Mineral Dust Interactions with Earth's Climate Systems in ESM4

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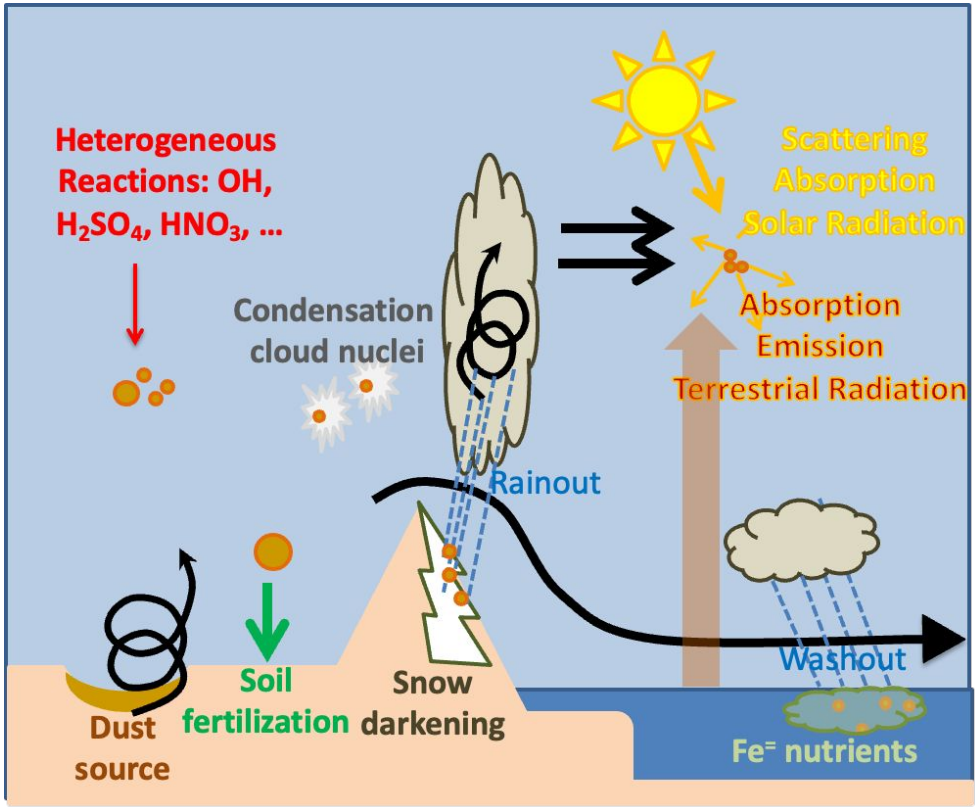
Q2: Concerning NOAA's key mission element of understanding, predicting, and projecting changes in the Earth System, how can GFDL drive further advances in these areas, including extremes and environmental hazards, through scientific innovation based on observations, theory, and modeling? Where are the strengths, gaps, and new frontiers?

Dust Interactions with Earth's Climate Systems (Atmosphere, Land, Ocean, Cryosphere)



1. **Radiation**:
Absorbing and scattering solar shortwave and terrestrial longwave radiations

2. **Cloud properties:**
brightness and lifetime, ICN and CCN

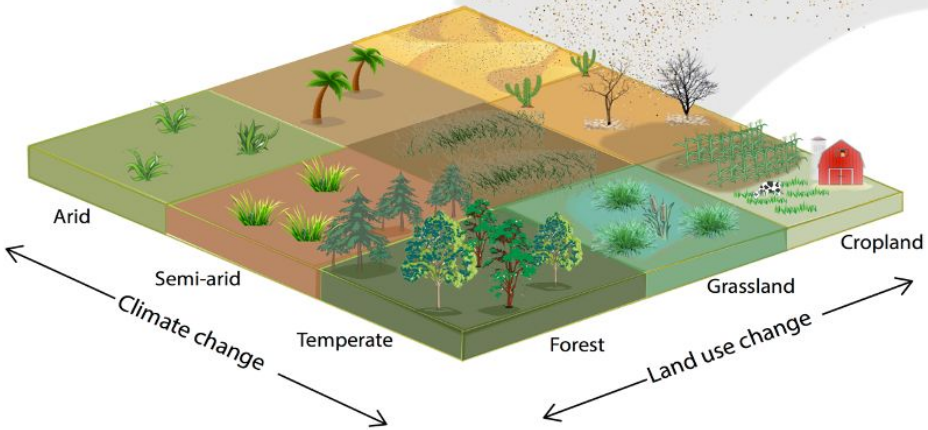
3. **Snow darkening**

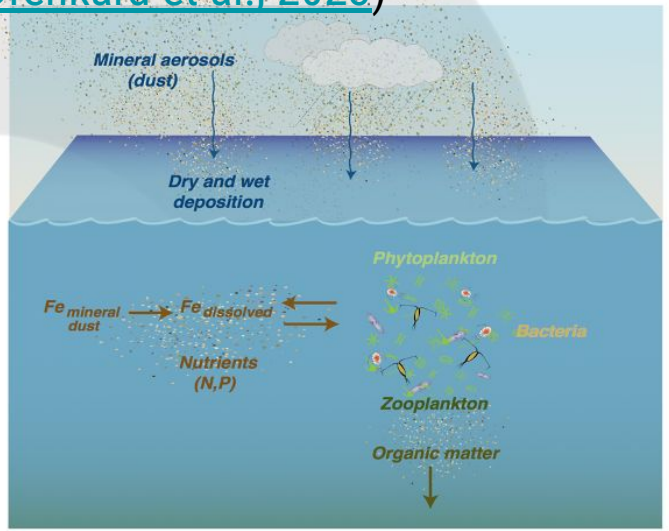
4. **Tropospheric chemistry:**
heterogeneous reactions on surfaces

5. **Source of nutrients** for land and oceanic biosphere

Dust Lifecycle in GFDL ESM4

- Dust emission and deposition are calculated within the vegetation canopy and wildfires of the GFDL dynamic land model LM4.1 with specific parametrization for each tiles (natural, secondary vegetation, pasture and cropland, rangeland; Shevliakova et al., 2024)
- Dust deposition to the ocean surface is a source term of soluble iron for the marine ecosystem model in ESM4.1 (Stock et al., 2020; Drenkard et al., 2023)



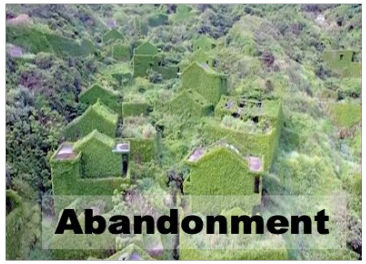


Dust sources expansion or shrinking with natural and anthropogenic changes

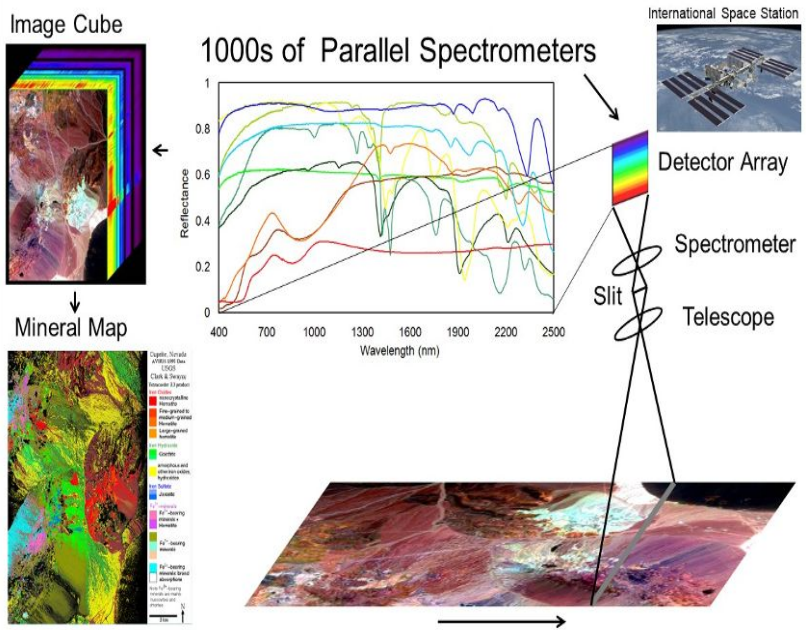
Expanding factors

All these factors are driving dust emission in LM4.1

Shrinking factors

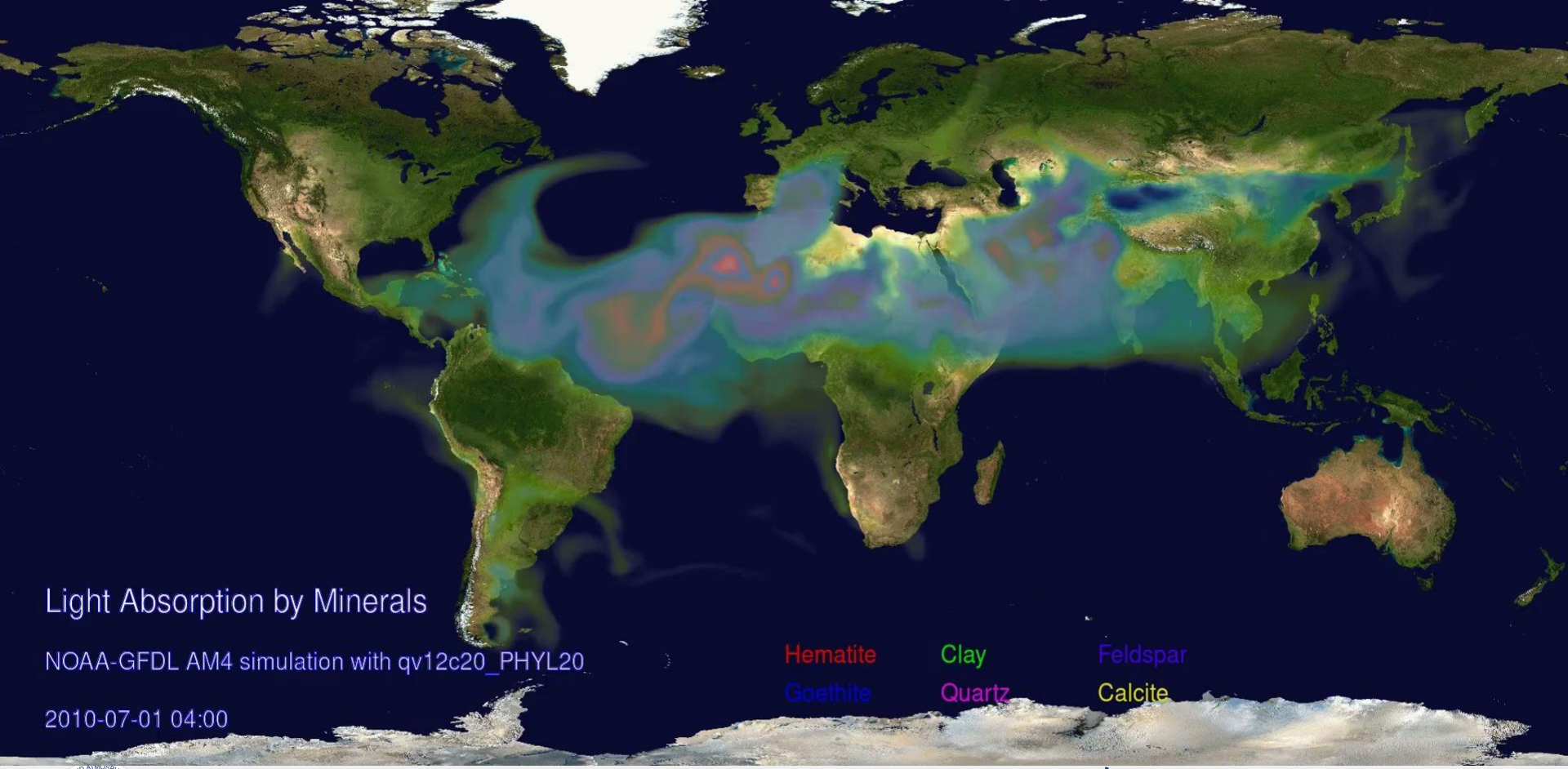


Sign and Amplitude of dust interactions depend on mineralogical composition



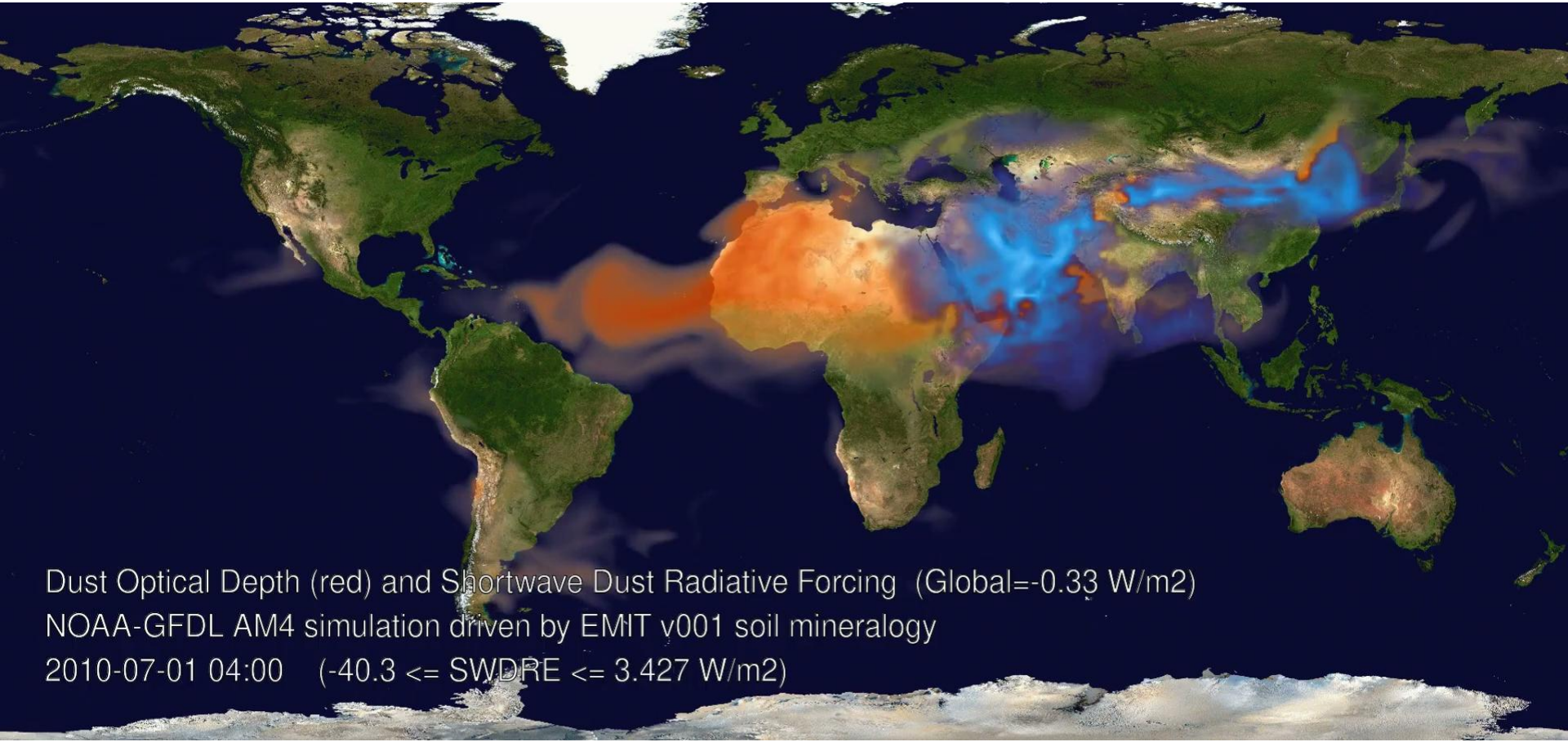
Green et al., IEEE, 2020; Thompson et al., 2024.

Since July 2022, **Earth Surface Mineral Dust Source Investigation (EMIT)** is measuring backscattered radiances from 450 to 2500 nm with a 10 nm interval from the International Space Station (ISS) at 65 m resolution. From these observations the mass fraction of 10 minerals (hematite, goethite, illite, vermiculite, calcite, dolomite, montmorillonite, kaolinite, chlorite, and gypsum) have been mapped over all dust sources. As Science Team member of EMIT, we have now the option to simulate one or all of these minerals in AM4, and improve the representation of dust interactions with the Earth's Climate Systems.



NOAA
GEOPHYSICAL FLUID DYNAMICS LABORATORY

5-Year Review
January 28-30, 2025


Dust Optical Depth (red) and Shortwave Dust Radiative Forcing (Global=-0.33 W/m2)
NOAA-GFDL AM4 simulation driven by EMIT v001 soil mineralogy
2010-07-01 04:00 (-40.3 <= SWDRE <= 3.427 W/m2)