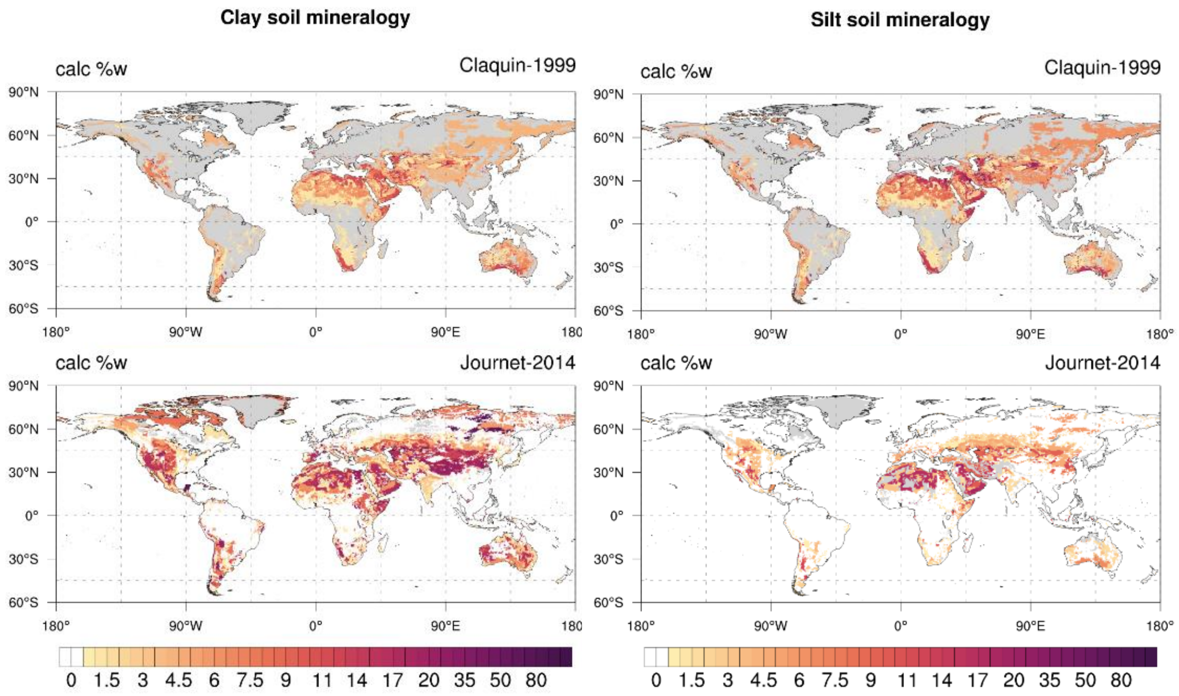


FAO soil classification



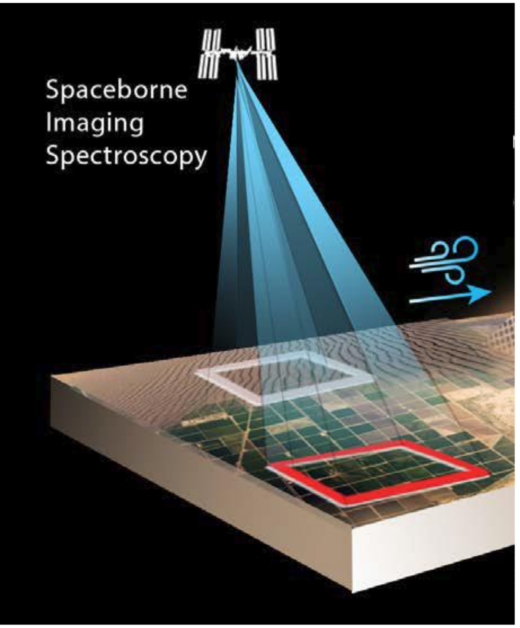
Journet et al. 2014

Mean mineralogy



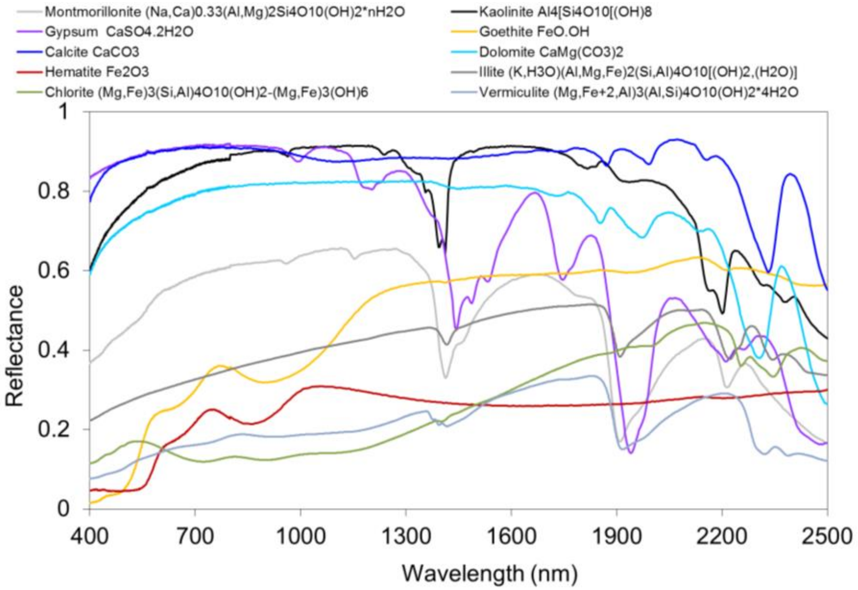
Mineralogical composition for clay (ϕ < 2 μm) and silt (ϕ 2-63 μm) size classes

New mineralogy maps from NASA EMIT (Green et al. 2020)

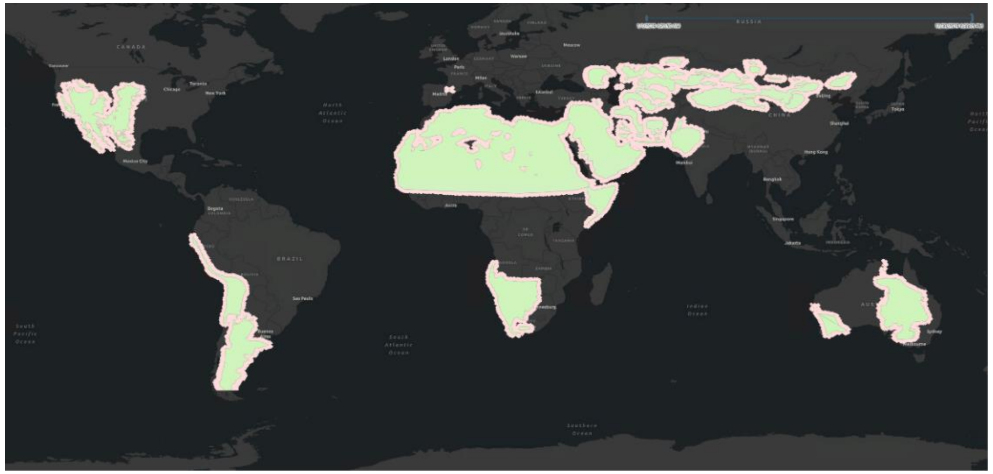


The EMIT instrument is measuring from the ISS since July 14, 2022.

VSWIR Spectra of Dust Source Minerals



Dust Minerals have distinct spectral signatures



Target mask for EMIT retrievals covering arid land regions

Level 3 products – map of 10 (+2) minerals to be used within ESMs

EMIT soil maps

EMIT data products

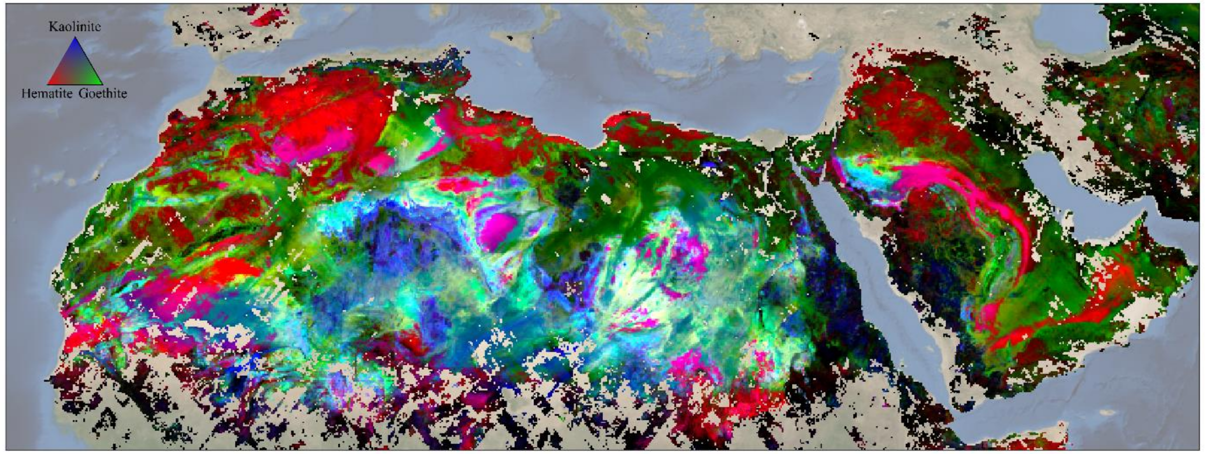


Image courtesy of Phil Brodrick (NASA-JPL)

- Abundance of 10 minerals in the soil relevant for their climate impact, with an unprecedented spatial resolution
- Quartz and feldspar are not retrieved
- No direct information on soil texture

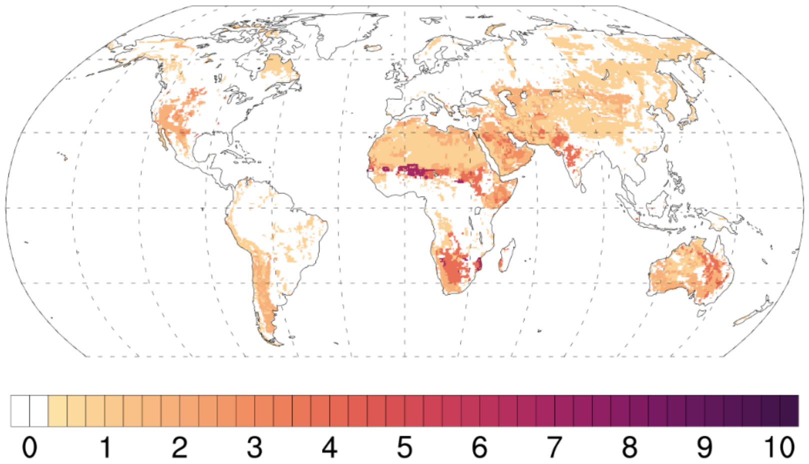
Check:

EMIT Global Dust Source and Emission Mineral Abundance Maps for Dust and Climate Modeling,
By C. Pérez García-Pando et al.
PICO 5.6

Barcelona Supercomputing Center – Centro Nacional de Supercomputación
Universitat Politècnica de Catalunya BarcelonaTech
Jet Propulsion Laboratory, California Institute of Technology

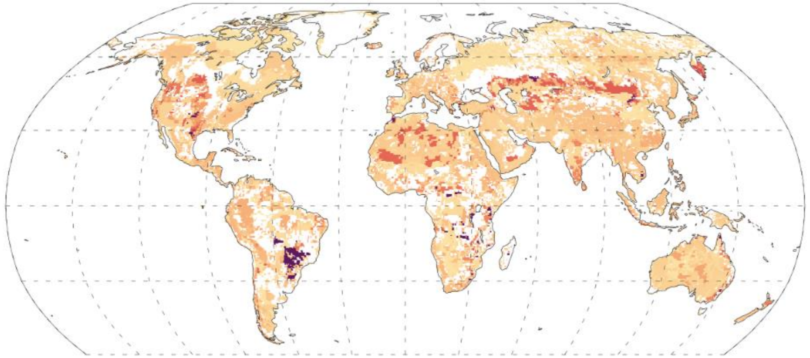
Soil mineralogy: iron oxides mass fraction (%w)

C1999 Hematite (%w) clay

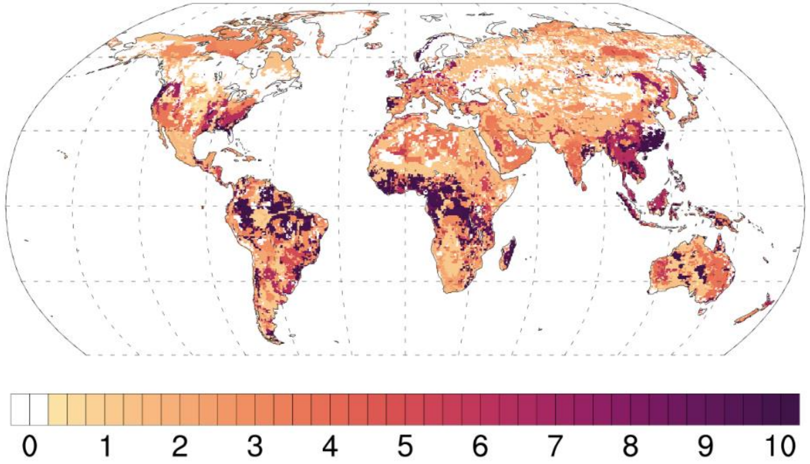


Claquin et al. (1999), Nickovic et al. (2012)

J2014 Hematite (%w) clay

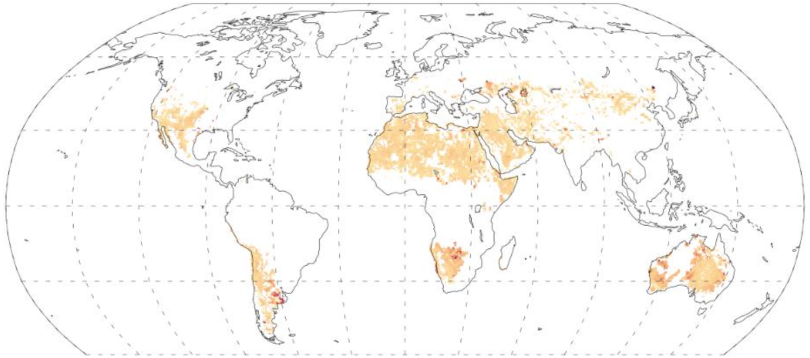


J2014 Goethite (%w) clay

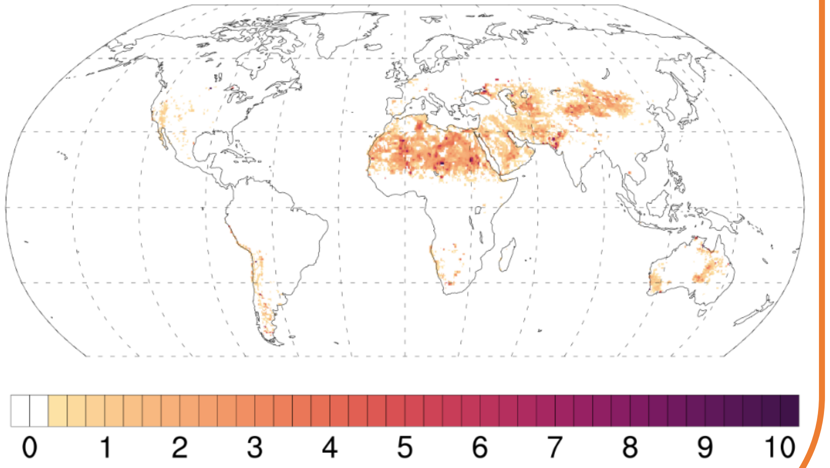


Journet et al. (2014)

EMIT Hematite (%w) clay



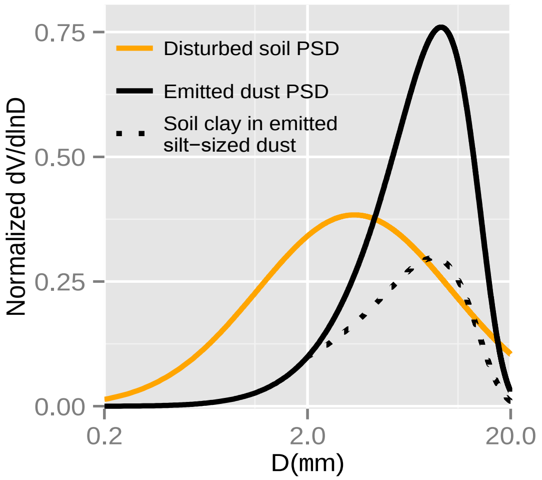
EMIT Goethite (%w) clay



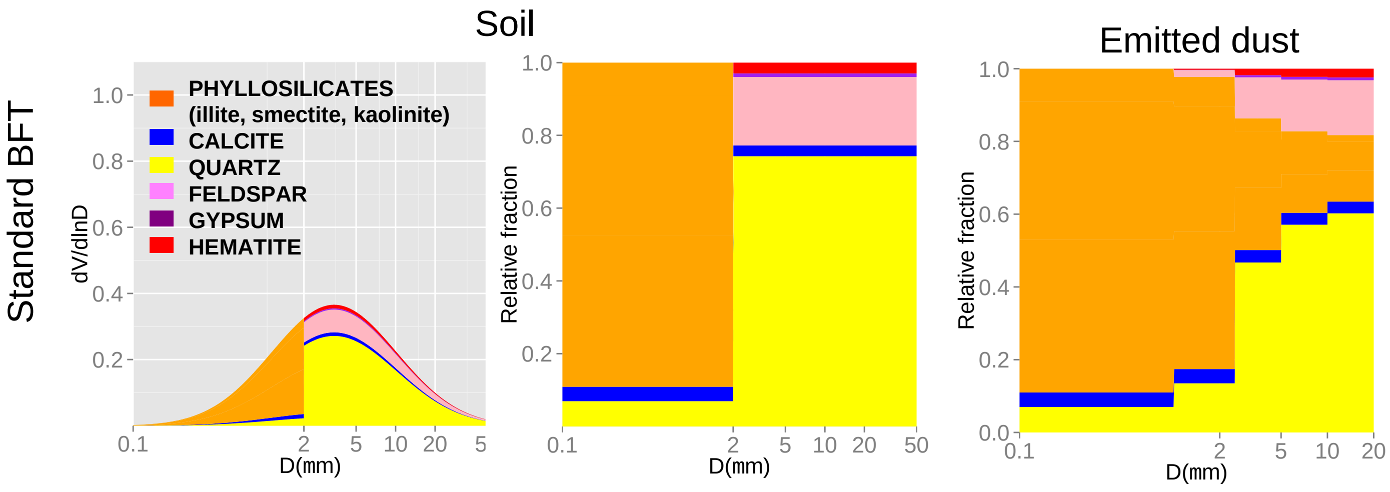
Li et al. (2021) multi-model study **attributes 97% of the uncertainty range** in **dust Direct Radiative Effect** to uncertainties in the abundance of **iron oxides**.

Emitted minerals' PSD

Size resolved mineral fractions at emission



Brittle Fragmentation Theory (Kok, 2011)

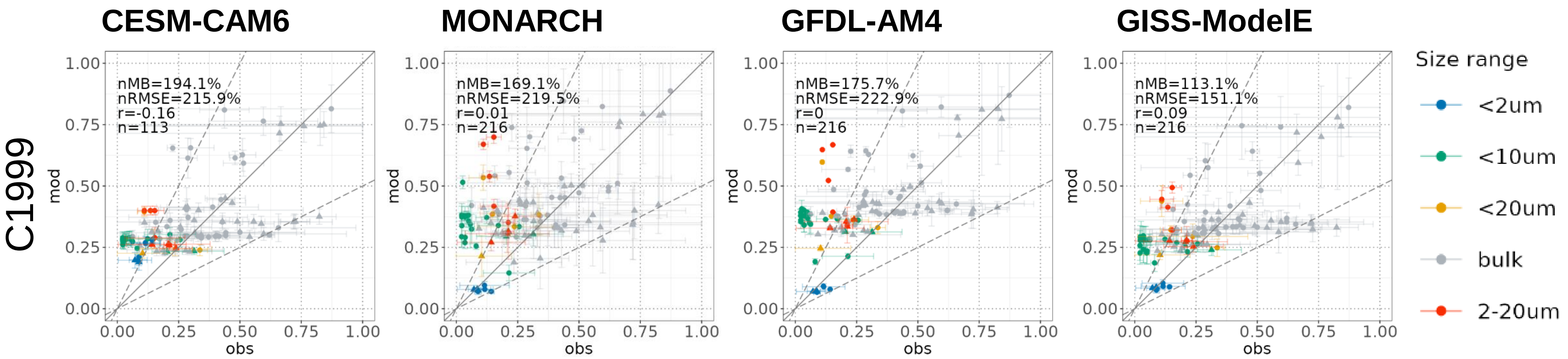


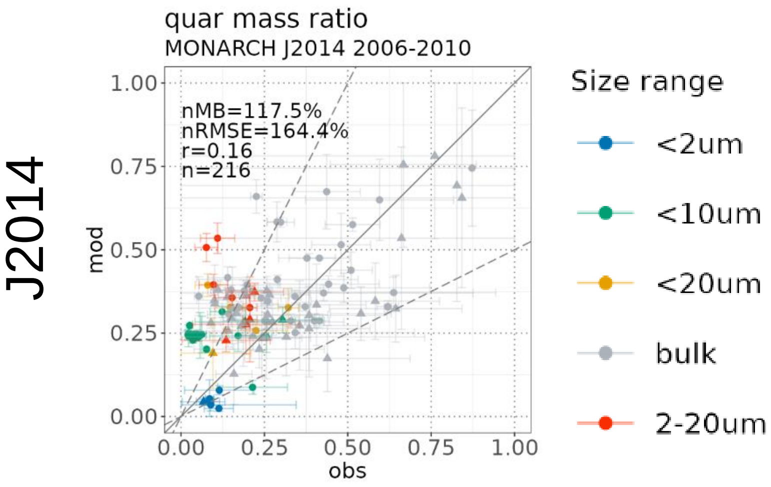
Basic BFT

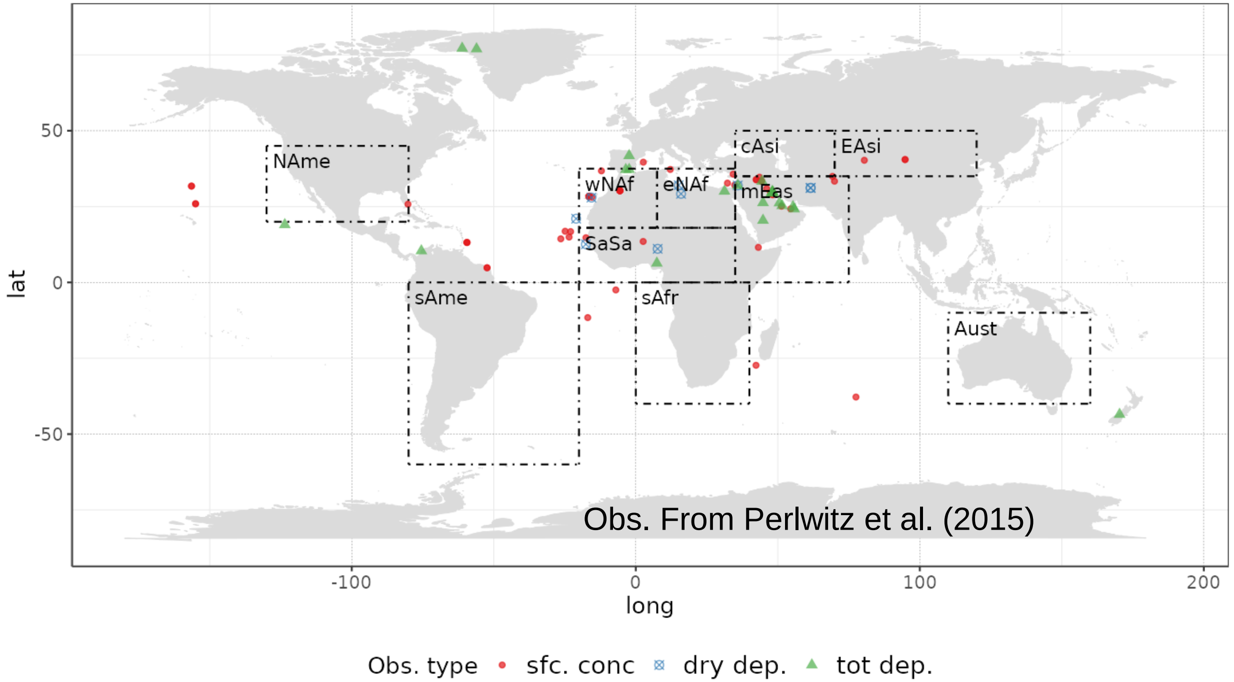
Perlwitz et al., 2015a,b; Pérez García-Pando et al., 2016;

Quartz mass fraction evaluation against in situ data

Multi-annual model experiments







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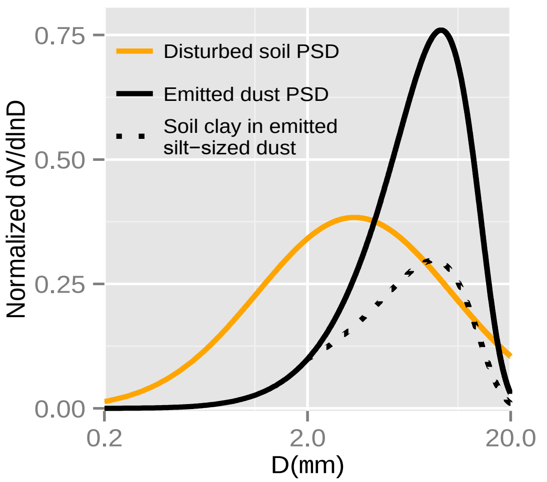
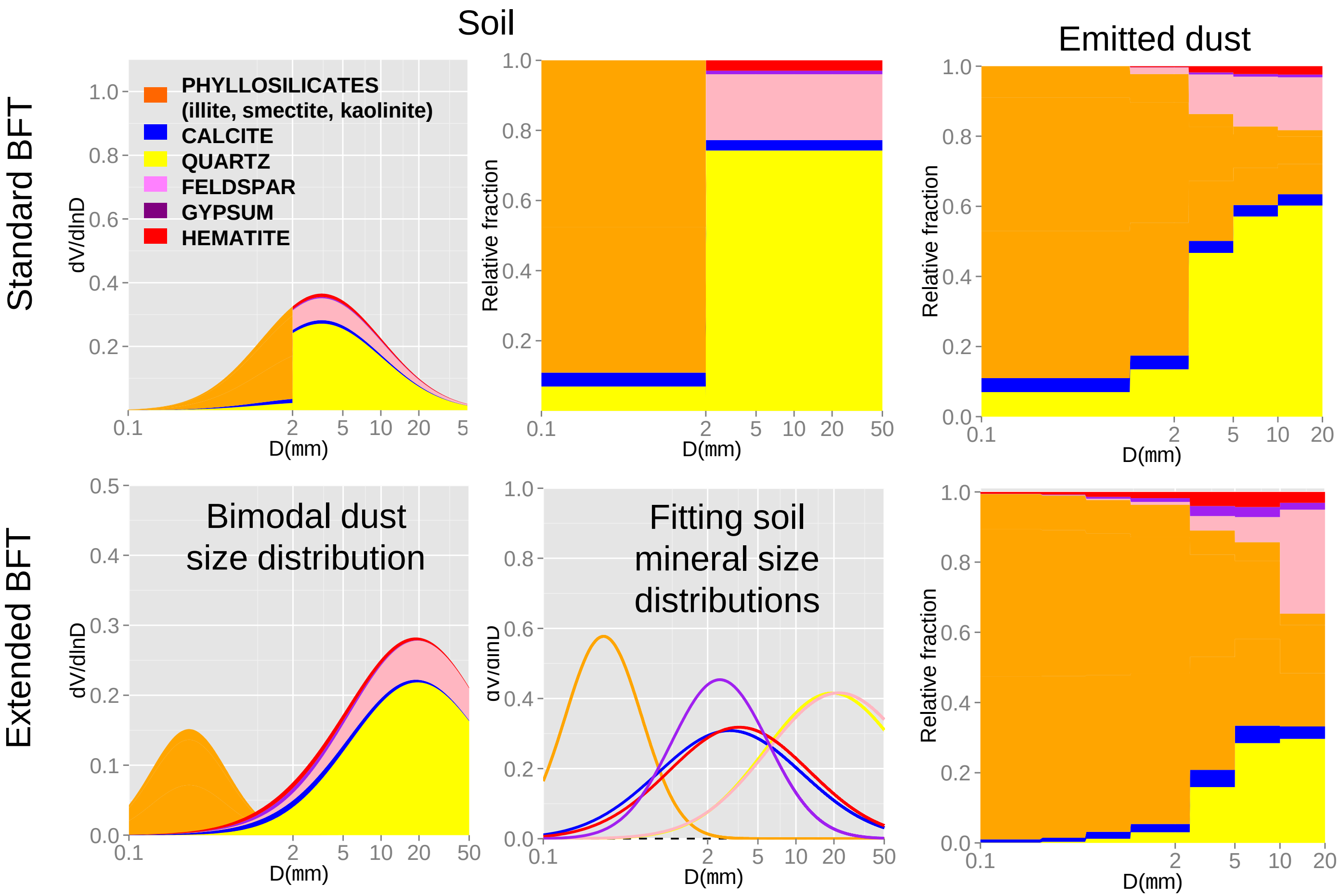
Refining the size-resolved mineral fractions at emission



Brittle Fragmentation Theory (Kok, 2011)



Basic BFT

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

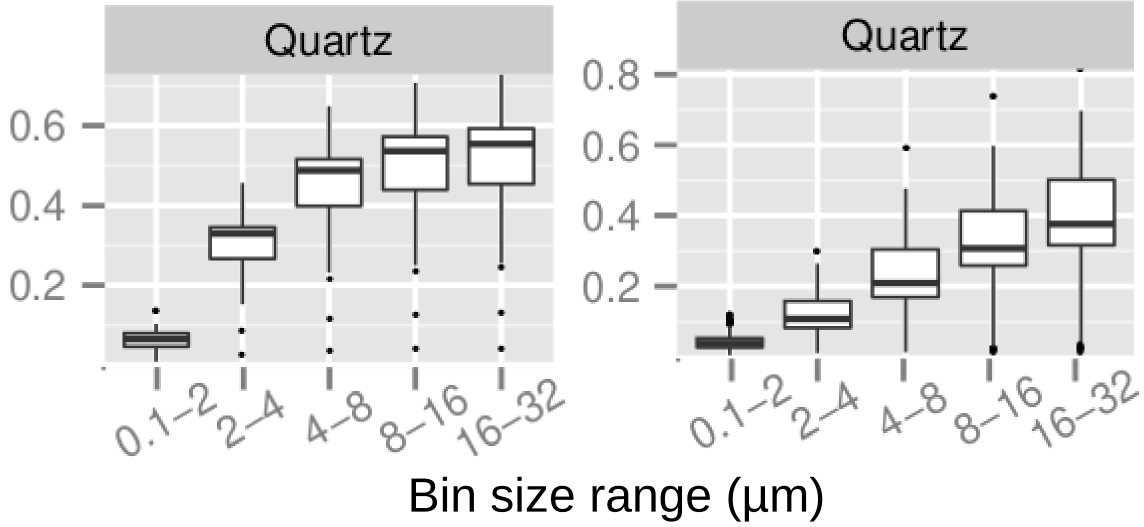
BFT with fitted mineral soil distributions

Pérez García-Pando et al., in prep.

Refining the size-resolved mineral fractions at emission: GISS-ModelE

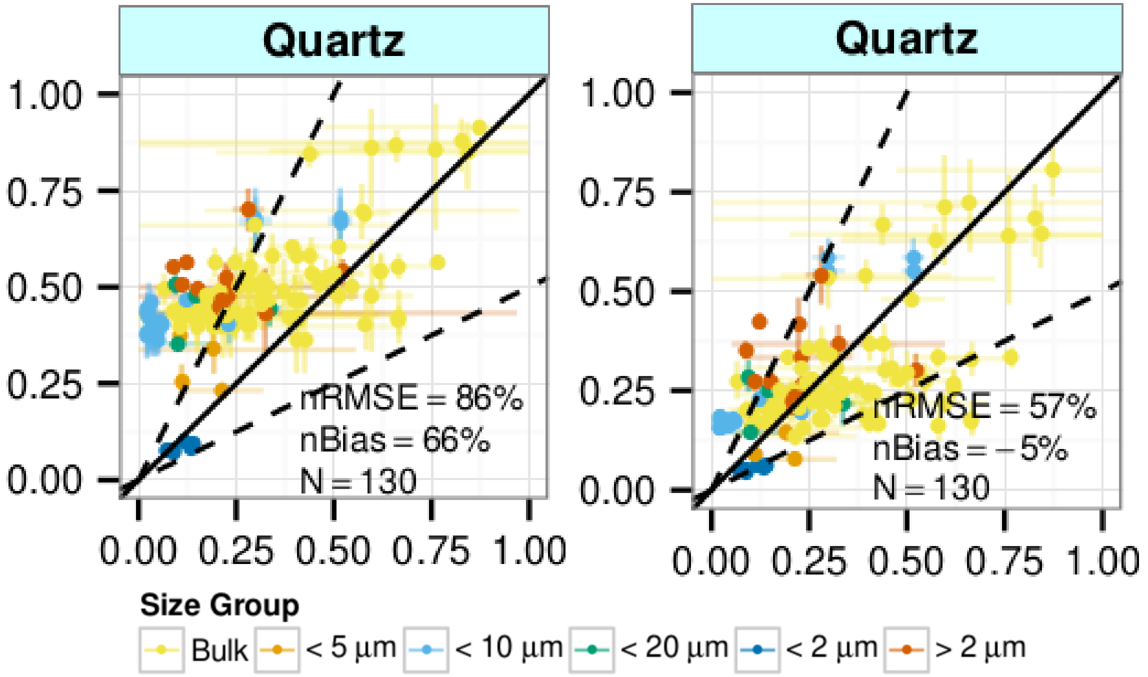
Relative mass mineral fraction per size bin

Basic BFT | **BFT with fitted mineral soil distributions**



Evaluation against in situ measurements

Basic BFT | **BFT with fitted mineral soil distributions**



Pérez García-Pando et al., in prep.

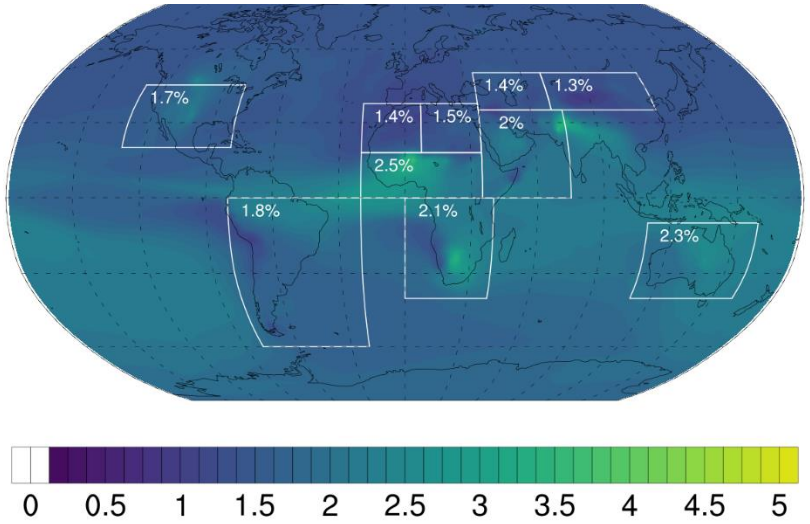
The atmospheric cycle of minerals

Model characteristics

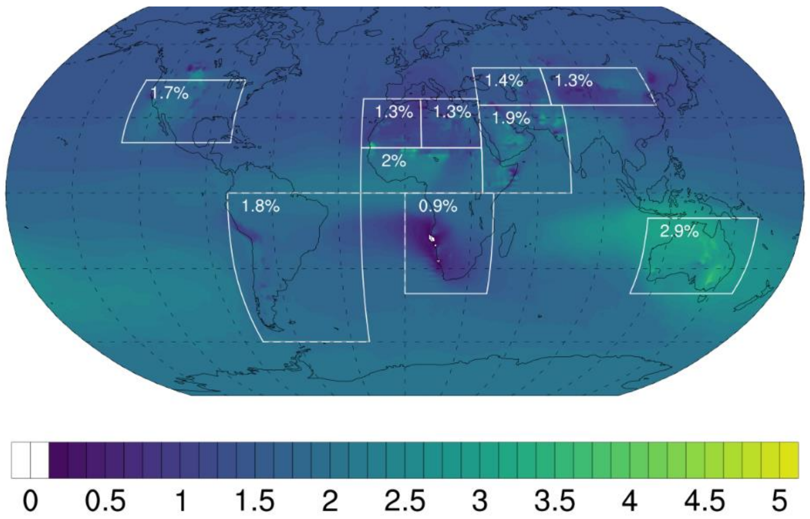
Model	CESM-CAM6	MONARCH	GFDL-AM4	GISS-ModelE
Soil mineralogy	C1999 / EMIT	C1999 / J2014 / EMIT	C1999 / EMIT	C1999 / EMIT
PSD	Modal model 3 modes	Sectional model 8 bins	Sectional model 5 bins	Sectional model 5 bins
Size range (diameter)	10 µm	20 µm	20 µm	32 µm
Emission method	BFT	BFT	BFT	Modified BFT
Mixing state	Internally mixed	Externally mixed Fraction of iron oxides mixed with other minerals	Externally mixed Fraction of iron oxides mixed with other minerals	Externally mixed Fraction of iron oxides mixed with other minerals
References	Scanza et al. (2015), Hamilton et al. (2019), Li et al. (2021; 2024, in review)	Gonçalves Ageitos et al. (in. prep), Klose et al. (2021)	Horowitz et al. (2020), Song et al. (2024, ACP in review)	Obiso et al. (2024, ACP accepted), Perlwitz et al. (2015a,b)

Sensitivity to model vs. soil map information
Iron oxides mass fraction (%w) at surface PM10 concentration

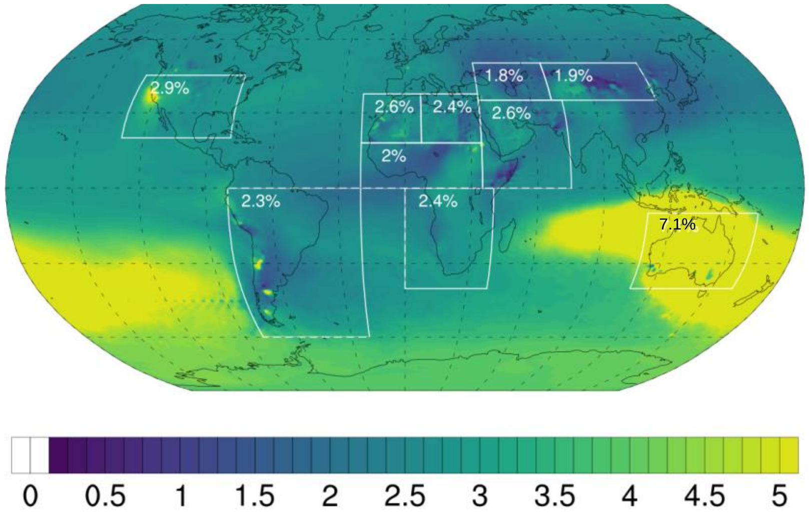
GISS-ModelE **C1999** (1.78%w)



MONARCH **C1999** (1.6%w)



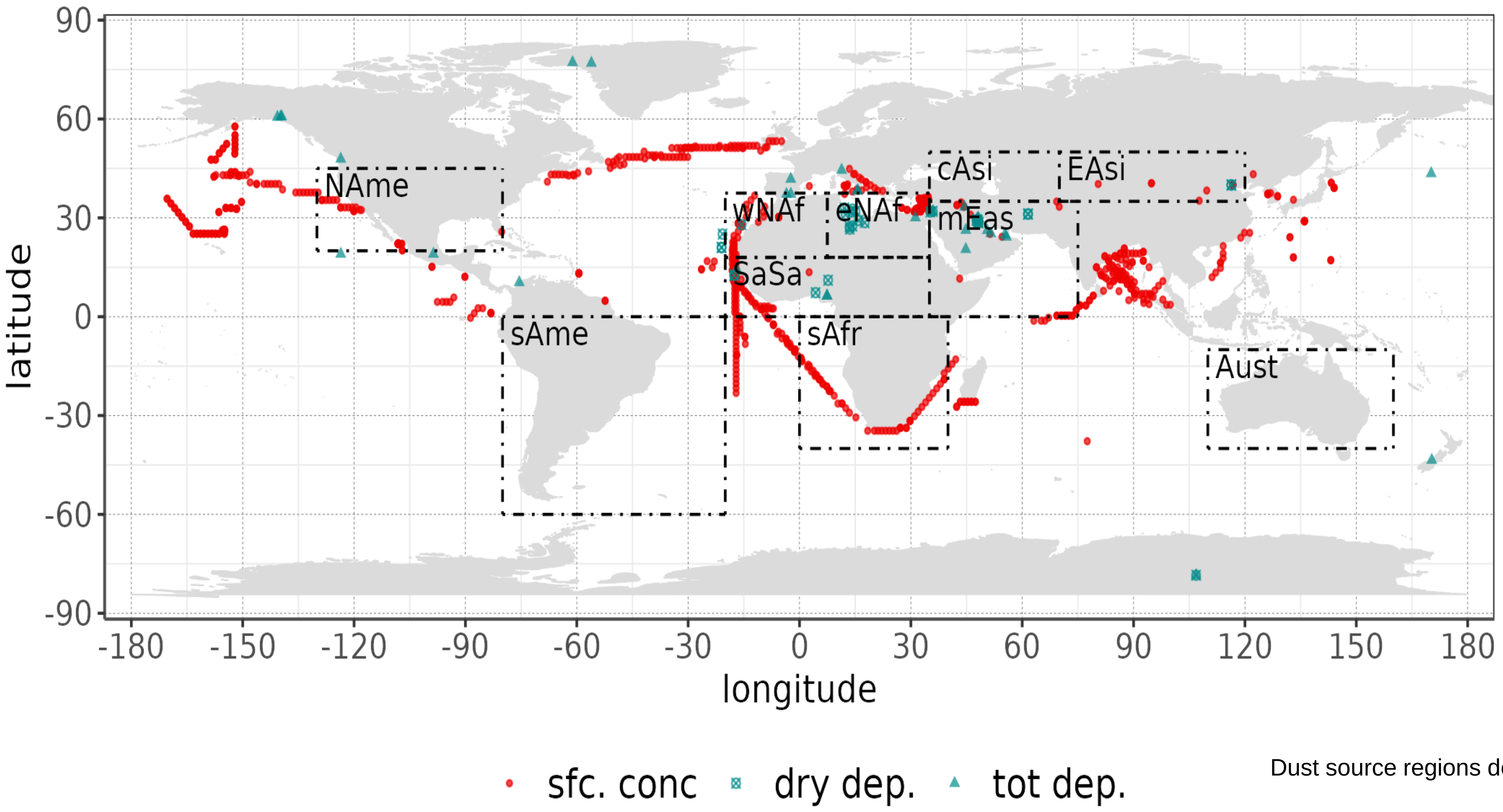
MONARCH **J2014** (2.3%w)



Same soil map, different model

Same model, different soil map

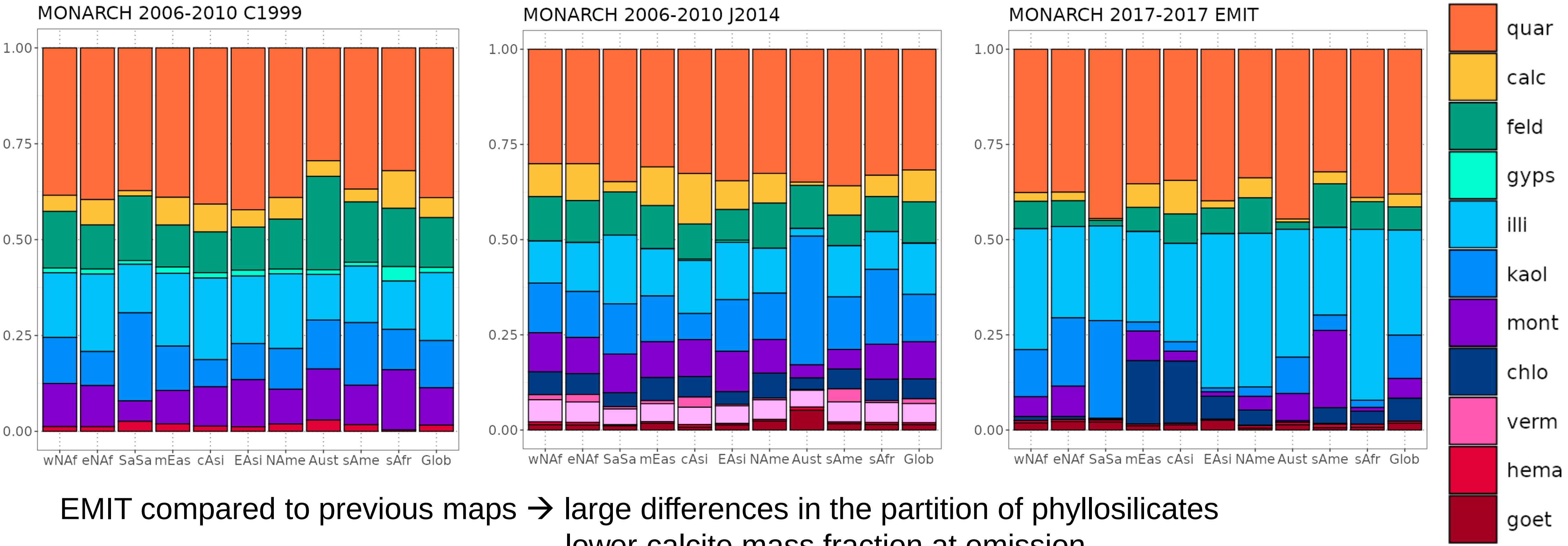
Regions and observations for the analyses



Dust source regions defined in Kok et al. (2021)

Emitted dust mineralogy (mass fractions)
MONARCH with C1999, J2014 and EMIT soil maps

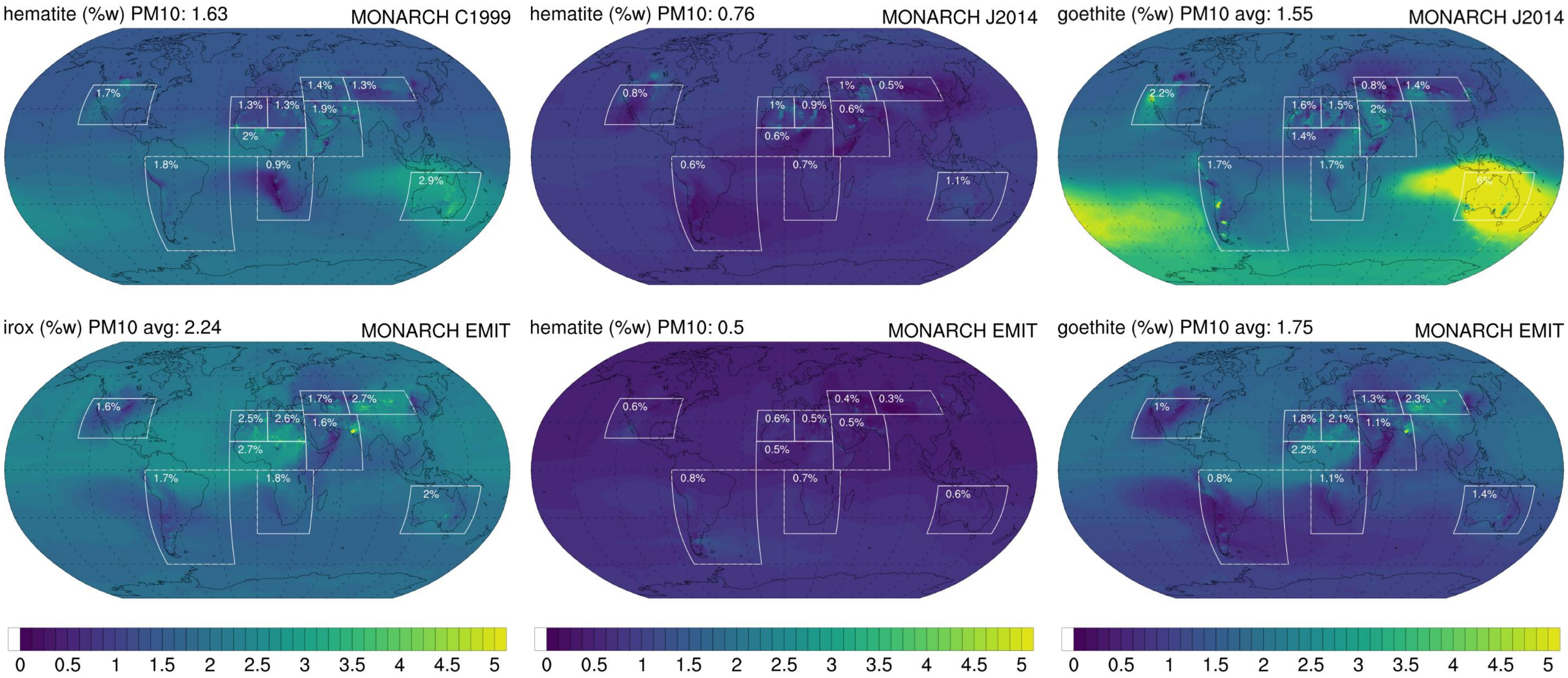
Emitted mass fractions per region and globally depending on the soil map used



EMIT compared to previous maps → large differences in the partition of phyllosilicates
lower calcite mass fraction at emission
larger fraction of goethite than hematite

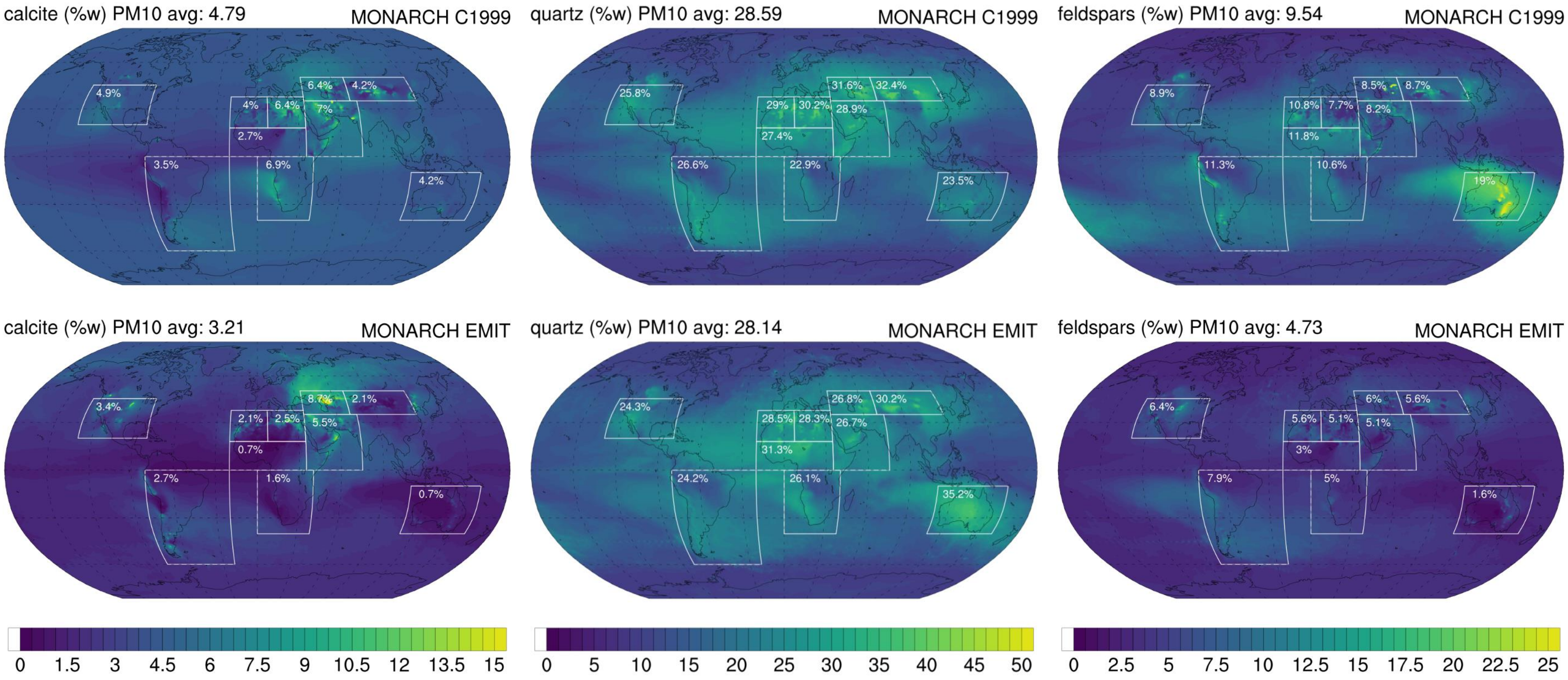
MONARCH: EMIT vs C1999 and J2014

Iron oxides (%w) in surface PM10 concentration



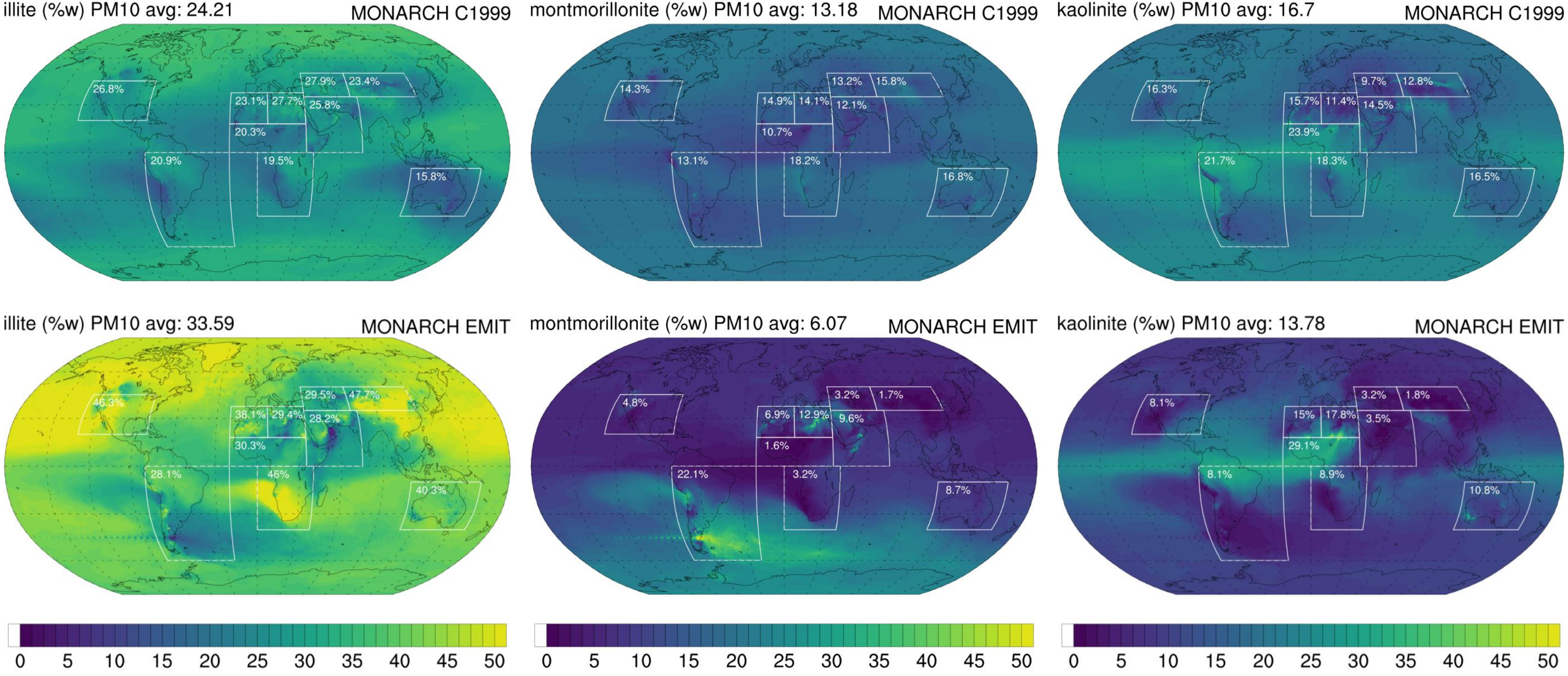
MONARCH: EMIT vs C1999

Calcite, quartz and feldspar (%w) in surface PM10 concentration



MONARCH: EMIT vs C1999

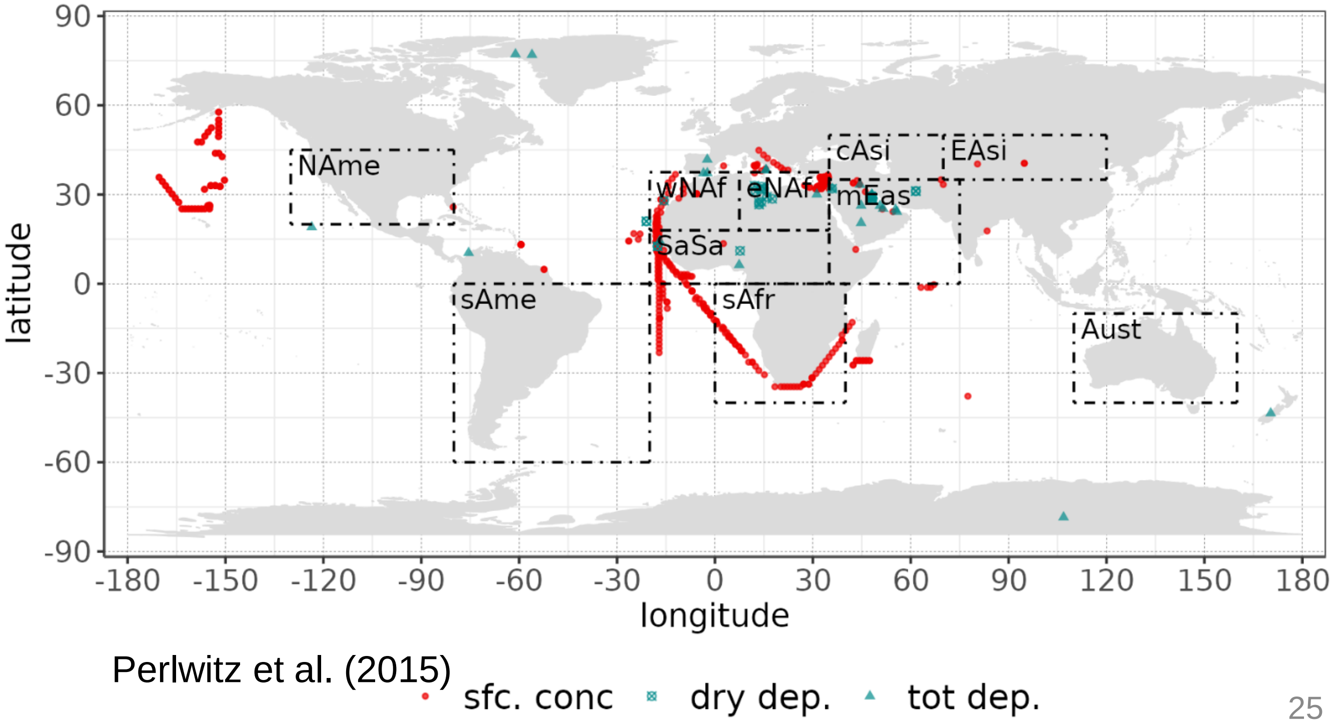
Phyllosilicates (%w) in surface PM10 concentration



Observations of mineral mass fractions

- Obs. from the late 60’s to date.
- Sampling time vs. model average: Temporal collocation – monthly basis
- Reported minerals vs. modelled minerals: Mineral fractions estimated over those minerals observed AND modelled
- Size range of observations vs. modelled size range: Size collocation

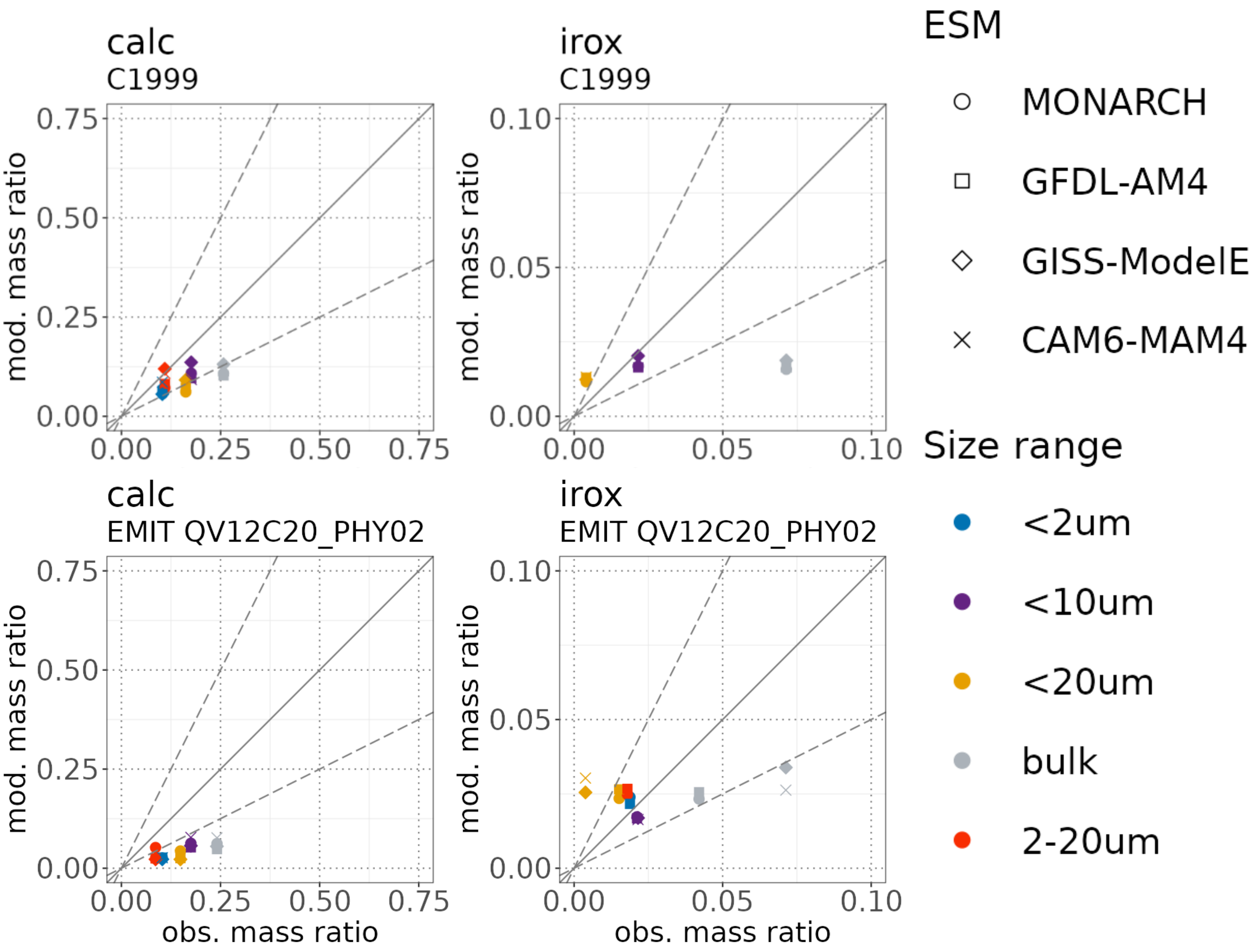
- Filtered for dust locations using model data



Perlwitz et al. (2015)

Evaluation of modelled mineral mass fractions: calcite and iron oxides

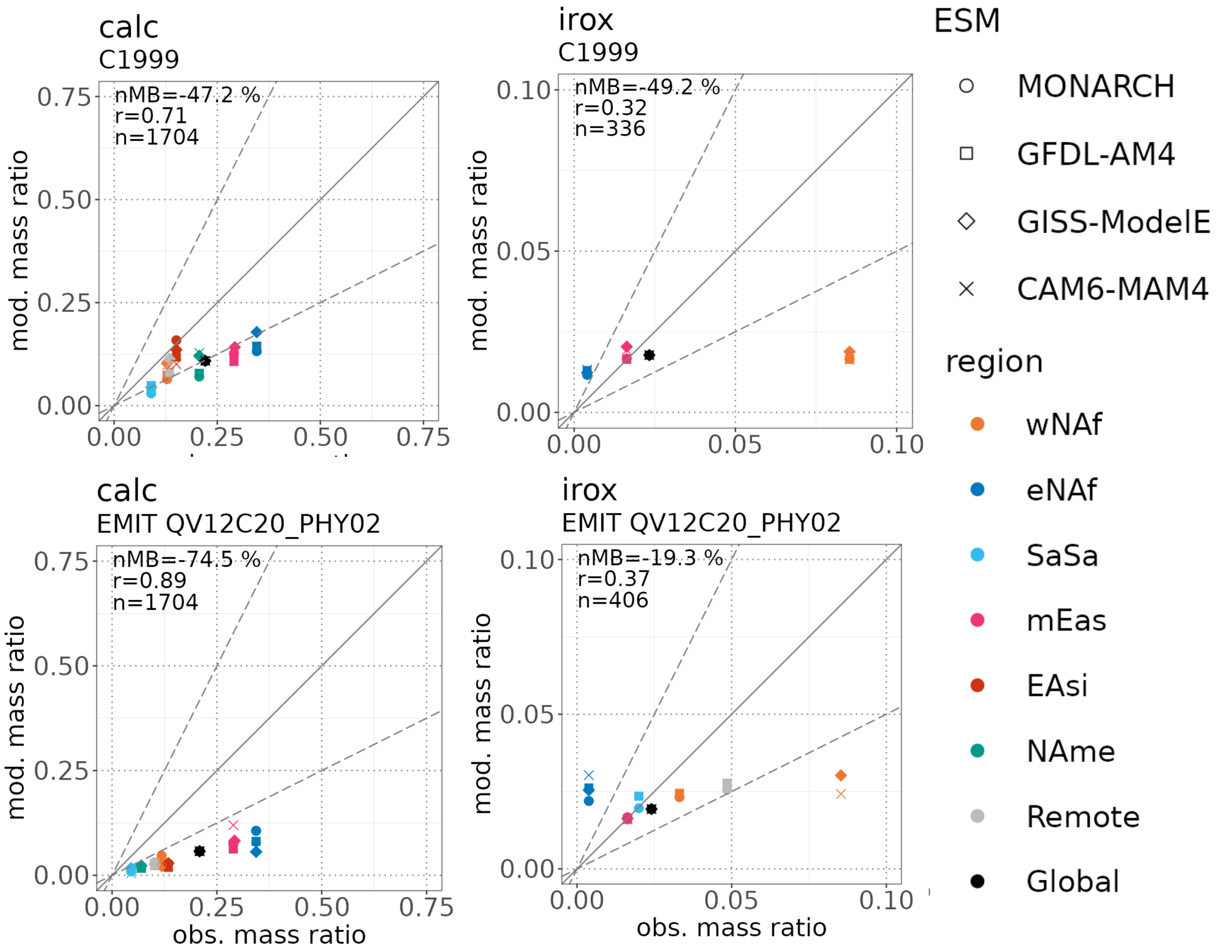
SIZE



- Small differences among models
- Calcite size distribution seems well represented
- Underestimation of observed calcite mass fraction with the EMIT ESM runs
- Few measurements for iron oxides
- EMIT ESM runs represent iron oxides fraction within 2x observed fraction

Evaluation of modelled mineral mass fractions: calcite and iron oxides

REGION

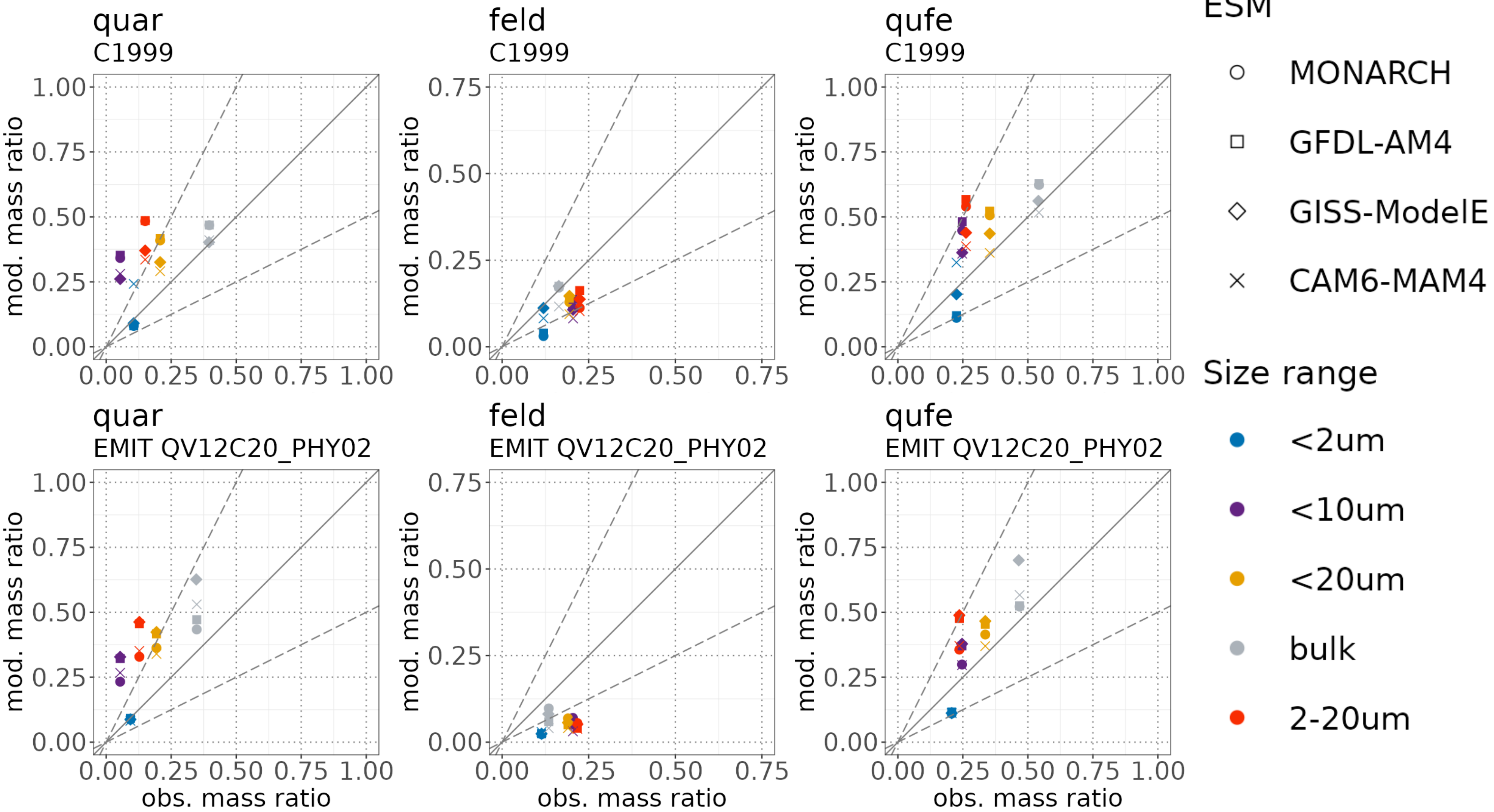


- Improved reproduction of spatial distribution of calcite with EMIT ESM runs compared to C1999

- EMIT ESM runs:
  - Iron oxides overestimation in eNAfr and underestimation in eNAfr.
  - Nicely match SaSa iron oxide levels

Evaluation of modelled mineral mass fractions: quartz and feldspar

SIZE

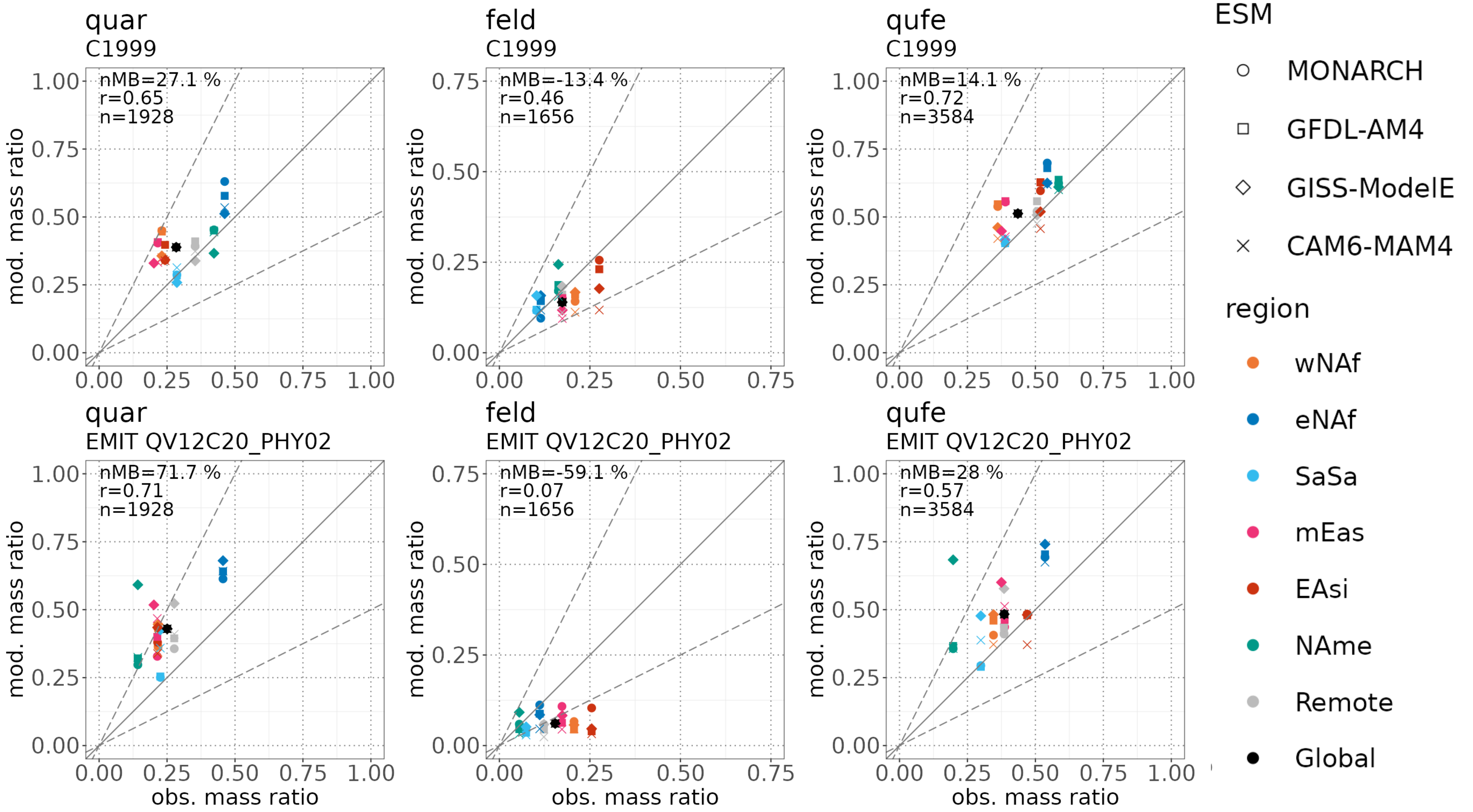


- Quartz overestimation in silt sizes
- Future work on emitted PSD

- More balanced in EMIT when we consider Q+F

Evaluation of modelled mineral mass fractions: quartz and feldspar

REGION

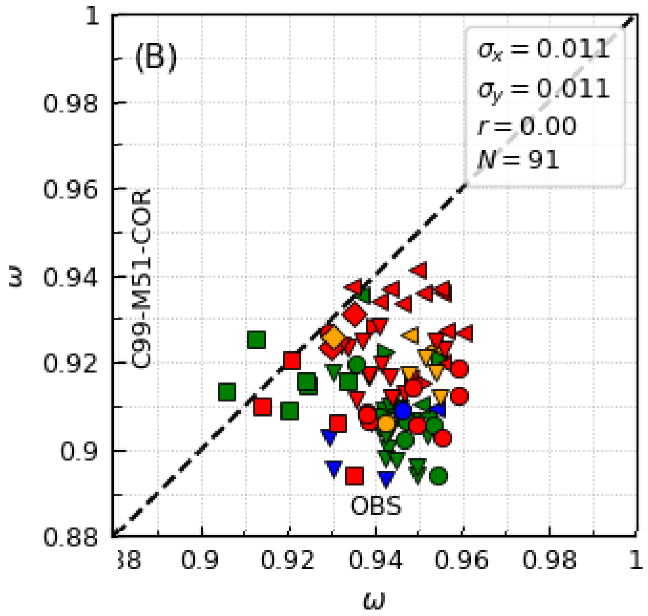


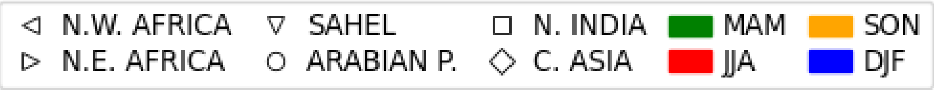
- Q+F are not directly retrieved by EMIT, but inferred.
- Overall, the C1999 and EMIT runs perform similarly against observations.

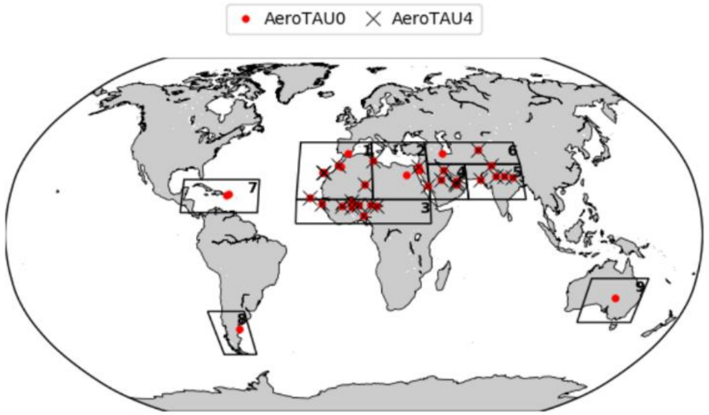
Dust single scattering albedo

Optical properties
Evaluation with AERONET SSA vis. filtered for dust events

MONARCH C1999

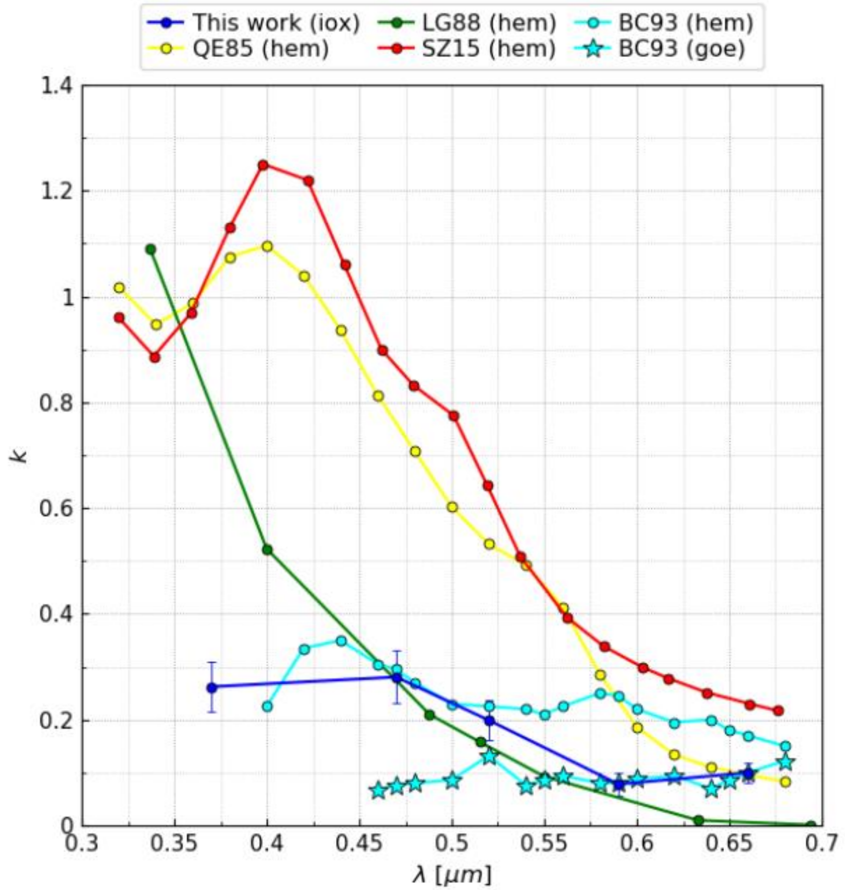






AERONETv3 Almucantar lev 2.0. Dust filters:

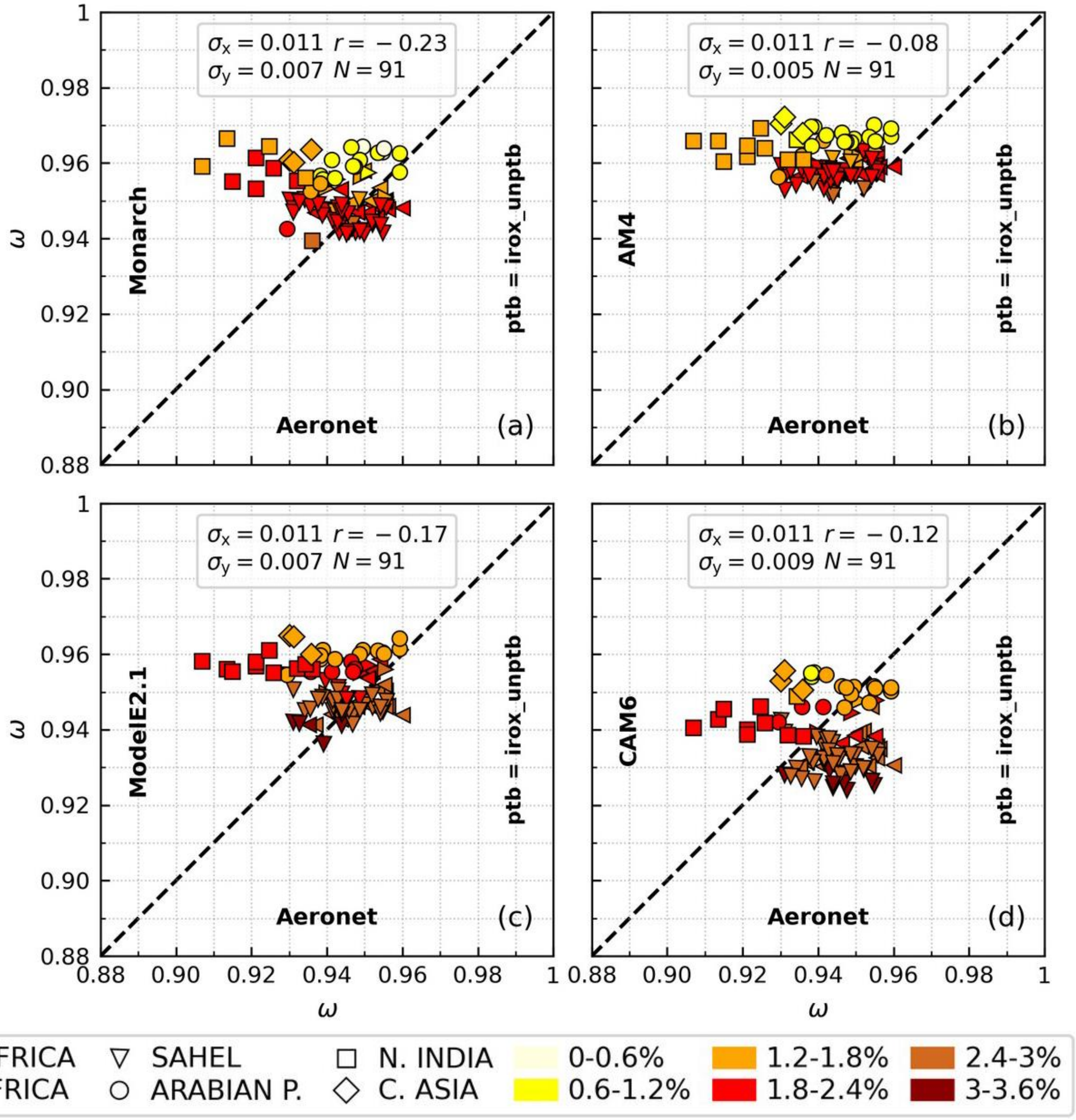
- Fine volume fraction lower than 0.1
- Sea salt filtered following Dubovik et al. (2002)
- BrC and BC filtered following Schuster et al. (2016)
- 2000-2020 monthly means produced only when at least 80 points are available



Obiso et al. 2023; egusphere 2023-1166
(accepted for publication in ACP)

Dust SSA (vis)
Offline estimates

- Calculated as a function of the iron oxides content in each model
  - Internal mixtures of iron oxides with host minerals: imaginary index from empirical relationships from Di Biagio et al. (2019).
  - Hematite + goethite in MONARCH and AM4
  - Iron oxides in ModelE and CAM6

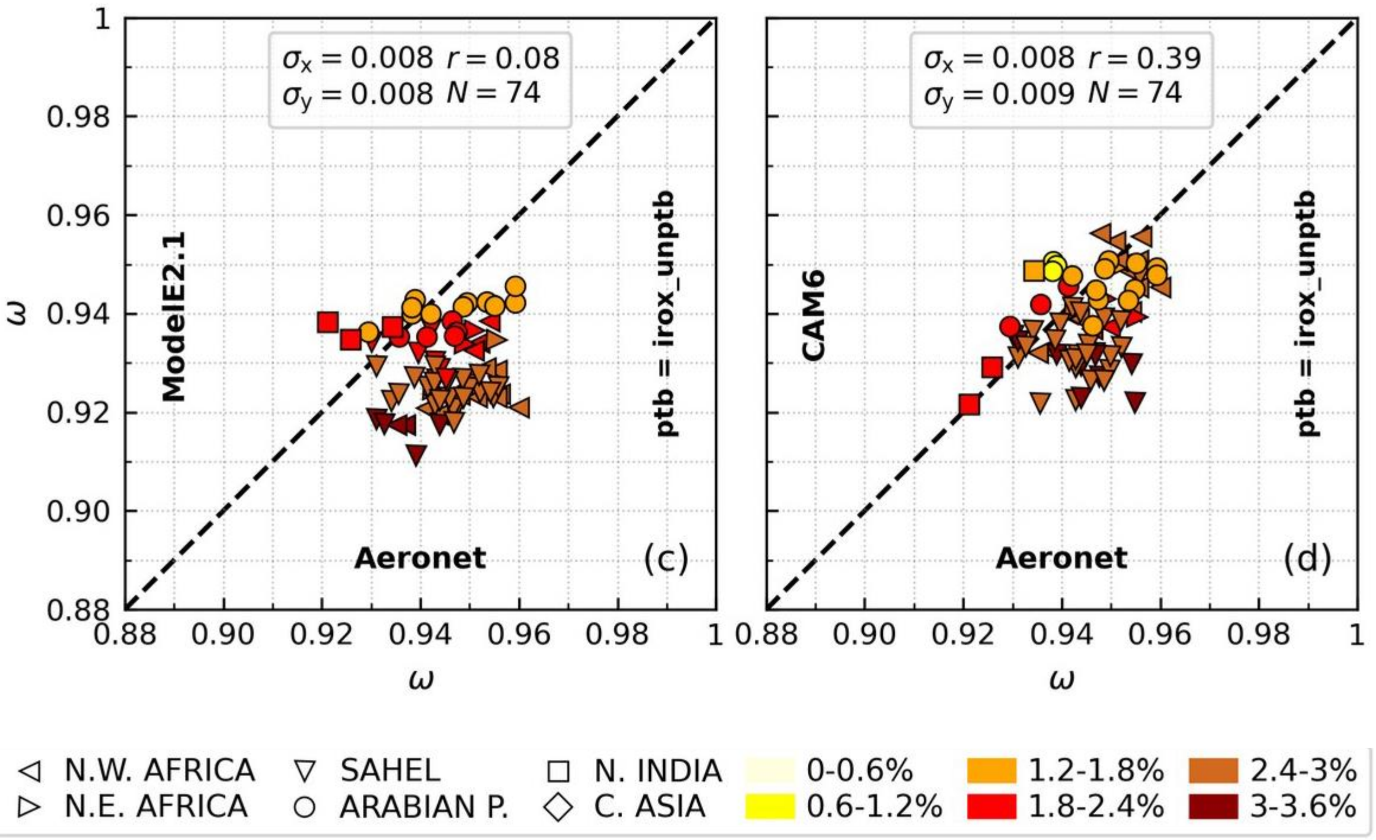


Monthly mean dust SSA in the visible band (400-700 nm) against AERONET filtered data.
Color levels represent the abundance of goethite as defined by MONARCH and AM4, and iron oxides as defined by GISS ModelE and CAM6.

Contact: vincenzo.obiso@bsc.es

Dust SSA (vis. band)
Calculated online by ESMs

- ModelE represents dust SSA, including 3 different species for minerals:
  - host minerals.
  - internal mixture between host minerals and iron oxides (5% by mass).
  - externally mixed iron oxides.
- CAM6 derives dust SSA from that of all aerosols, including anthropogenic and other natural aerosol species. A filter is applied to select dust-dominated points.



Colour levels represent the abundance of iron oxides.

Contact: vincenzo.obiso@bsc.es

Conclusions

- Soil mineralogy and size distribution at emission are key to represent the atmospheric cycle of minerals in Earth System Models.
- EMIT brings in additional constraints to the soil mineralogy at the global scale.
- The first analyses on EMIT ESM experiments show increased spatial correlation with mineral mass fractions for calcite and iron oxides with respect to baseline maps.
- Insight on partition between goethite and hematite and their geographical distribution, with a relevant impact in SSA.
- Ongoing work:
  - Continued evaluation of mineralogy, elemental composition, dust SSA.
  - Long-term experiments to derive dust Effective Radiative Forcing.
  - Refinement of EMIT base maps.

Thank you !

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STAY TUNED FOR EMIT UPDATES!

Open positions at BSC:

Post-doc on dust mineralogy and ocean biogeochemistry

Other positions at the ES Department

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