CERTAINTY
CLOUD-AEROSOL INTERACTIONS
& THEIR IMPACTS IN THE EARTH SYSTEM

FOCI

EC EARTH

Linking Dust Mineralogy and Ice Nucleation in Mixed-Phase Clouds into EC-Earth4

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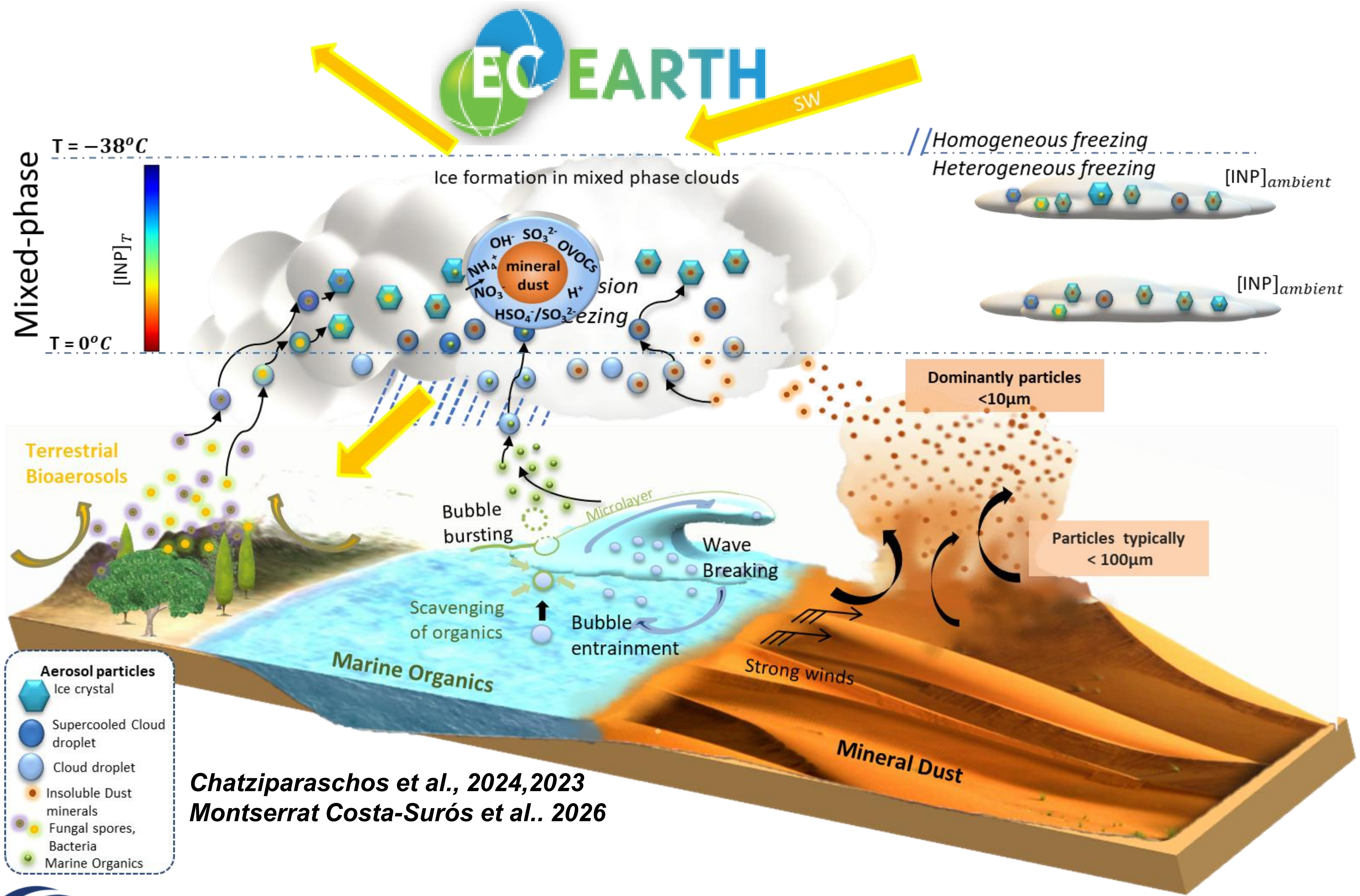
Room F2,*07-05-2026*

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Funded by the European Union

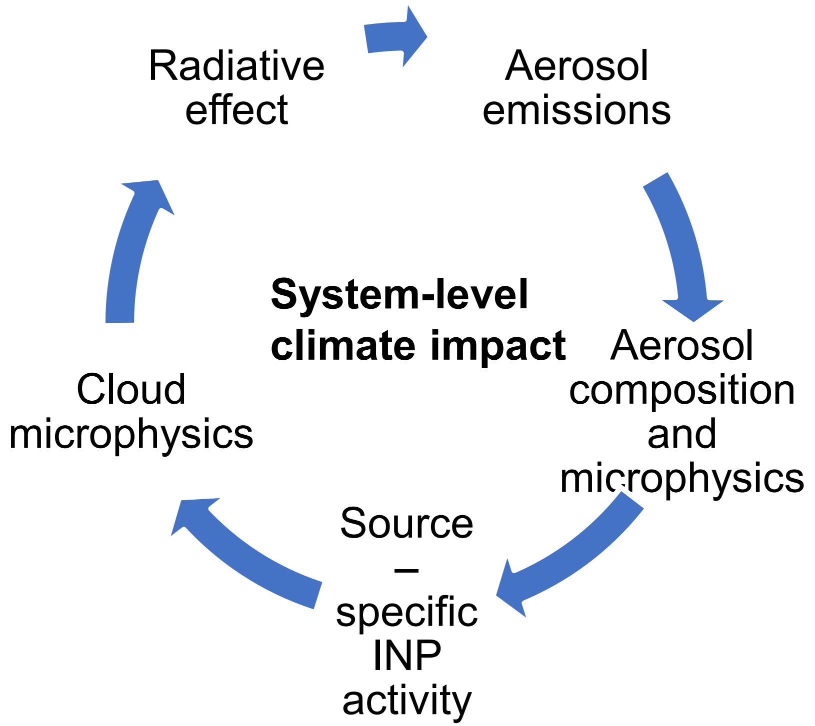
This project has received funding from Horizon Europe programme under Grant Agreement No 101137680 via project CERTAINTY (Cloud-aERosol inTeractions & their impActs IN The earth sYstem).

Objective: Improve the representation of **mixed-phase clouds** by explicitly linking dust mineralogy [and bioaerosols] with PIN , enhancing the model's sensitivity to present and future changes in aerosol sources.



Chatziparaschos et al., 2024,2023
Montserrat Costa-Surós et al.. 2026

Road map of model developments on **aerosol–cloud interactions:**



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CERTAINTY: Constrain mineral dust, marine organics and Bio-aerosols as Primary ice-nucleating particles and SIP in MPC **FOCI**: Mineral dust evaluation against observations.

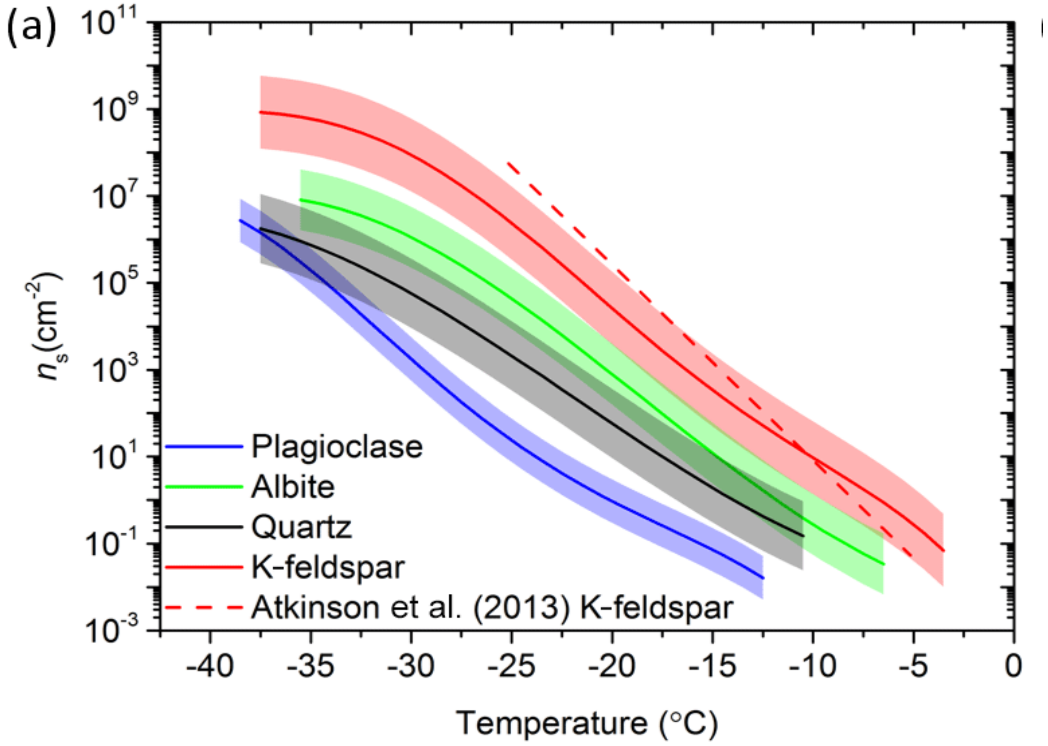
Why mineral dust?
Mineral is the main precursor of primary ice nucleation process in MPC

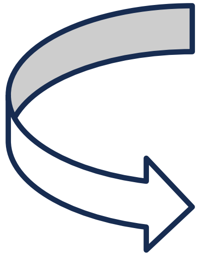
•Dominant source of **primary ice-nucleating particles (INPs)** in mixed-phase clouds (MPCs) *(DeMott et al. 2010)*

•Controls the onset of **heterogeneous ice nucleation** *(Murray et al. 2012)*

•Strongly depends on **mineral composition** (Kiselev et al. 2017)

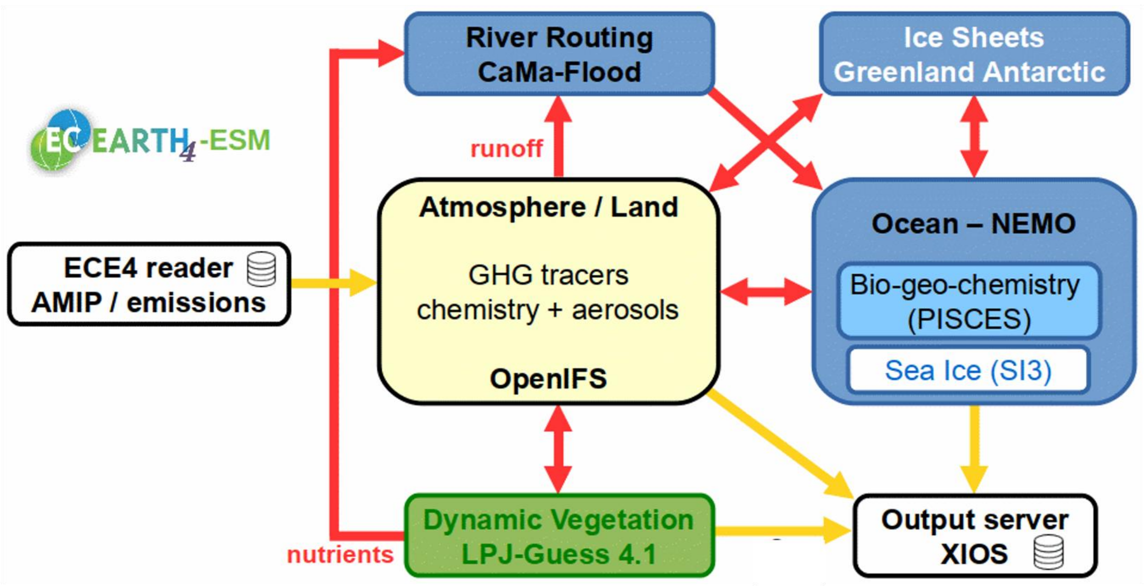
•**Feldspars and quartz** are particularly efficient INPs (*Harrison et al. 2019)*





Need of:
climate-sensitive representation of dust emissions and mineralogy

Methodology: Earth System Model EC-Earth4



Atmosphere

Setup:

- Interactive **aerosol scheme** : **M7 aerosol microphysics** with prescribed oxidant fields
- **Tegen Dust emission** scheme traced in 4 modes (acc./coa. & sol./insol.)
- **Explicit mineralogy** of dust minerals
- Vertical levels: 91
- Horizontal resolution: 255 lat x 512 lon. (~0.7º)
- Time step: 2700s
- Model output: 3h

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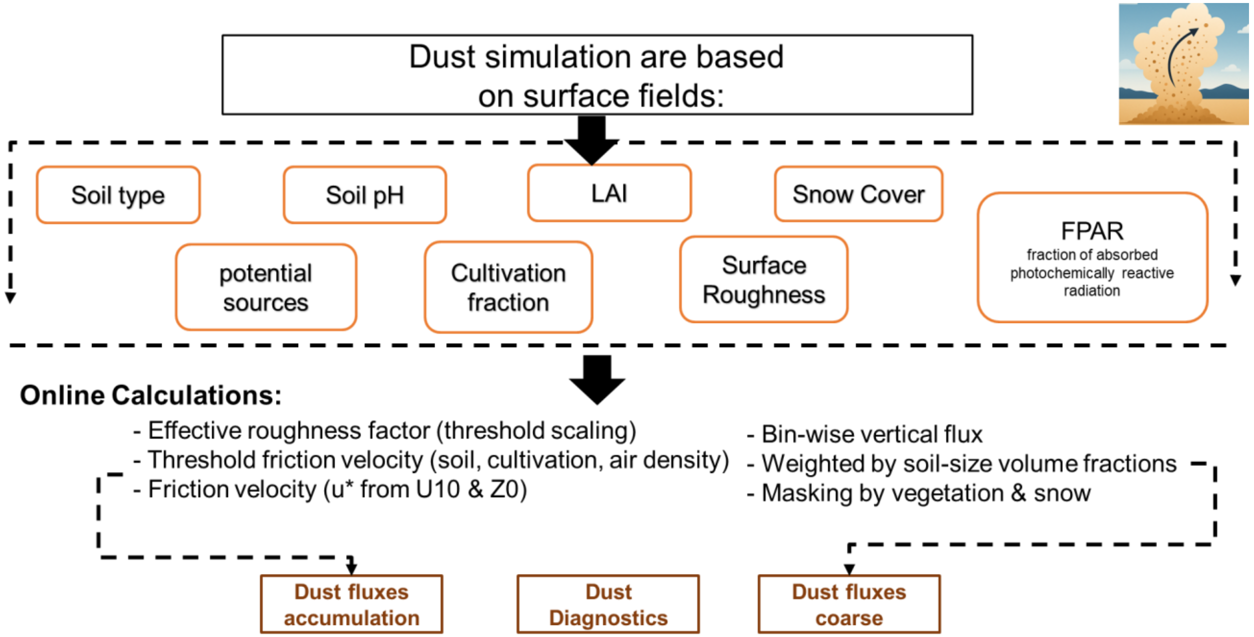
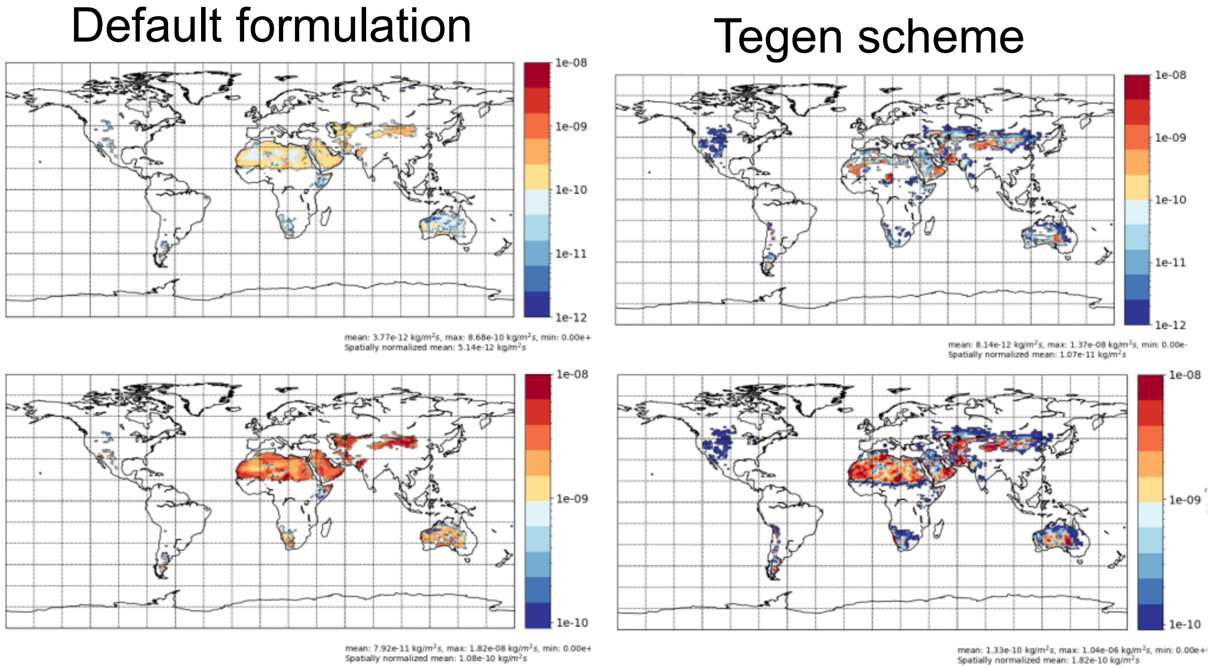
1. **Methodology:** Dust emission scheme

Mineral dust:

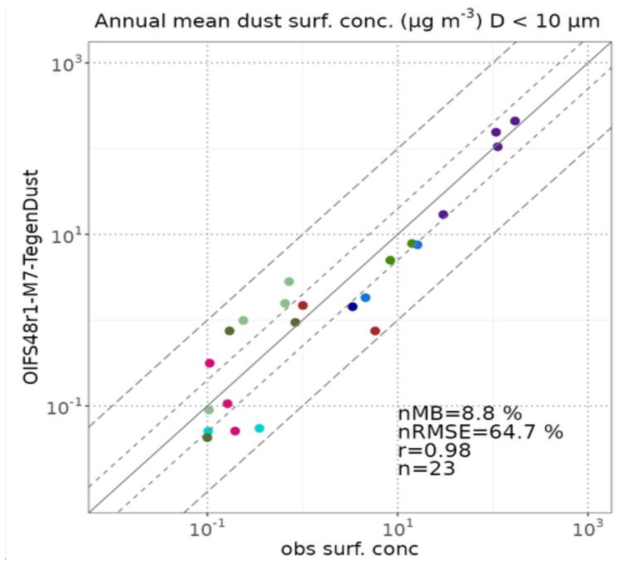
- Tegen et al. (2002, 2004)



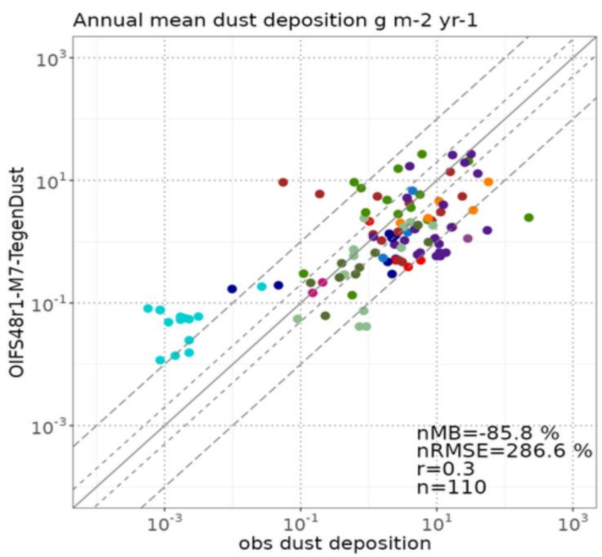


Aiming at a more climate-sensitive representation of emissions

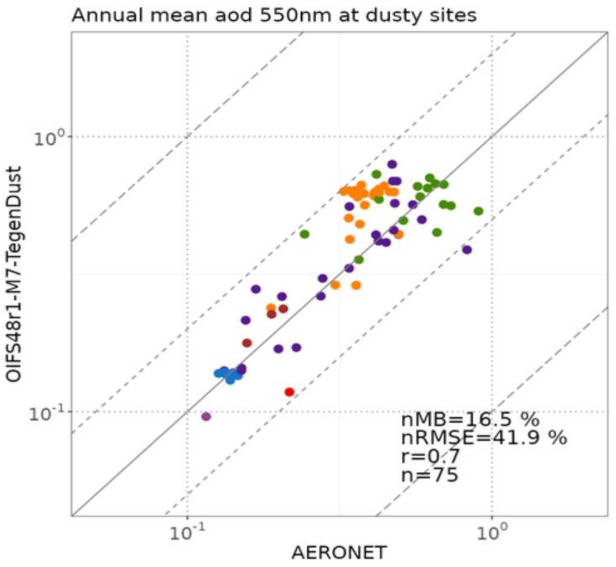
1. **Results:** Evaluation



Surface dust concentrations: Compared with **AMMA**[1] *(Marticorena et al., 2010) and* with **RSMAS**[2] datasets *(Prospero, 1996, 1999)*.



Dust deposition fluxes: Compared with the global observational compilation *(Albani et al., 2014)*.



Aerosol Optical Depth (AOD): Compared with **AERONET** observations.

CMIP7 FT:

- New homogeneous dust emission scheme [DONE]
- Merge request has been done ECE4[DONE]
- Recalibration through the tuning stage

[1]African Aerosol Multidisciplinary Analysis
[2]Rosenstiel School of Marine and Atmospheric Science

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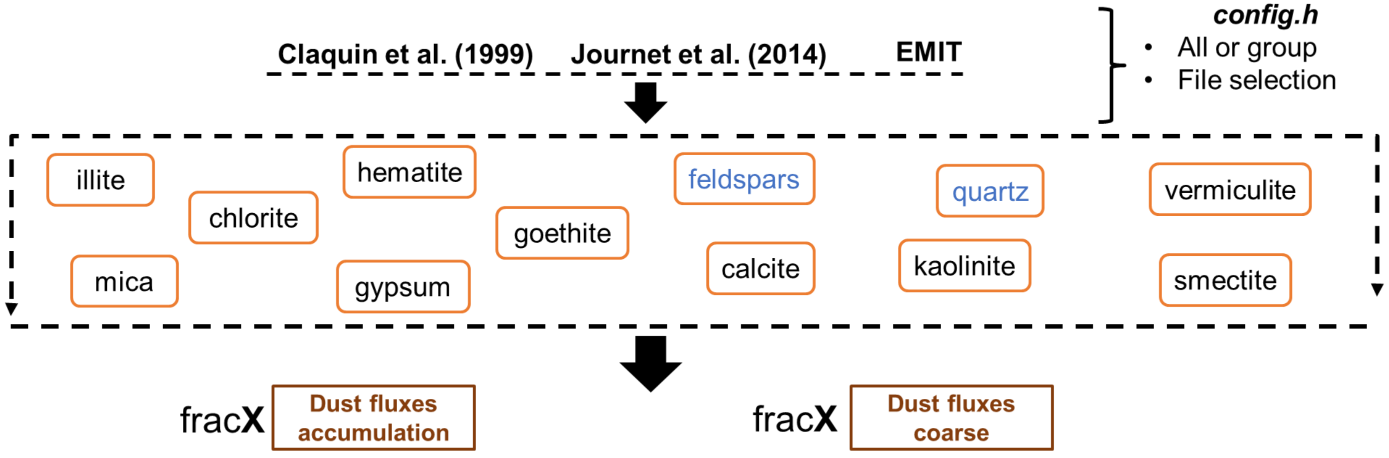
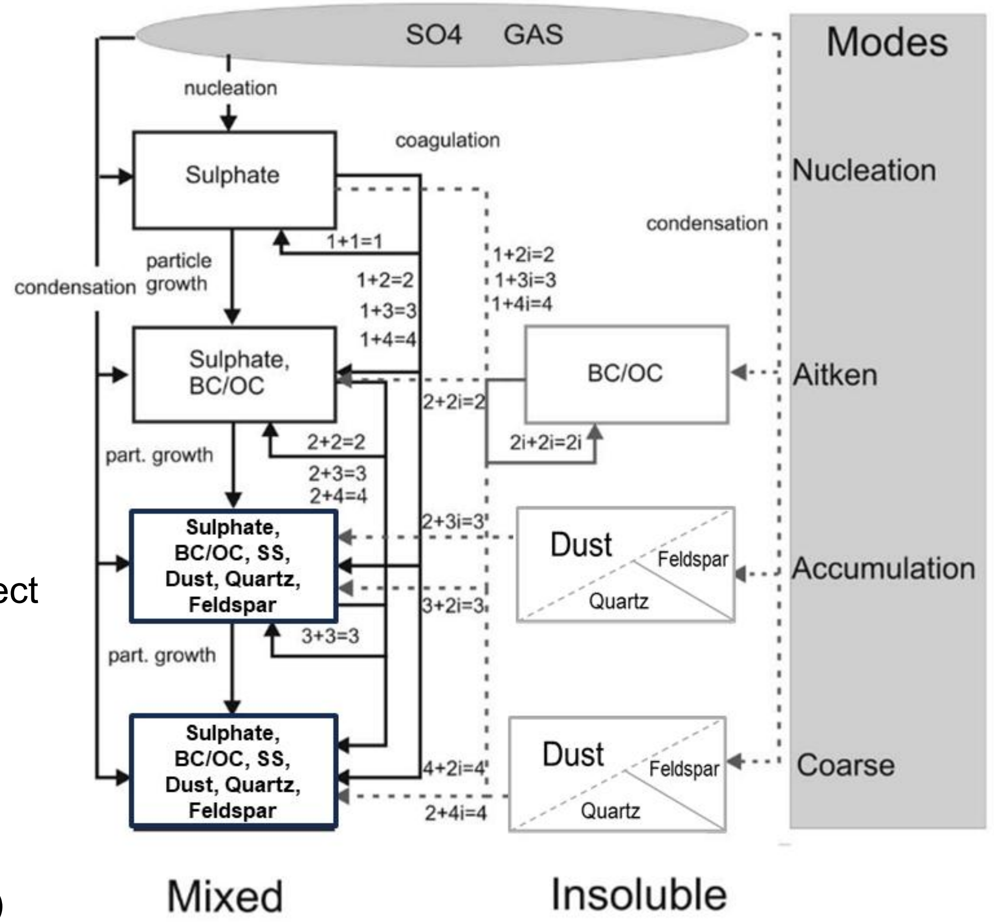
2. Methodology: Dust mineralogy and aging scheme



- **Minerals fractions** are precalculated based on **state-of-the-art mineralogical datasets** from Claquin et al. (1999), Journet et al. (2014), or the EMIT NASA project and accounting for the emitted PSD by Kok et al. 2011.

- **The emissions of individual minerals** are calculated by multiplying the mineral fraction in the soil by dust fluxes in **accumulation** and **coarse** modes

- **Ageing** of dust minerals (coagulation, condensation, particle growth) and **transportation** is treated analogously as **internally mixed dust** (represented by **M7**)



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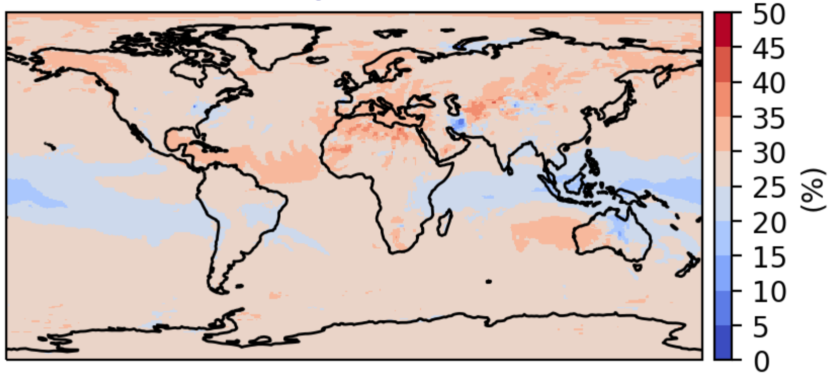
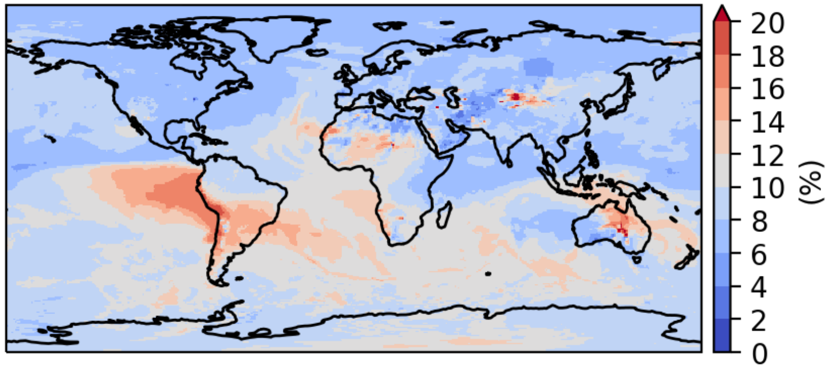
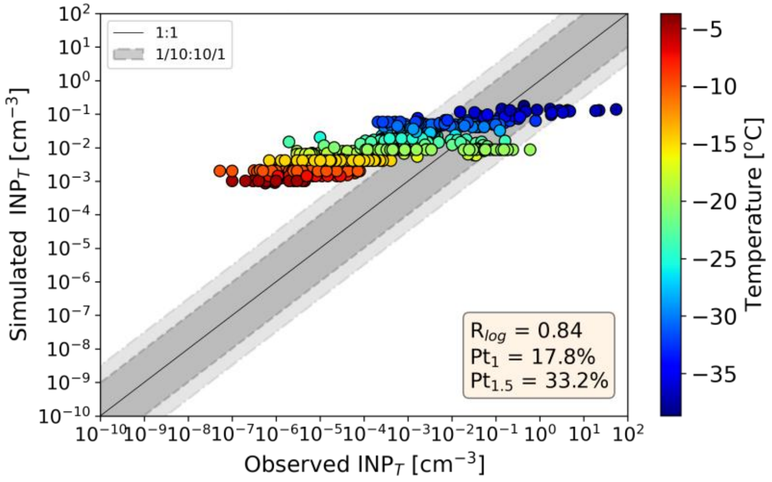
2. Results: dust minerals in the atmosphere and offline INP evaluation

Mineral fractions in surface concentration using Claquin et al. (1999)

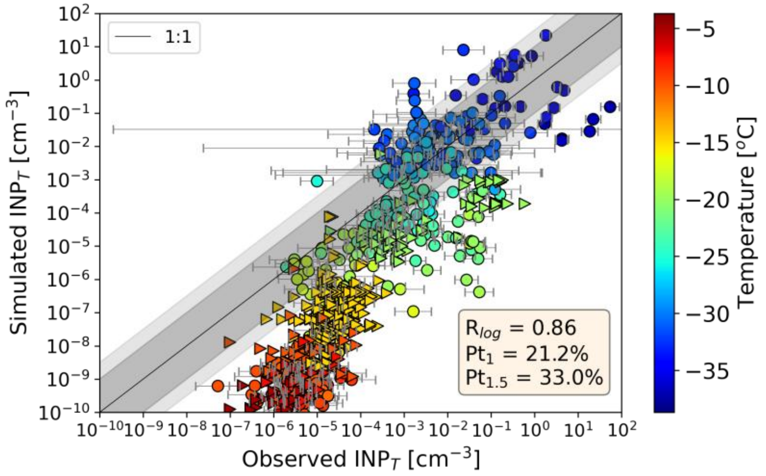




Meyers et al. (1992)



Harrison et al. (2019)



- **Mineral dust–derived INPs** show **better correlation** with observations at **colder temperatures**.
- A **significant underestimation** occurs at **warmer temperatures** (< −20 °C).
  This likely reflects **missing INP** sources in the model, such as primary marine and terrestrial **bioaerosols**.

Global INP observations from the **BACCHUS database**, including **Arctic, Southern Ocean, and multi-ocean ship-based measurements** (Wex et al., 2019; McCluskey et al., 2018a; Tatzelt et al., 2020; Welti et al., 2020).

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Next Steps

1. New Aerosol Implementation	• **Primary marine organic aerosols** • **Primary terrestrial bio-aerosol** (Bacteria, Fungal Spores and Pollen)
2. Ice Nucleation scheme	• Intergrade online calculation of PIN by testing advanced **aerosol-dependent parameterizations** • Constrain mineral dust and Bio-aerosols as PIN along with SIP in MPC see: *Montserrat Costa Surós [The Role of Secondary Ice Production in Shaping Mixed- Phase Clouds in EC-Earth4]*
3. Climate Impact Assessment	• Assess the long-term climate impacts of these developments, **CMIP7 FT**
3. Model Integration	• Integrate developments into EC-Earth4

Towards a more realistic representation of aerosols –cloud interactions and their impact in **climate**

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Special acknowledgement:
EC-Earth Atmospheric
Composition Working Group

Thank you

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Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management

FMI

ECMWF

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