Optical properties and direct radiative effects of aerosol species at global scale based on the synergistic use of MERRA-2 optical properties and the FORTH radiative transfer model

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Data and Methodology

Aim of the study: quantification of the aerosol Direct Radiative Effect (DRE), per aerosol type using MERRA-2 optical properties and the FORTH radiative transfer model during 1980-2019 (40 years).

Here, we presents the **initial results** of this study, under clear-sky conditions, during the period of one full-year (2015).

- **Spatial resolution**: 0.5 x 0.625 °
- **Temporal resolution**: monthly

- **The aerosol DREs are calculated on the Earth's surface, within the atmosphere and at the Top of the Atmosphere (TOA), for sulfate, dust, sea salt, organic carbon, black carbon and the total aerosol load.**

Data and Methodology

MERRA-2 3-hourly vertically resolved aerosol mixing ratios and relative humidity

lookup tables with the scattering and absorption efficiencies per particle type, size bin and rel. humidity

Monthly vertically and spectrally (25 wavelenghts) resolved optical properties:

- aerosol optical depth (AOD),
- single scattering albedo (SSA),
- asymmetry parameter (g), per aerosol type (sulfate, dust, sea salt, organic carbon, black carbon, total)

MERRA-2
surface albedo,specific humidity and ozone concentration

FORTH deterministic spectral radiative transfer model

Radiative fluxes from multiple model runs (with and without aerosols)

Aerosol effects:

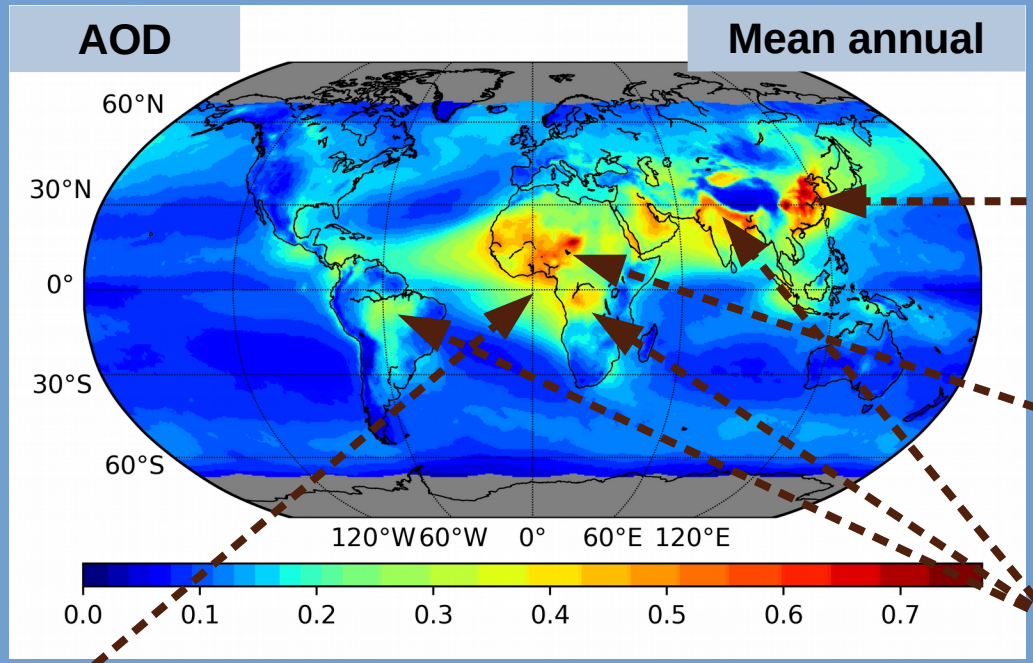
$$DRE_x = F_{aer} - F_{no\text{-}aer\text{-}x}$$

x: aerosol type

F_{aer}**:** net downward fluxes considering all aerosol types

$F_{no\text{-}aer\text{-}x}$**:** net downward fluxes without considering the aerosol type x

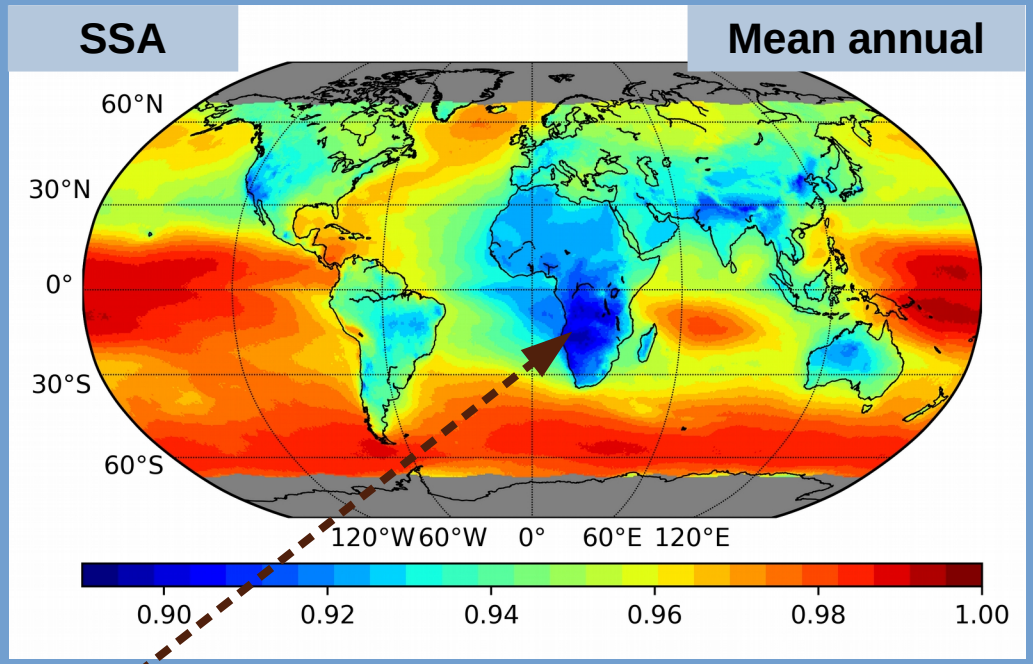
Aerosol optical properties for the year 2015



- Low AOD over oceans, except in regions where long-range transport of continental particles occurs (e.g. tropical Atlantic ocean, Arabian Sea)

- Mean annual (year 2015) AOD ~ 0.137 Significant spatial variability.
- The highest AOD (up to 0.77) is observed at east China (strong presence of mainly sulfate and carbonaceous (organic and black carbon) particles)
- AOD up to 0.73 over arid and semi-arid regions, such as North Africa (dust particles).
- High AOD also over the Indo Gangetic Plain (carbonaceous particles), Central-South Africa and America (biomass burning -related carbonaceous particles)

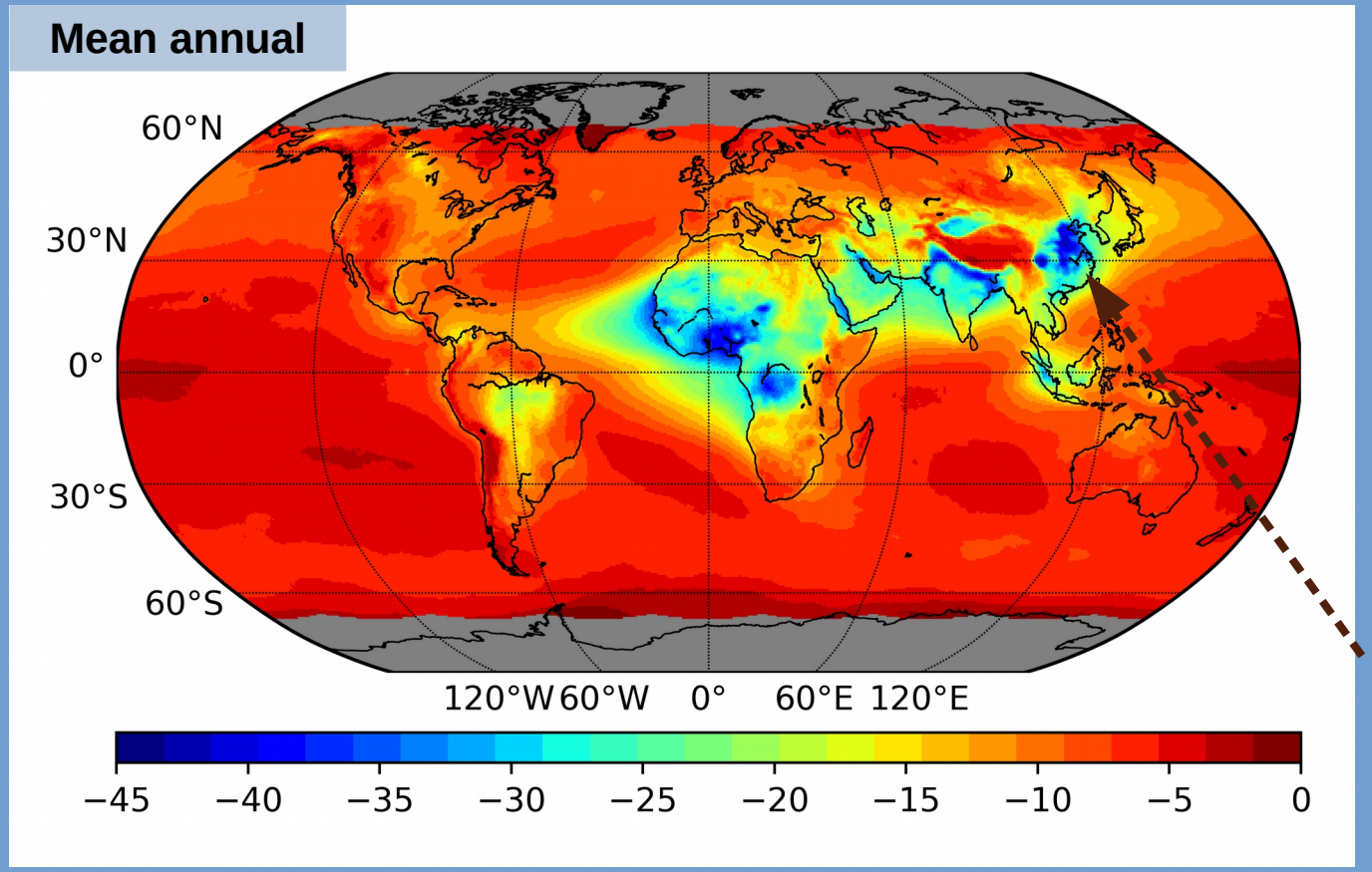
Aerosol optical properties for the year 2015



- Mean annual (year 2015) SSA ~ 0.96
- Generally lower SSA over land than over oceans
- High SSA values over the Southern Ocean and most of the Pacific Ocean (strong presence of highly scattering sea salt particles)

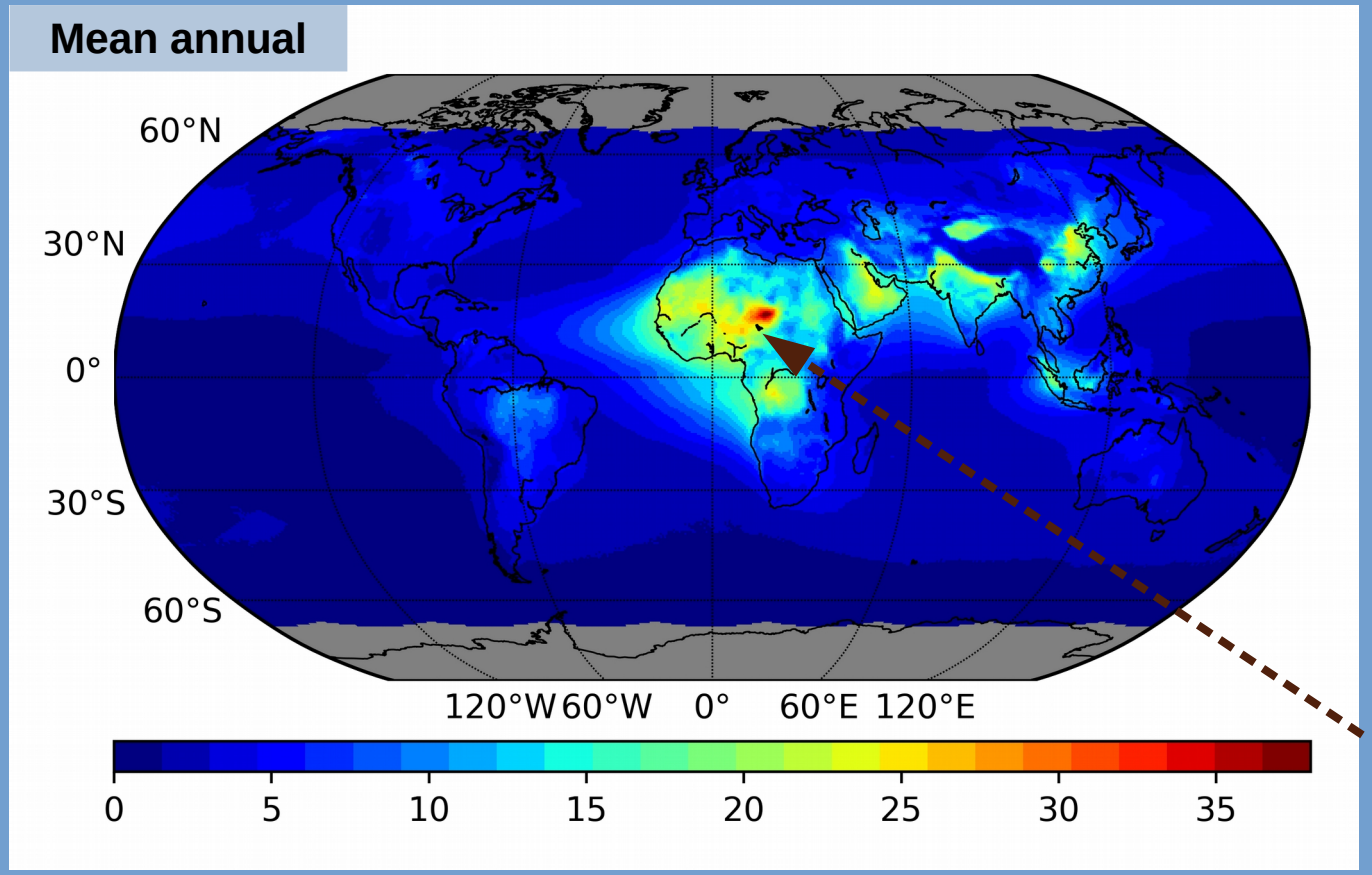
- Lowest SSA values in Southern Africa (biomass burning -related strong absorbing black carbon particles)

Aerosol radiative effects at the Earth's surface (total aerosol load)



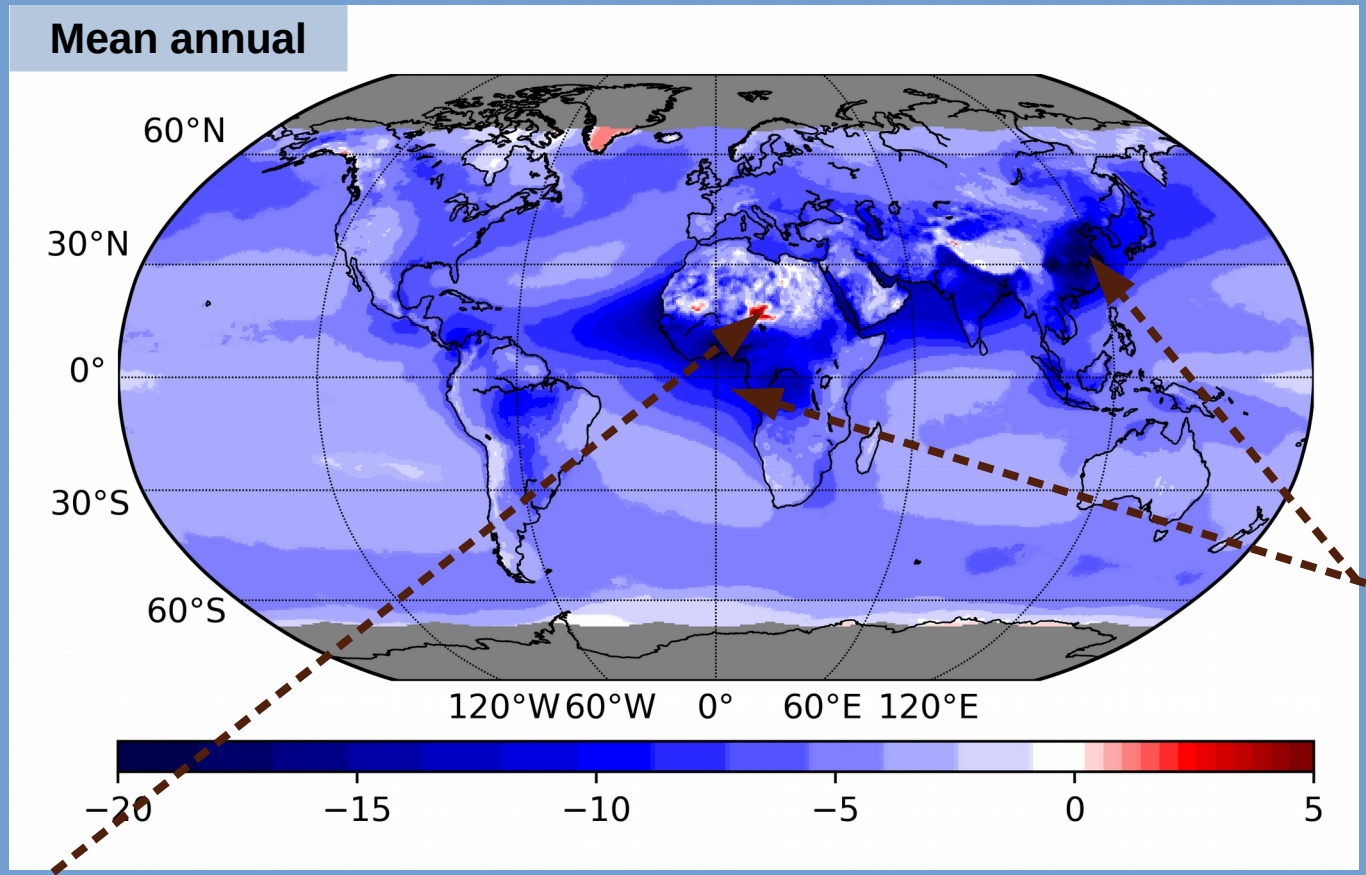
- **Surface cooling effect** due to aerosols
- Mean annual, globally averaged DRE ~ -8.73 Wm^{-2}.
- Stronger cooling in regions with high aerosol load.
- DRE up to -45 Wm^{-2} in east China

Aerosol radiative effects within the atmosphere (total aerosol load)



- **Atmospheric warming effect** due to aerosols
- Mean annual, globally averaged DRE ~ 3.94 Wm^{-2}.
- Similar geographic distributions with the aerosol DRE at the Earth' surface, opposite sign
- DRE up to 38 Wm^{-2} in North Africa (Sahara Desert)

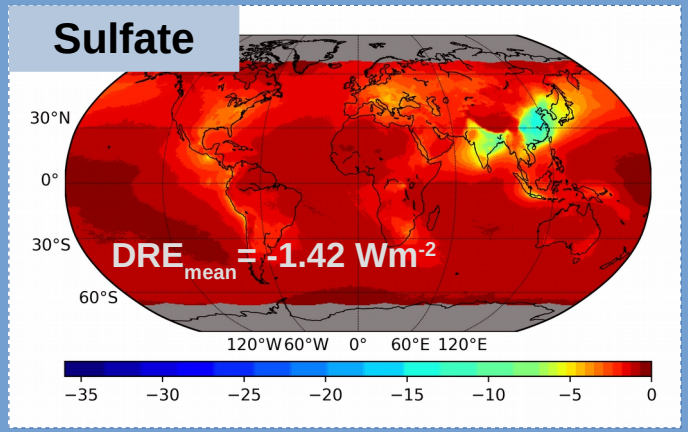
Aerosol radiative effects at the Top of the Atmosphere (TOA) (total aerosol load)



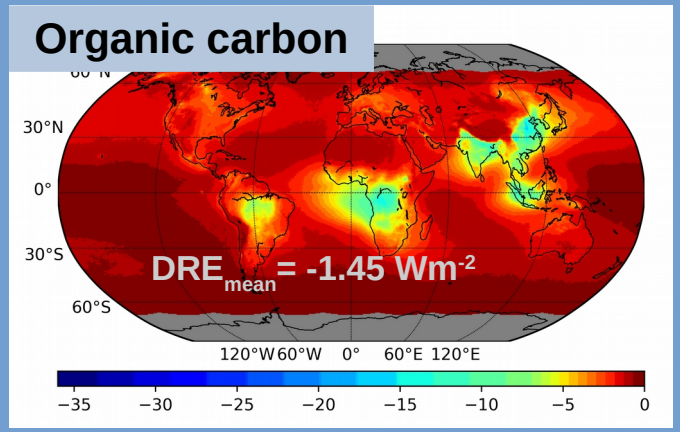
- Mean annual, globally averaged DRE ~ 3.94 Wm^{-2}.
- DRE range between -21 Wm^{-2} (**planetary cooling effect**) to 5 Wm^{-2} (**planetary warming effect**).
- Strongest cooling effect above East China and Central Africa and oceanic regions where continental aerosols are advected).
- Small cooling effect and locally a warming effect is observed above Sahara Desert and the arctic (role of large surface albedo and multiple scattering between surface and aerosols)

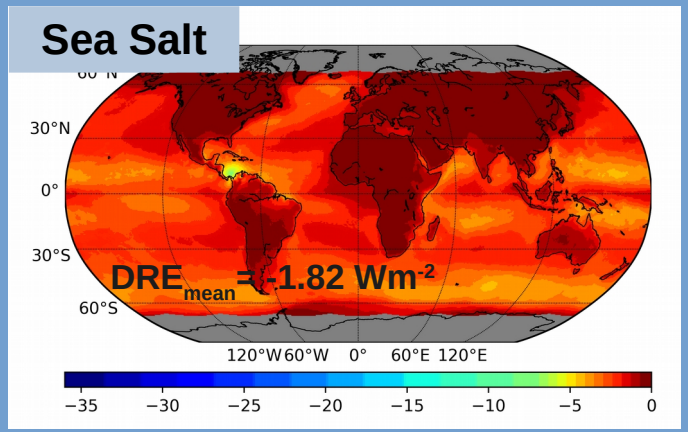
Aerosol radiative effects at the Earth's surface (per aerosol type, mean annual)

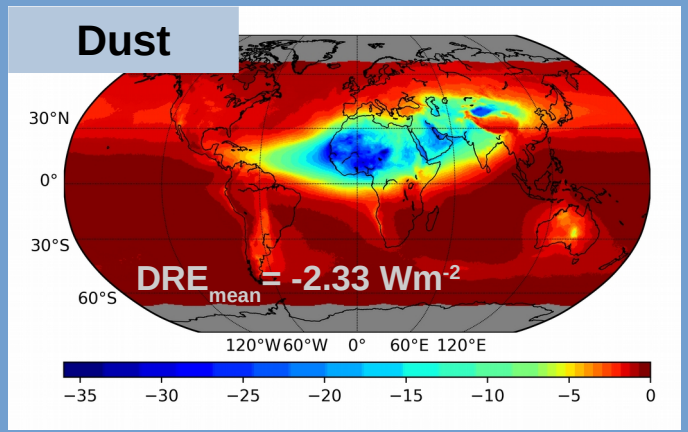
DRE_{mean}: Mean annual, globally averaged DRE

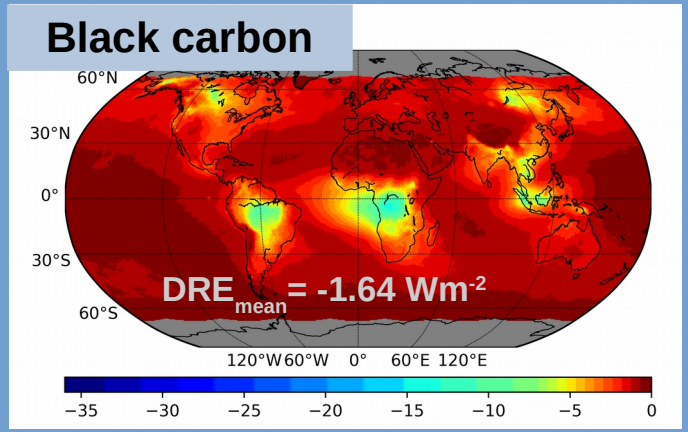


- The strongest cooling effect on the Earth' surface is caused by desert dust, followed by sea-salt, black, organic carbon and sulfate particles.



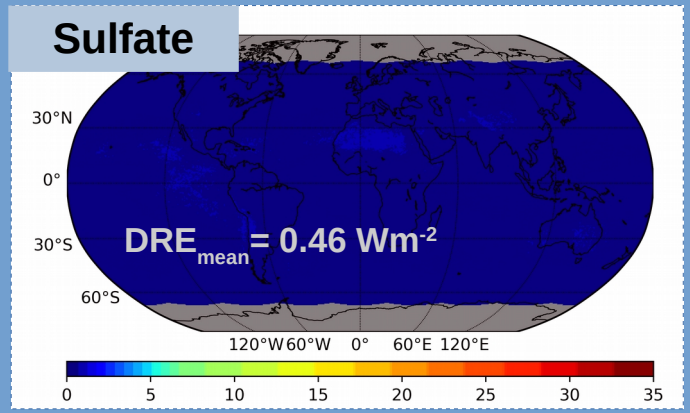




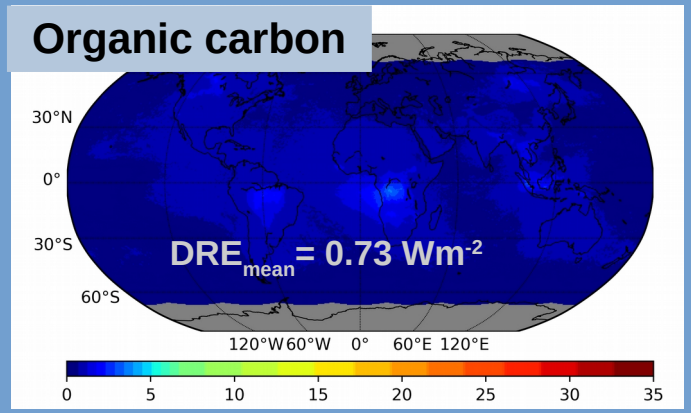


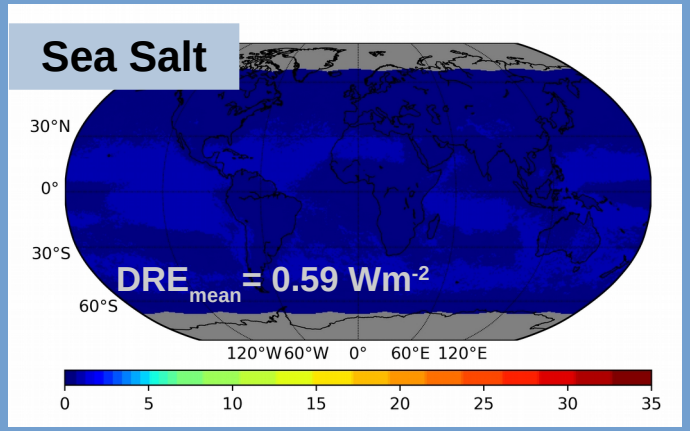
Aerosol radiative effects within the atmosphere (per aerosol type, mean annual)

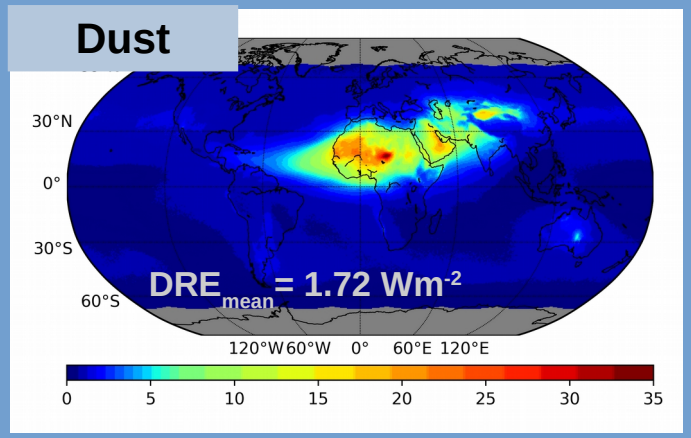
DRE_{mean}: Mean annual, globally averaged DRE

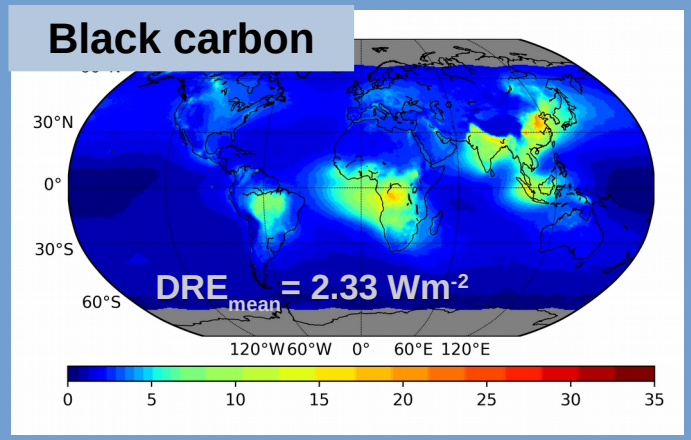


- The strongest heating is caused by black carbon particles, followed by dust
- The heating effect of the almost purely scattering sea-salt and sulfate is small.



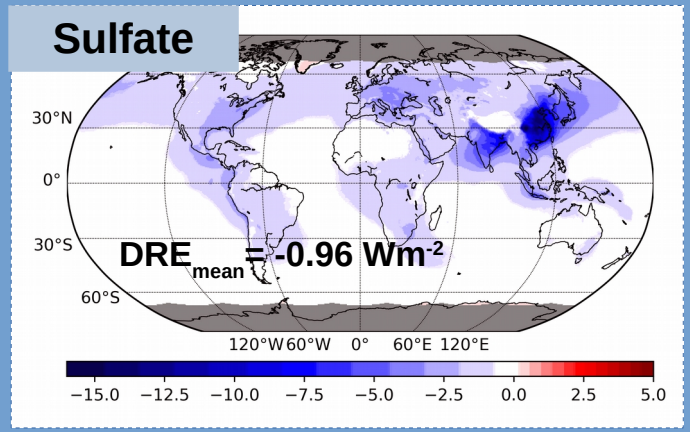




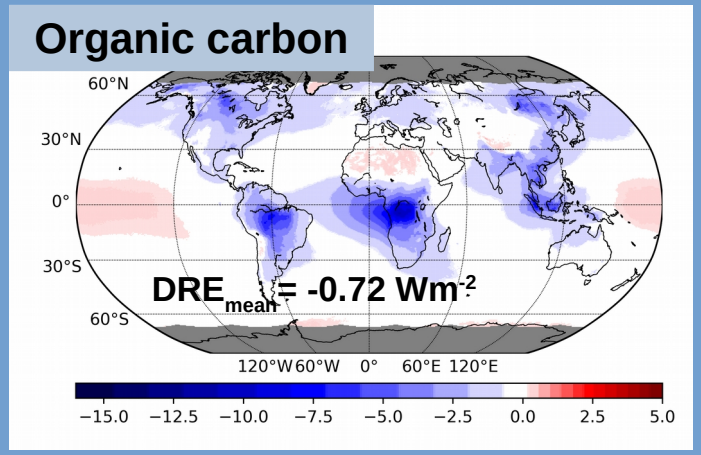


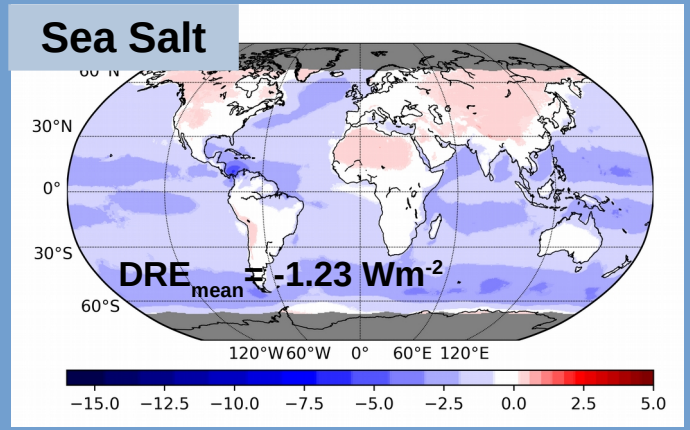
Aerosol radiative effects at the Top of the Atmosphere (TOA) (per aerosol type, mean annual)

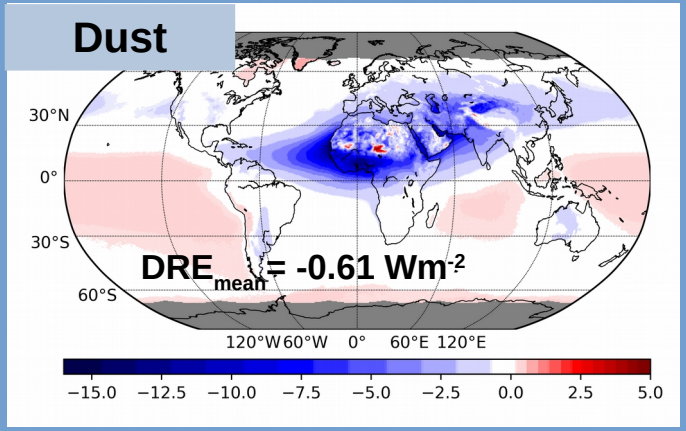
DRE_{mean}: Mean annual, globally averaged DRE

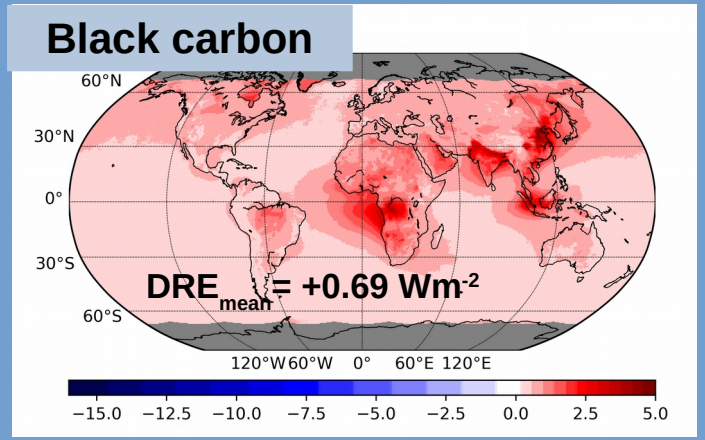


- The strongest TOA cooling is observed for sea-salt and sulfate particles.
- Smaller cooling effect for organic carbon and dust.
- Heating effect for black carbon particles due to their strong absorptivity.









Conclusions

- Aerosols cause a **cooling** of the Earth's surface **(-8.73 Wm^{-2})** and a
- **warming** of the atmosphere **(3.94 Wm^{-2})**.

- These effects are stronger in regions with high aerosol loads, especially consisted of absorbing particles.

- The reduction of solar radiation at the Earth's surface contributes to global dimming
  => very important for climate (reducing of the evaporation rates, slowdown of the water cycle)
- atmospheric warming +surface cooling : stabilization of the atmosphere, suppression of cloud formation, enhancing of desertification processes

- Overall, aerosols result in a planetary TOA **cooling effect (-3.94 Wm^{-2})**. Cooling over most of the globe, with the exception of a few regions with high surface albedo (e.g. Sahara, Arctic).

- Profound differences are found between the obtained DREs for different aerosol types. The strongest TOA **cooling** effect is found for sea-salt and sulfate aerosols **(-1.23 and -0.96 Wm^{-2}**, respectively) while black carbon aerosols cause a planetary **warming (0.69 Wm^{-2})**.