EGU General Assembly 2022

AS1.15 – Ice clouds observations and modelling

A global climatology of ice nucleating particles at cirrus conditions derived from model simulations with EMAC-MADE3

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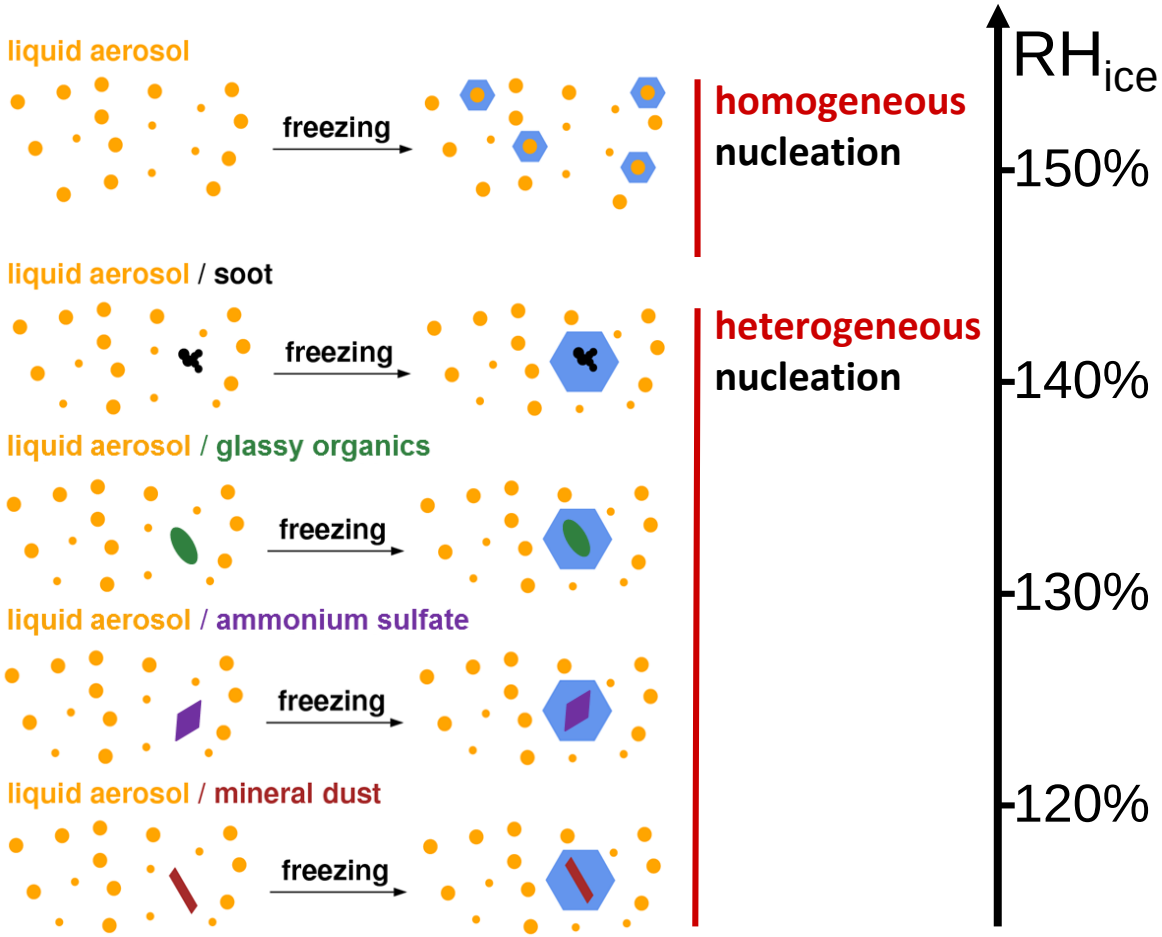
DLR

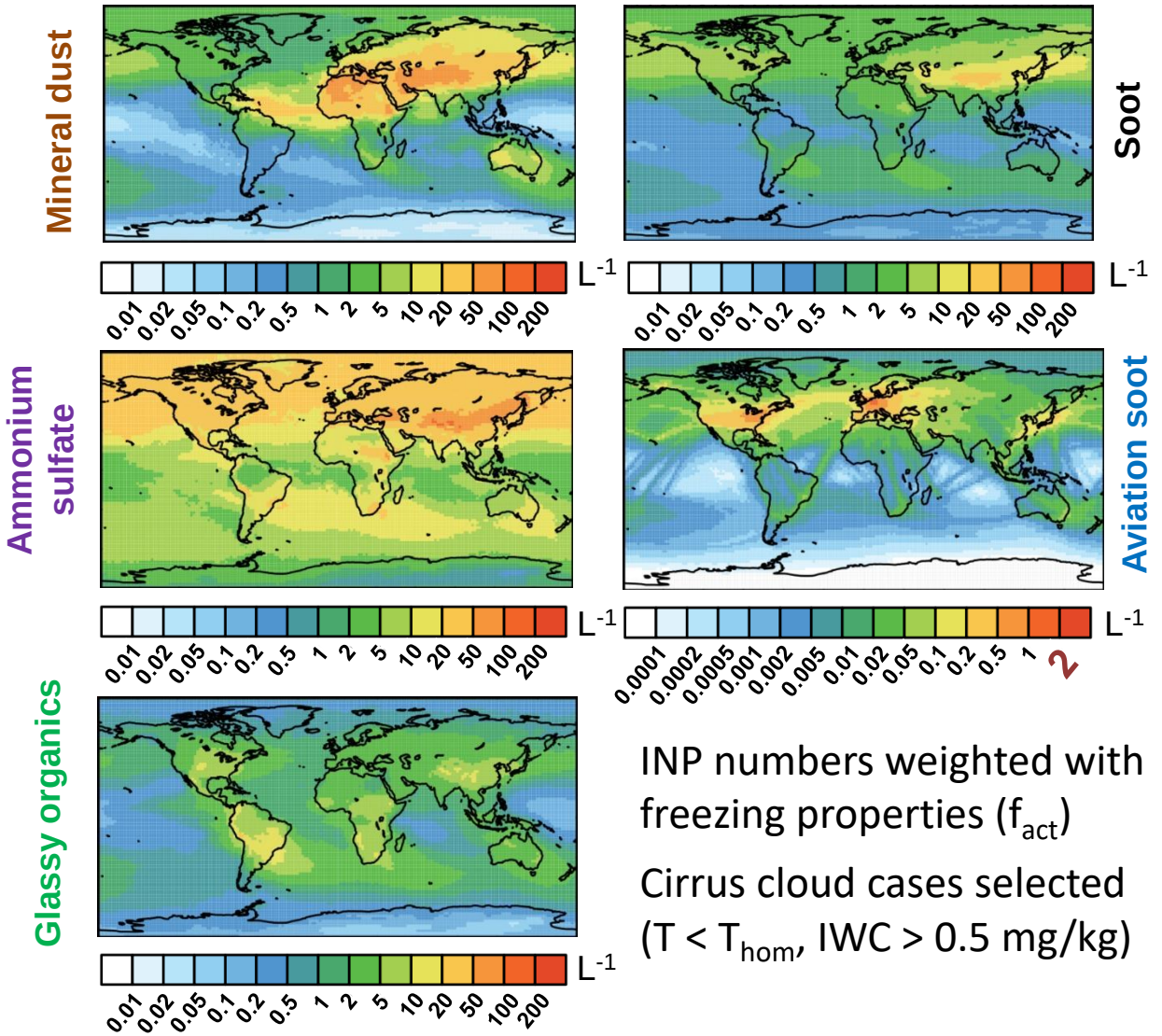
Sharing is encouraged

Global climatology of ice nucleating particles at cirrus formation (1)

INP-types: mineral dust, soot, aviation soot,
crystalline ammonium sulfate,
glassy organics

NEW!



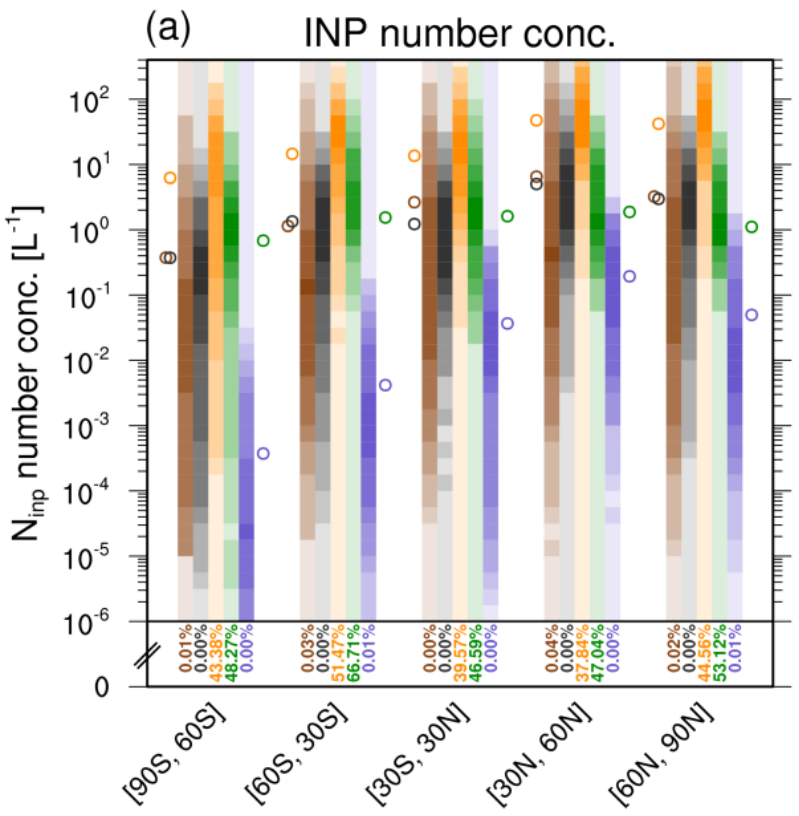


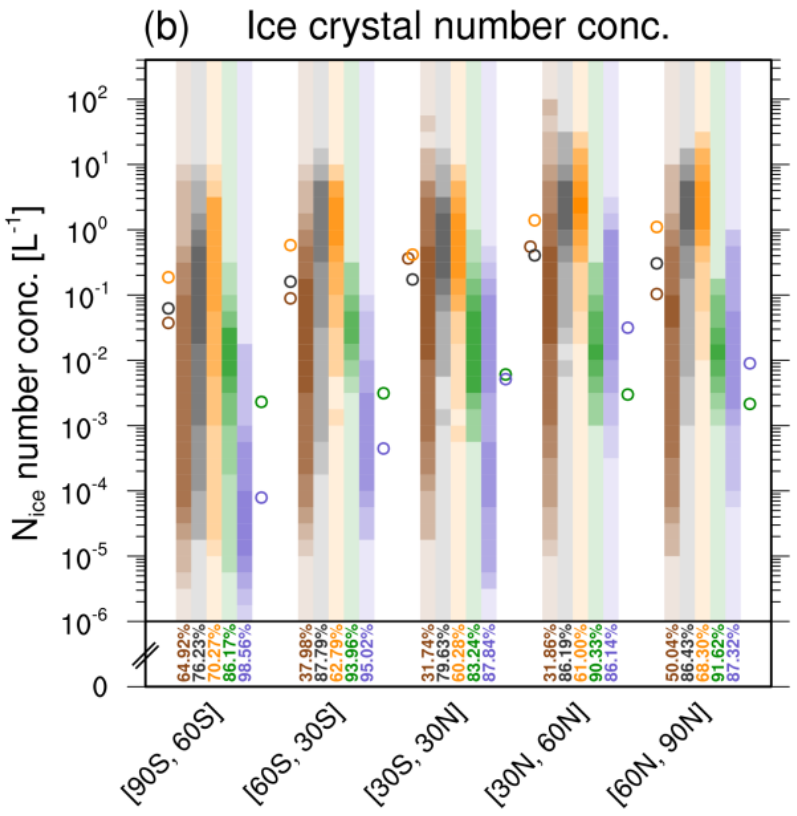
INP numbers weighted with freezing properties (f_{act})

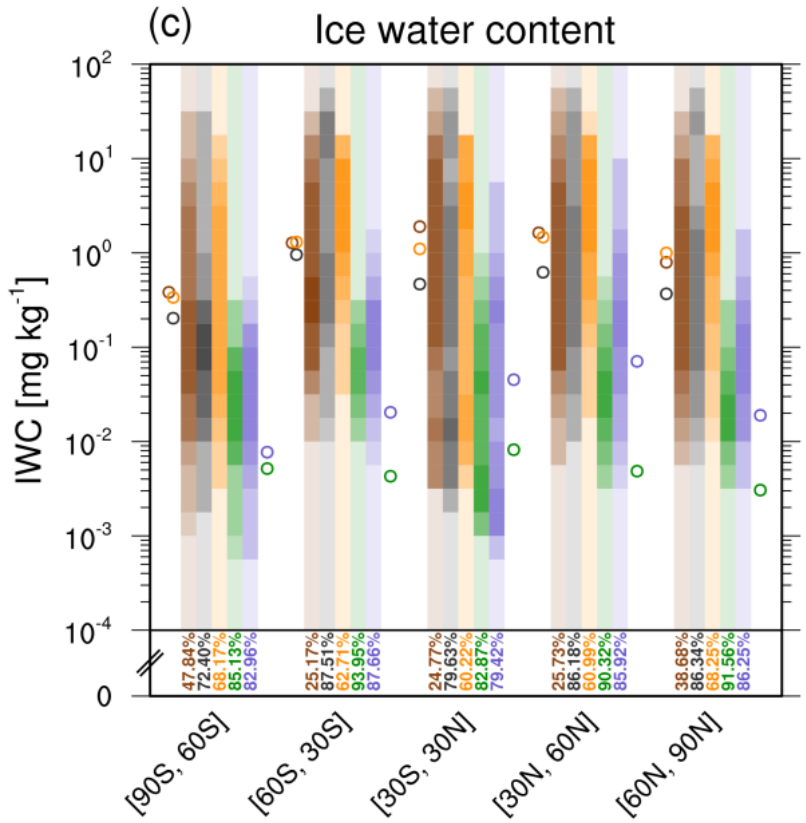
Cirrus cloud cases selected ($T < T_{hom}$, IWC > 0.5 mg/kg)

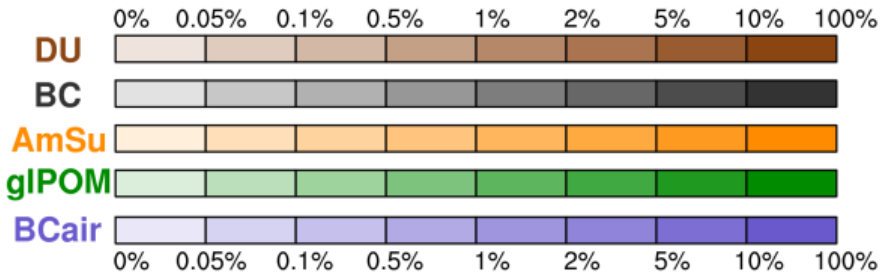
Beer (2021, PhD thesis); Beer et al., (2022 in prep.)

Global climatology of ice nucleating particles at cirrus formation (2)









Frequency distributions of:
INP number conc., pristine ICNC,
pristine IWC (per latitude-region,
open circles represent mean values)

Cirrus cloud cases selected
($T < T_{hom}$, IWC > 0.5 mg/kg)

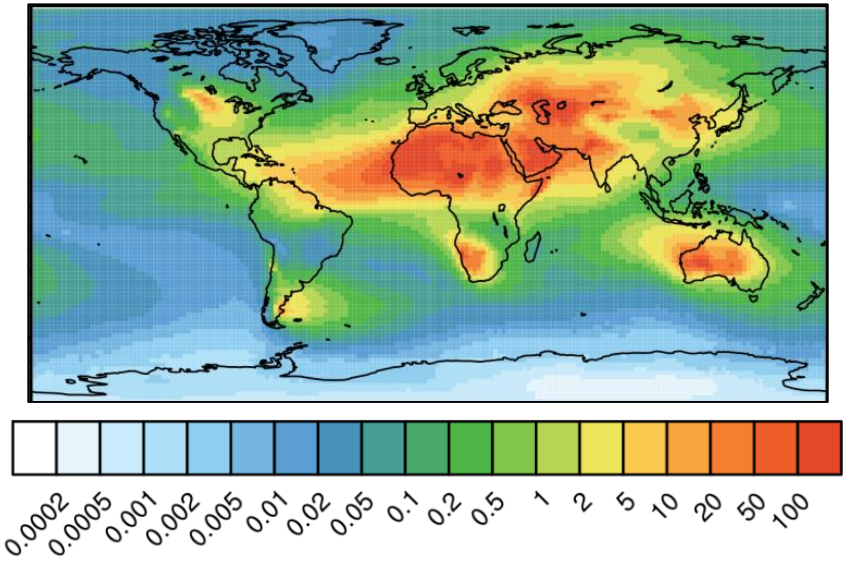
Beer (2021, PhD thesis); Beer et al., (2022 in prep.)

Global climatology of ice nucleating particles at cirrus formation -- Summary

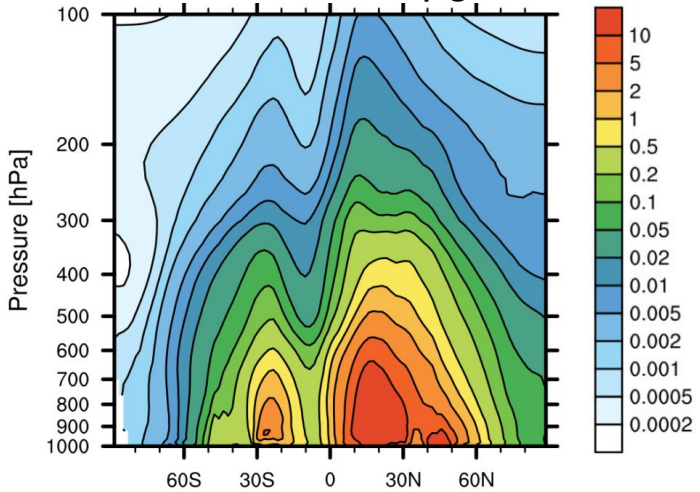
- Including different INP-species: mineral dust, (aviation) soot, crystalline ammonium sulfate, glassy organics
- Simulated INP number conc. in the range of 1 – 100 L^{-1} agree well with in situ observations and other global model studies
- Including additional INP-species is important; especially crystalline ammonium sulfate shows large INP conc. and should be considered in future global model studies
- By coupling the different INP-types to the microphysical cirrus cloud scheme, their ice nucleation potential at cirrus formation is analysed; e.g. number conc. of pristine ice crystals / ice water content per freezing mode

Simulated aerosol concentrations (1)

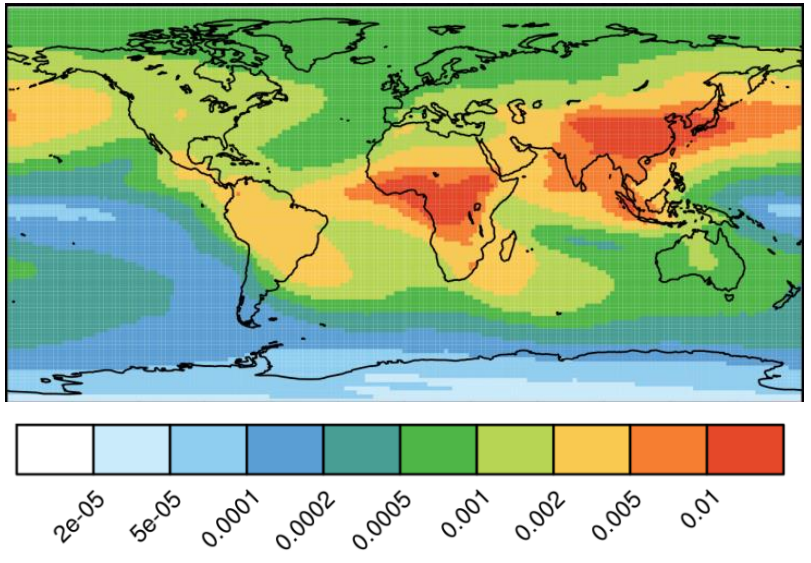
Mineral dust, 300 hPa µg m^{-3}



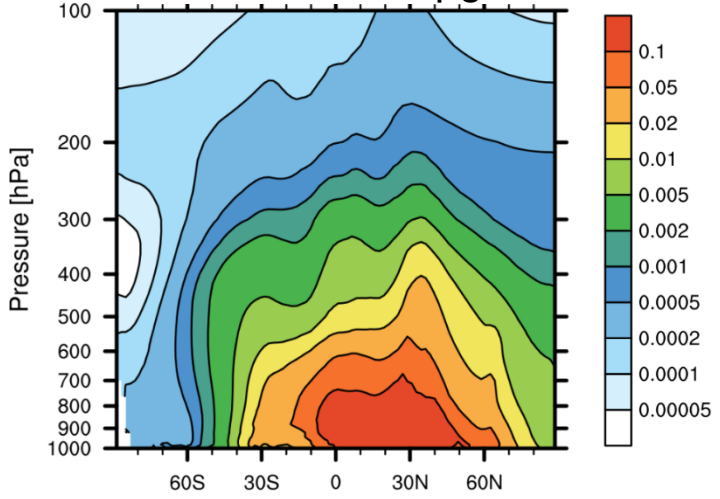
Zonal mean µg m^{-3}



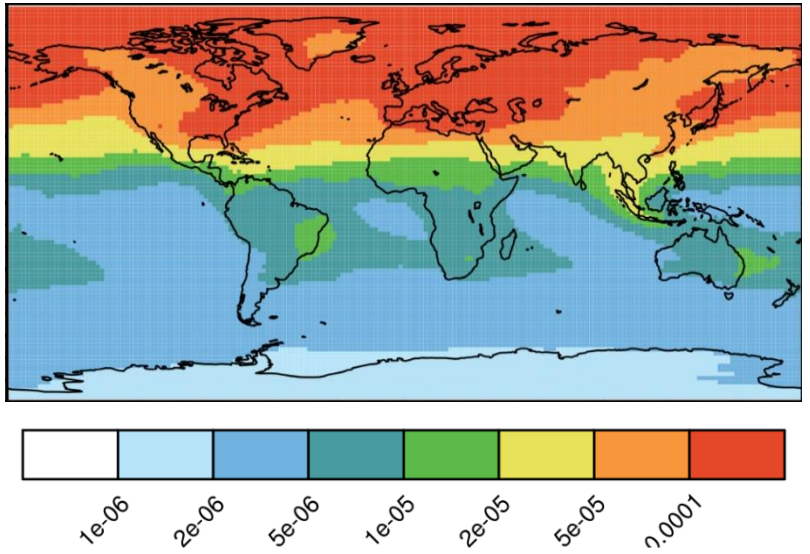
Soot, 300 hPa µg m^{-3}



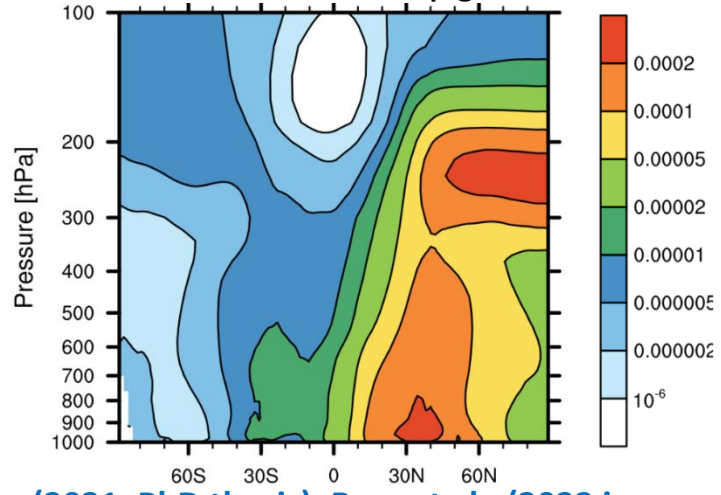
Zonal mean µg m^{-3}



Aviation soot, 300 hPa µg m^{-3}



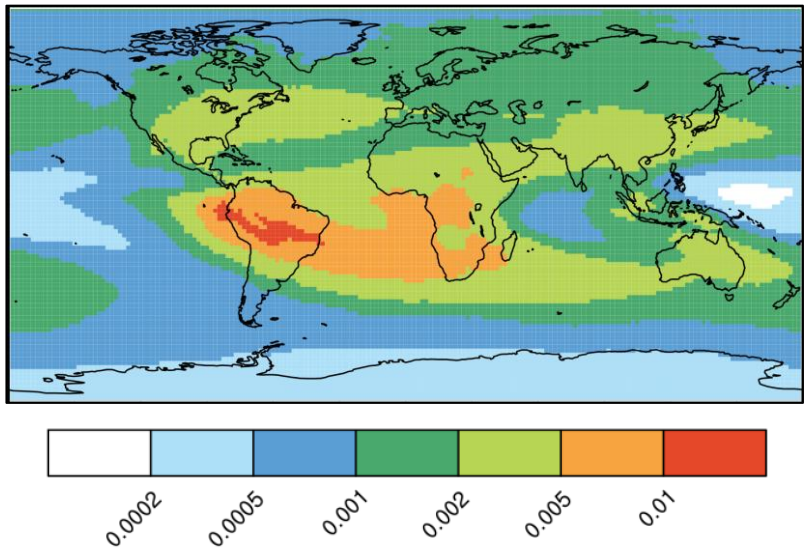
Zonal mean µg m^{-3}



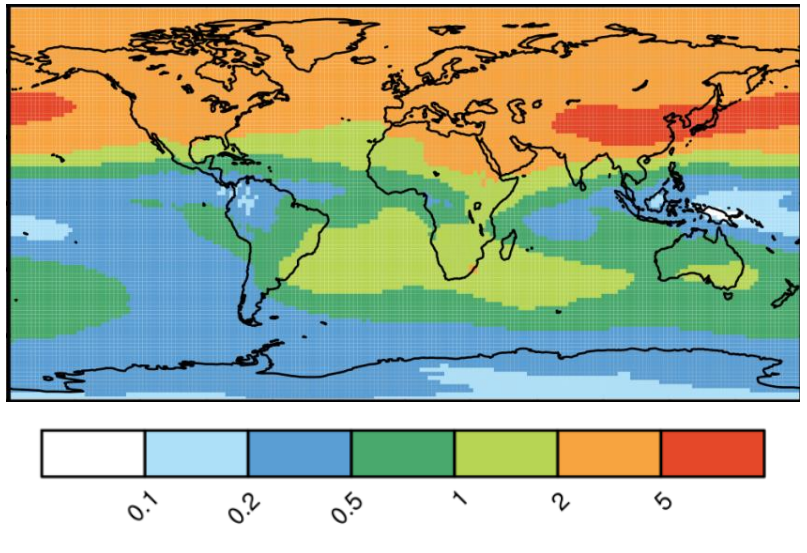
Beer (2021, PhD thesis); Beer et al., (2022 in prep.)

Simulated aerosol concentrations (2)

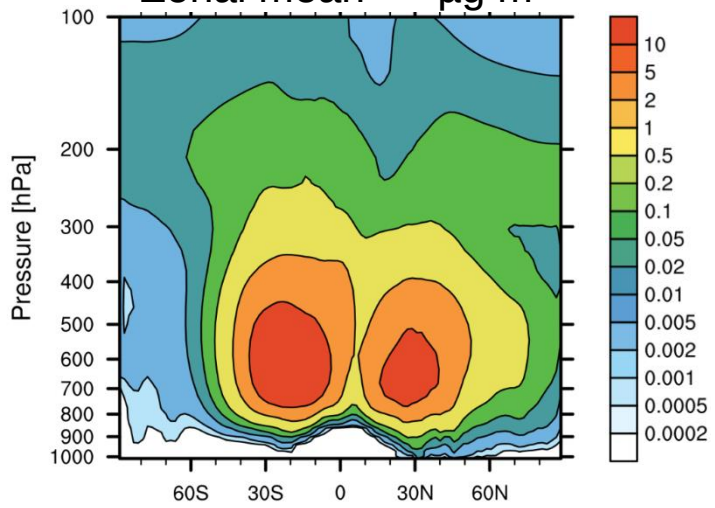
Glassy organics, 300 hPa μg m^{-3}



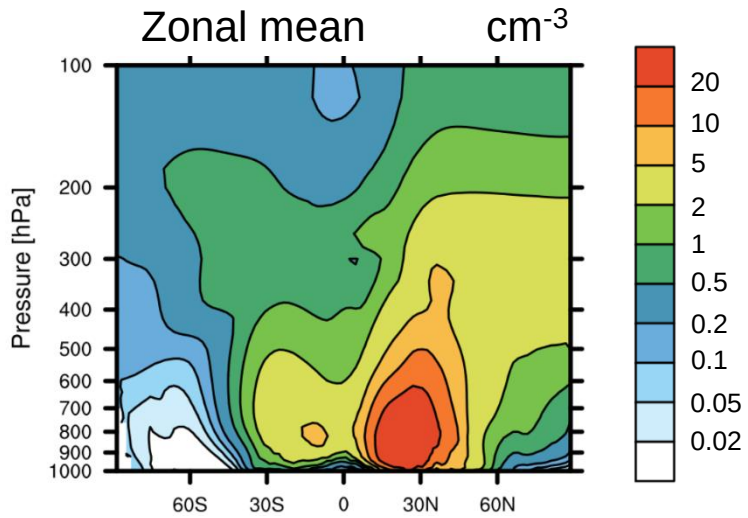
Ammonium Sulfate, 300 hPa cm^{-3}



Zonal mean μg m^{-3}

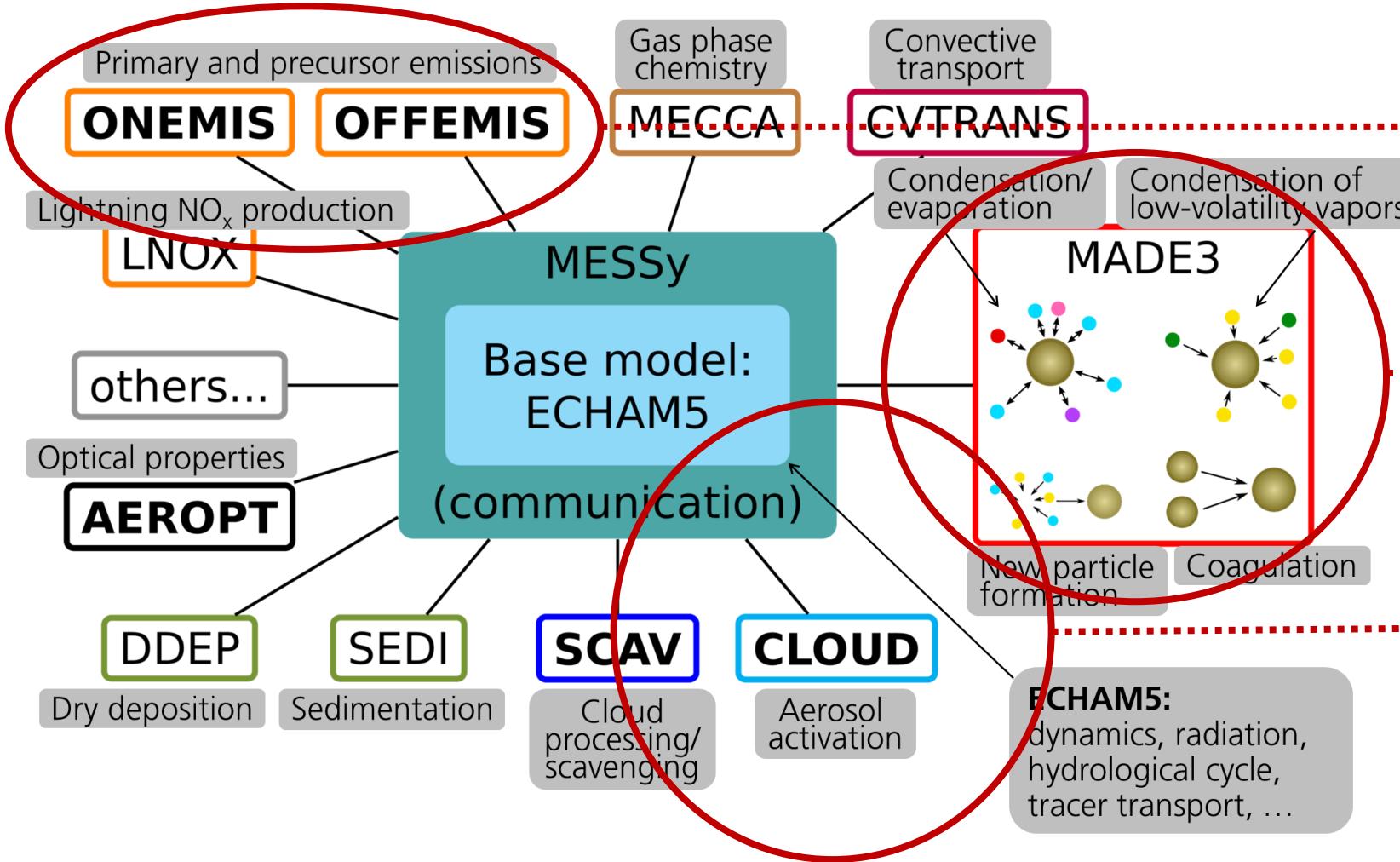


Zonal mean cm^{-3}



Beer (2021, PhD thesis); Beer et al., (2022 in prep.)

Global aerosol-climate model EMAC-MADE3



Emissions
incl. aviation,
CMIP6, 2014
(Feng et al. GMD, 2020)

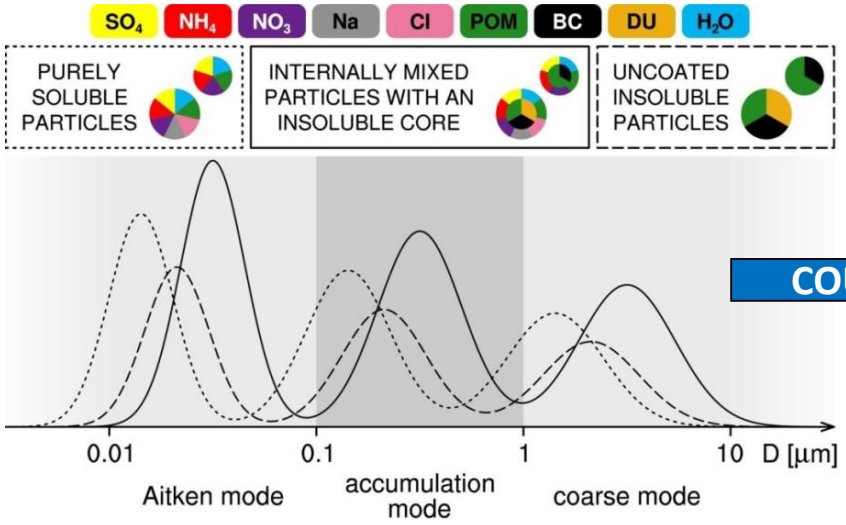
wind-driven mineral dust
(Beer et al., GMD, 2020)

Aerosol submodel MADE3
(Kaiser et al., GMD, 2019)

Clouds and aerosol-cloud-coupling
incl. aerosol-cirrus interaction
(Righi et al., GMD, 2020)

ECHAM5: Roeckner et al. (2006); **MESSy/EMAC:** Jöckel et al. (2005, 2006, 2010);
EMAC with MADE: Lauer et al. (2007), Aquila et al. (2011), Righi et al. (2011, 2013, 2015),
Kaiser (2016), Kaiser et al. (2019), Beer et al. (2020), Righi et al. (2020), Righi et al. (2021)

The EMAC-MADE3 global aerosol model (with cirrus)



MADE3 aerosol submodel in EMAC

- **9 aerosol types**
- **3 mixing states** (soluble, insoluble and mixed) in 3 log-normal size modes ⇨ **9 modes**
- Explicit simulation of aerosol **mass and number** concentrations
- Microphysical processes: **new particle formation**, **coagulation**, **condensation** and gas-aerosol **partitioning**

Kaiser et al. (2014, 2019)

BCtag

COUPLING

Externally mixed DU and BC
→ deposition nucleation

DU and BC with soluble coating
→ immersion freezing

Supercooled solution droplets
→ homogeneous freezing

Pre-existing ice crystals

Additional INPs: **Crystalline ammonium sulfate** **Glassy organics**

Dynamical forcing (updraft)

Nucleation and growth of ice crystals

Ice formation processes

Competition for supersaturated water vapor

Ice crystals (number concentration and size)

Cirrus parametrization

- Competition between **homogeneous** and **heterogeneous** freezing
- Consideration of **pre-existing ice crystals**
- Ice nucleating particles: **black carbon** (BC) and **mineral dust** (DU), **ammonium sulfate**, **glassy organics**

Kärcher et al. (2006), Hendricks et al. (2011), Kuebbeler et al. (2014)

Righi et al. (2020)

References

- Beer, C. G.: Global modelling of ice nucleating particles and their effects on cirrus clouds, Ph.D. thesis, Ludwig-Maximilians-Universität München, https://doi.org/10.5282/edoc.28470, 2021

- Righi, M., Hendricks, J., and Beer, C. G.: Exploring the uncertainties in the aviation soot–cirrus effect, Atmos. Chem. Phys., 21, 17 267–17 289, https://doi.org/10.5194/acp-21-17267-2021, 2021

- Righi, M., Hendricks, J., Lohmann, U., Beer, C. G., Hahn, V., Heinold, B., Heller, R., Krämer, M., Ponater, M., Rolf, C., Tegen, I., and Voigt, C.: Coupling aerosols to (cirrus) clouds in the global EMAC-MADE3 aerosol-climate model, Geosci. Model Dev., 13, 1635–1661, https://doi.org/10.5194/gmd-13-1635-2020, 2020