Aerosol-cloud interaction in 1985 and today

Roland Schrödner, Christa Genz, Bernd Heinold, Holger Baars, Silvia Henning, Nils Madenach, Cintia Carbajal Henken, Montserrat Costa Surós, Odran Sourdeval, Jonas Hesemann, Matthias Brueck, Guido Cioni, Corinna Hoose, Ina Tegen, Johannes Quaas

schroed@tropos.de

Leibniz Gemeinschaft

HD(CP)²
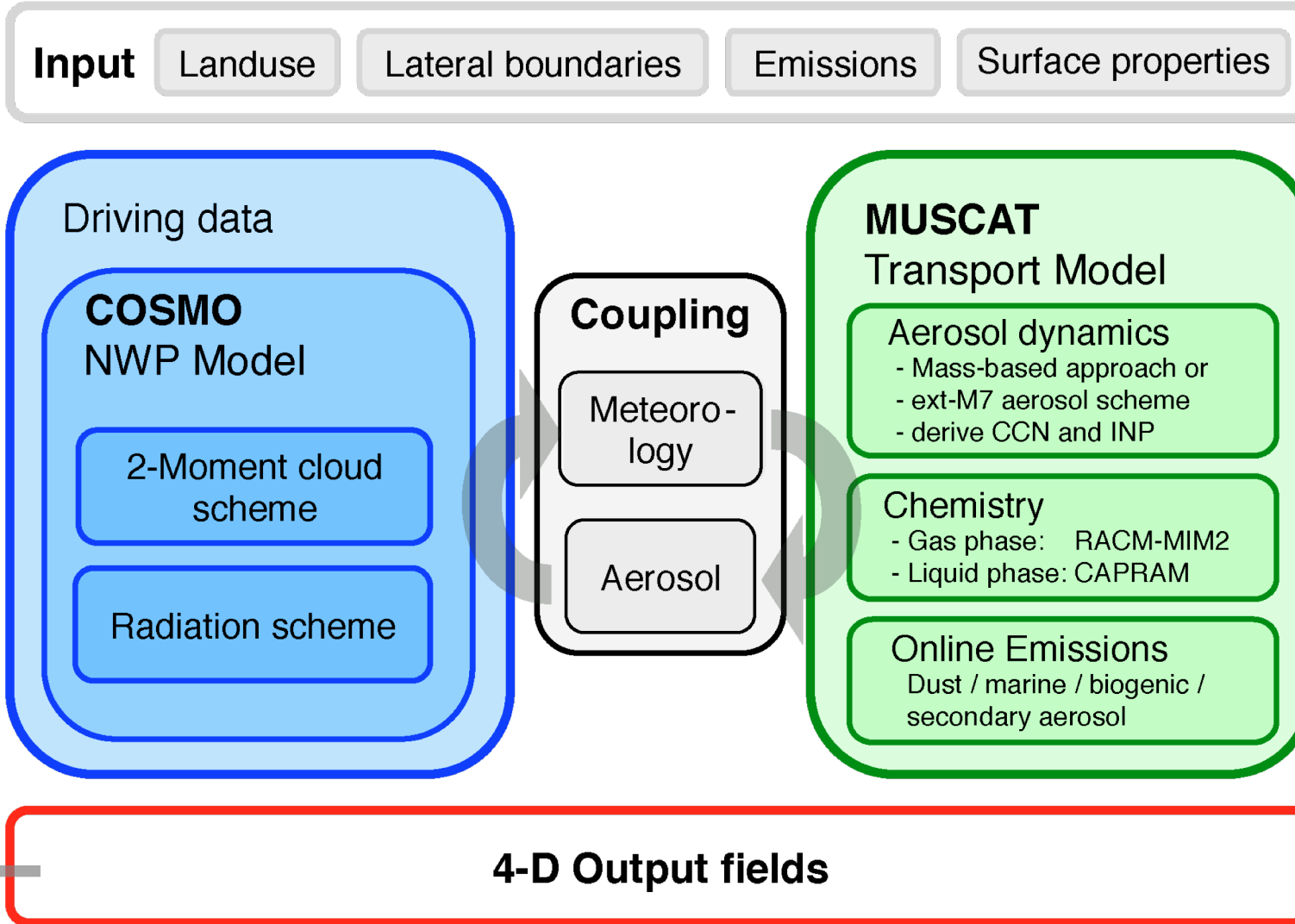High definition clouds and precipitation
for advancing climate prediction

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Objectives

- Investigate aerosol-cloud-interaction as aerosols are perturbed

- Compare modelled aerosol conditions of the mid 1980's („peak aerosol" over Europe) to 2013

- Use modelled aerosol to derive CCN number concentration

- Use the derived CCN as input for high-resolution meteorological simulations (ICON-LEM)

- Compare to available observations (HOPE campaigns, AVHRR)

COSMO-MUSCAT

TROPO's aerosol & chemistry transport model system

Output was ingested into ICON-LEM simulations

Input | Landuse | Lateral boundaries | Emissions | Surface properties

Driving data

COSMO
NWP Model

2-Moment cloud scheme

Radiation scheme

Coupling

Meteoro-logy

Aerosol

MUSCAT
Transport Model

Aerosol dynamics
- Mass-based approach or
- ext-M7 aerosol scheme
- derive CCN and INP

Chemistry
- Gas phase: RACM-MIM2
- Liquid phase: CAPRAM

Online Emissions
Dust / marine / biogenic / secondary aerosol

ICON-LEM ← **4-D Output fields**

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Model setup

- Nested Germany domain (resolution 7x7 km^2)

- Simulation period: 2013/03/26 - 06/16
  - 1985 scenario using the same meteorology

- 1985 emissions estimated using scaled 2009 emission inventory

- Overall annual emissions over Germany for 1985 from UBA

- CCN derived according to Abdul-Razzak and Ghan (2000)
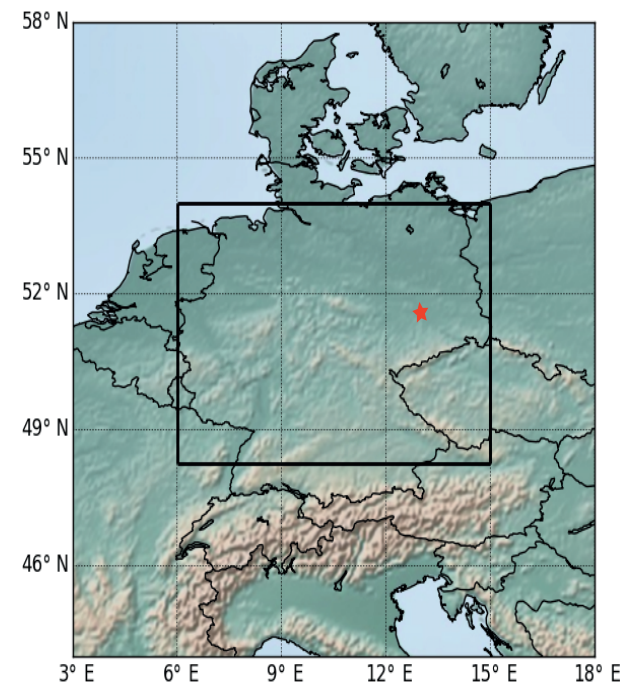
	1985	2013	ratio 1985/2013
dust (incl. soot)	2.65	0.35	7.7
SO_2	7.73	0.41	19
NH_3	0.86	0.74	1.2

Emissions over Germany in Mt a^{-1}

Genz et al., ACPD, in review

Result: Aerosol 1985 vs 2013 (3-month domain mean)

On average: Much more ammonium sulfate, but slightly less ammonium nitrate in 1980's

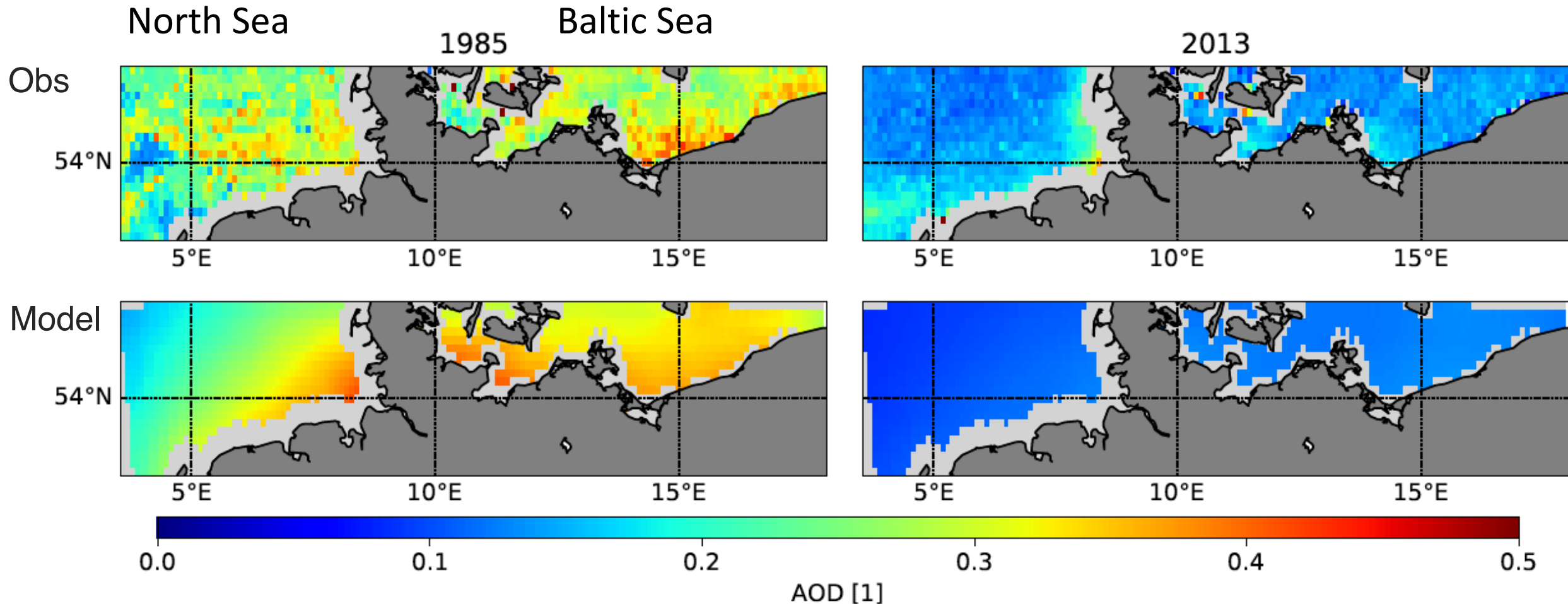A factor of ~5 difference in particle mass between 1985 and 2013
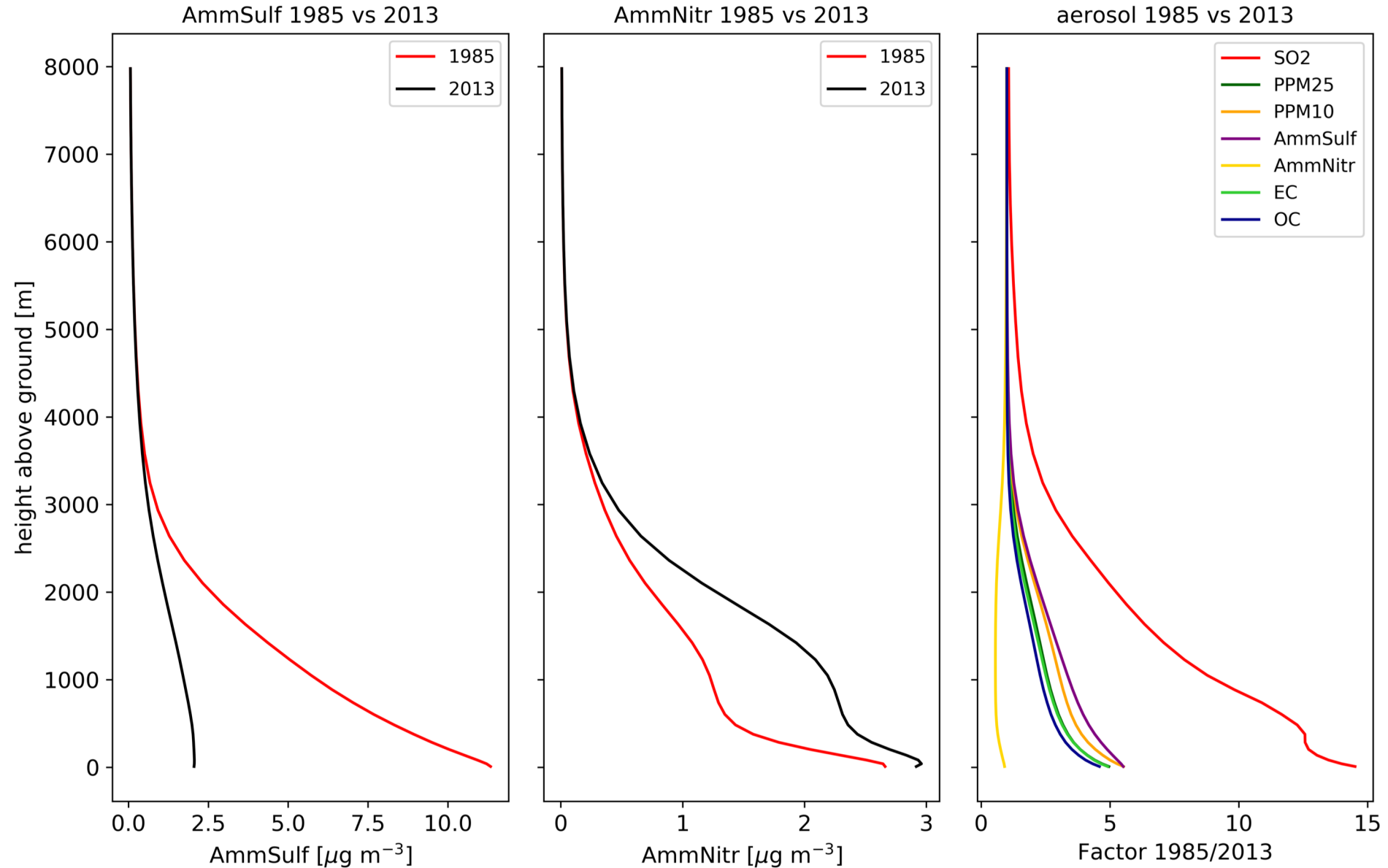
Result: CCN 1985 vs 2013 (3-month domain mean)

Assuming the same aerosol size distributions as in 2013, the average CCN number in 1985 in the boundary layer is a factor of ~2-3 higher than in 2013.
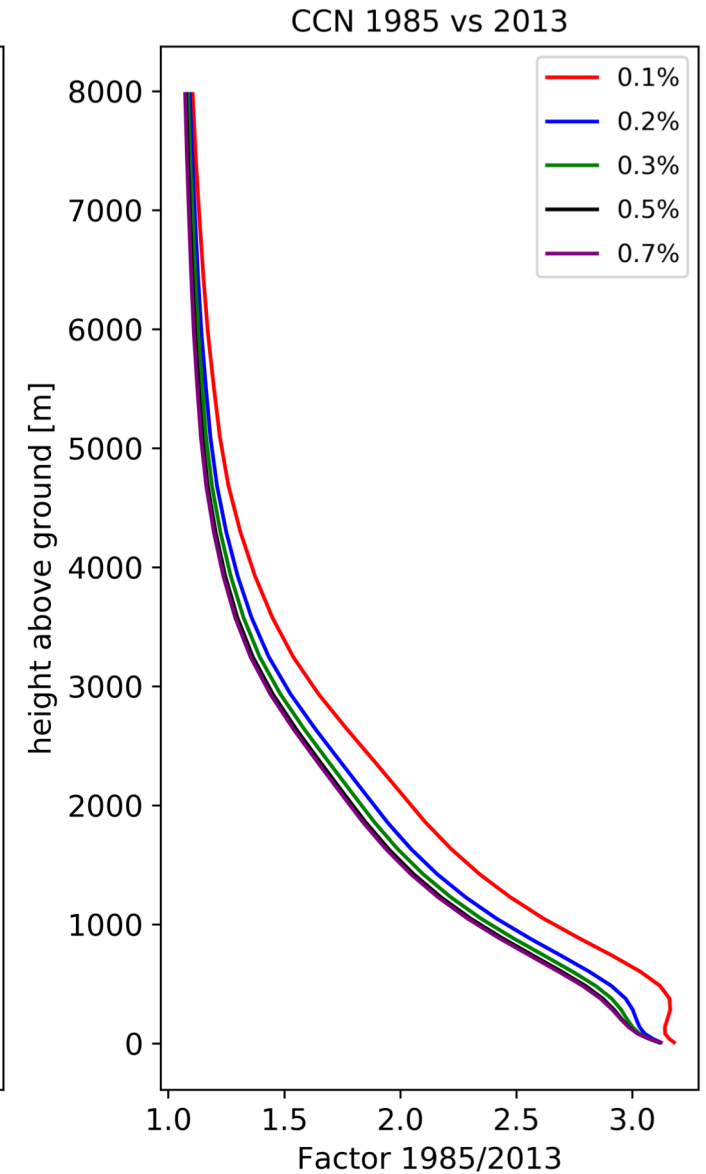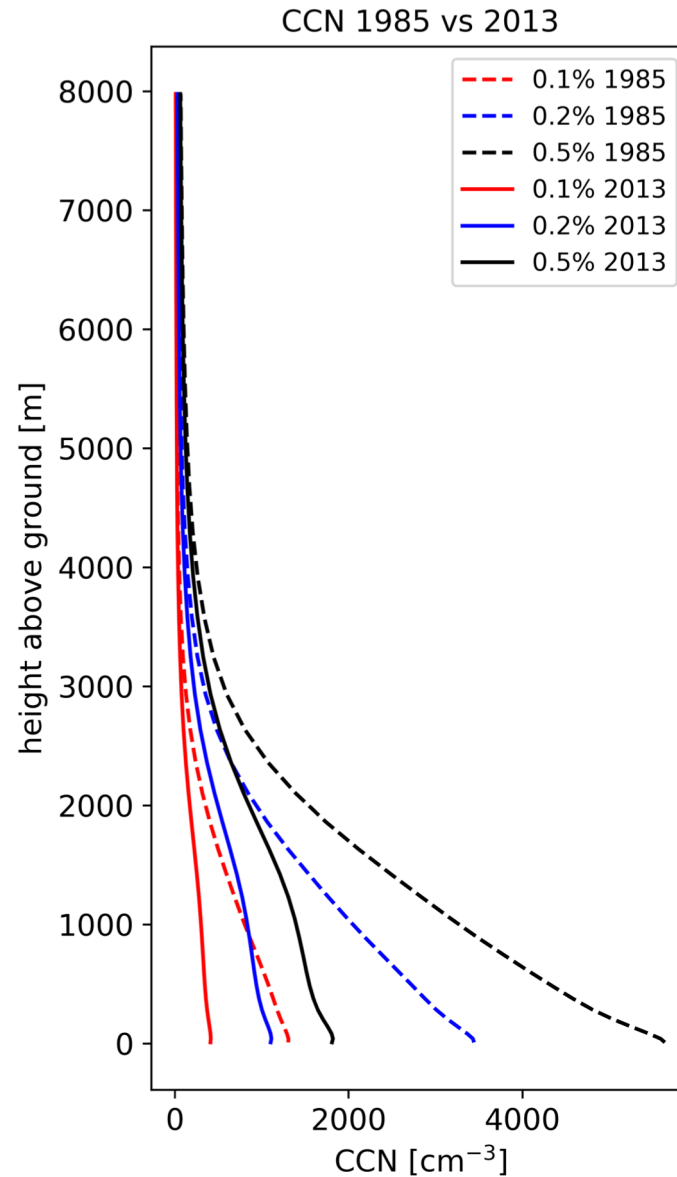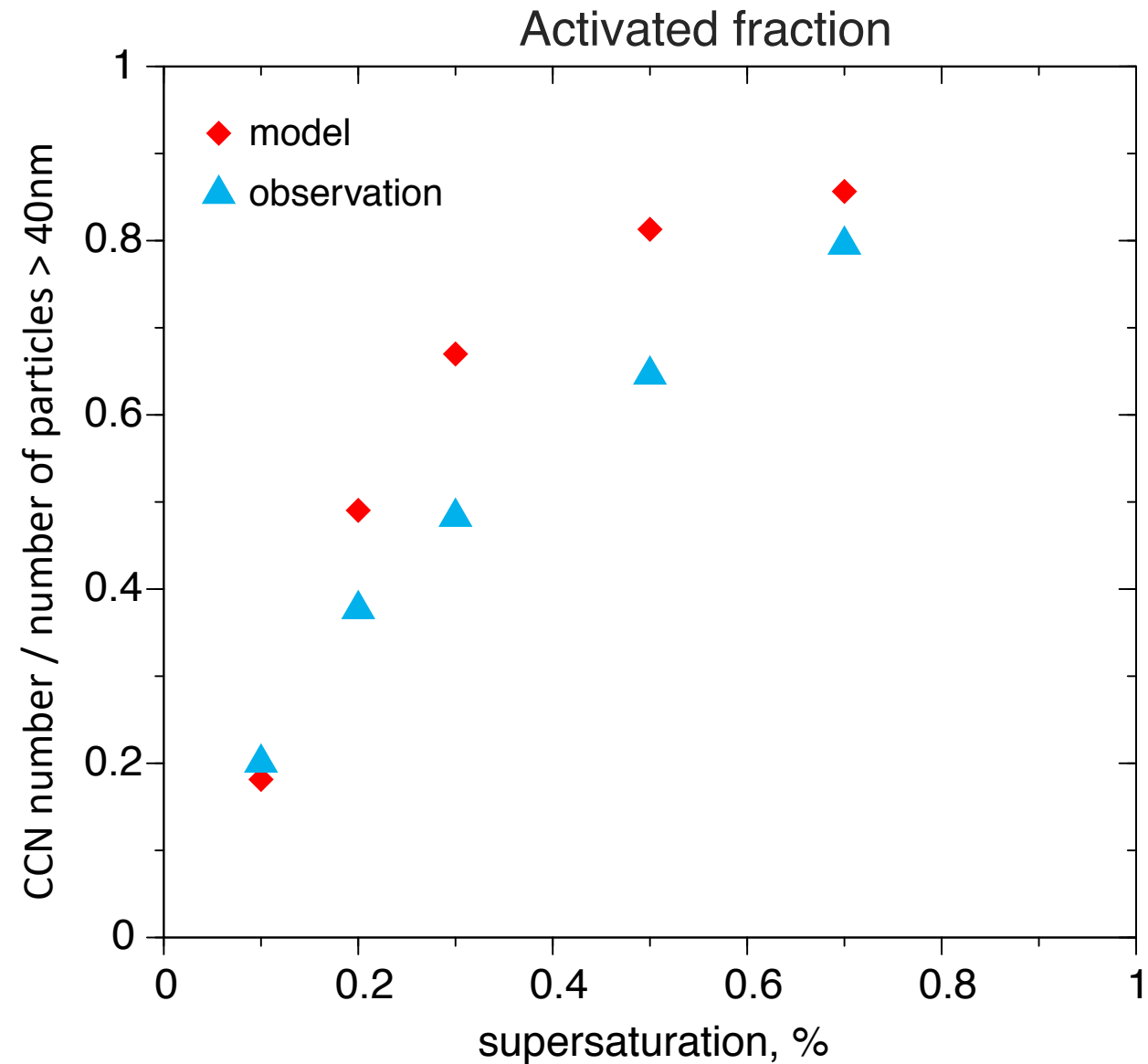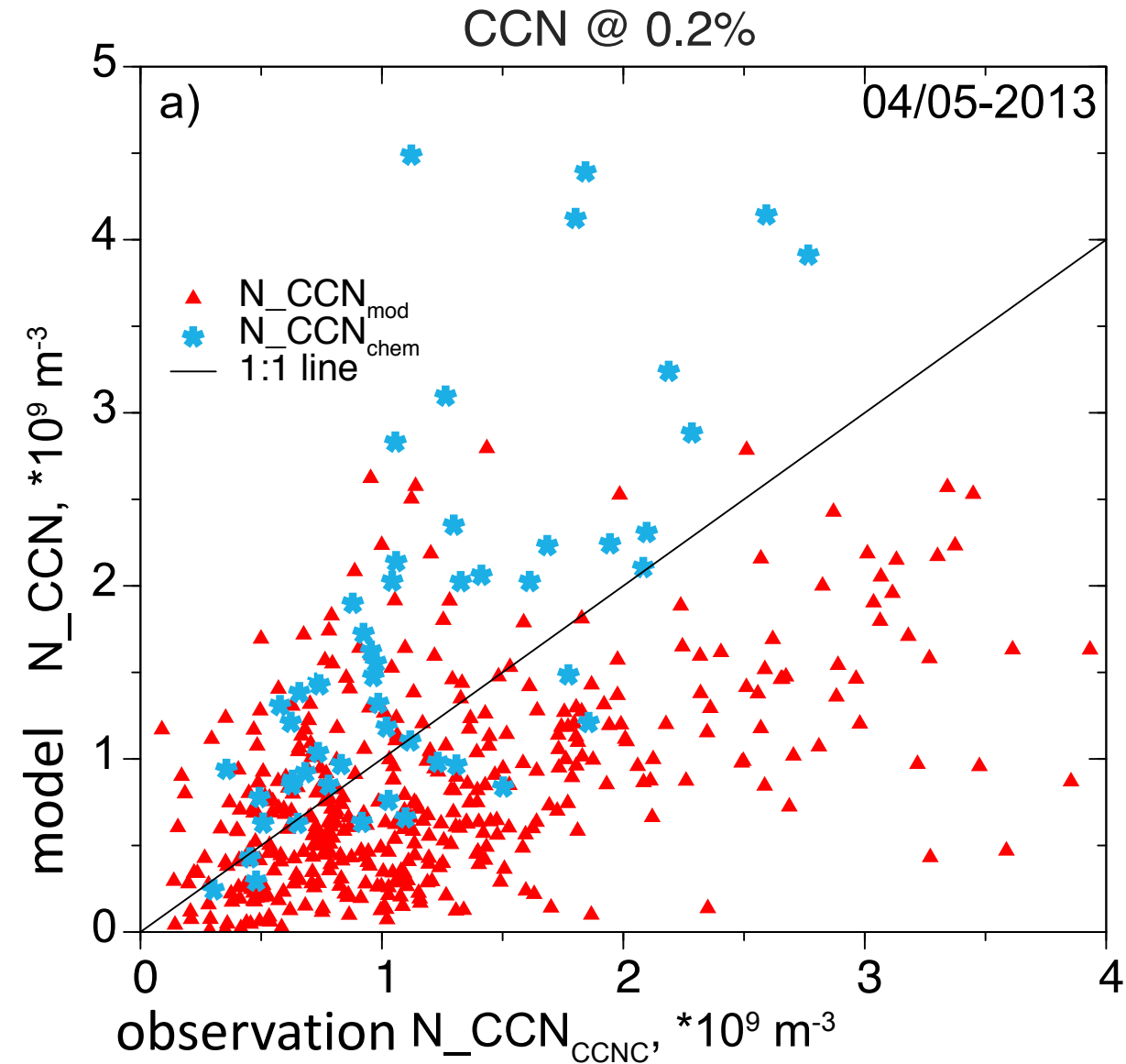
Comparison to observations (AOD: AVHRR, Northern Germany)

AOD compares well to observations in both periods, in particular the modelled reduction since 1985
Over- and underestimations are difficult to interpret because of observation uncertainty, especially for small
AOD, and scarceness of observational data set, and same meteo scenario for both cases in the model

Comparison to observations (CCNc @Melpitz, Germany)

CCN @ 0.2%

a)   04/05-2013

- ▲ N_CCN_{mod}
- ✴ N_CCN_{chem}
- —— 1:1 line

model N_CCN, $*10^9$ m^{-3}

observation N_CCN_{CCNC}, $*10^9$ m^{-3}

Activated fraction

- ◆ model
- ▲ observation

CCN number / number of particles > 40nm

supersaturation, %

N_CCN_{chem}: applying activation parameterization to chemical aerosol mass measurements

CCN @ 0.2%

Activated fraction

a)

04/05-2013

- generally good agreement
- model slightly underestimates CCN numbers at 0.2%
- this is caused by an underestimation of particles <100nm in the assumed size distributions
- size resolved treatment of aerosols is expected to improve the model system

Legend (left plot):
- N_CCN_{mod}
- N_CCN_{chem}
- 1:1 line

Legend (right plot):
- model
- observation

Left plot axes:
- y-axis: model N_CCN, $*10^9$ m^{-3}
- x-axis: observation N_CCN_{CCNC}, $*10^9$ m^{-3}

Right plot axes:
- y-axis: CCN number
- x-axis: supersaturation, %

N_CCN_{chem}: applying activation parameterization to chemical aerosol mass measurements

Genz et al., ACPD, in review

Comparison to observations (CCN: LIDAR @Melpitz, Germany)

- Modeled CCN concentrations of 2013-scenario are in the range of observations (overlap of 25-75% percentile)
- Mean overestimation is factor of ~2.
- Modeled CCN concentration of 1985 strongly exceeds today's CCN concentrations

CCN @ 0.2% Mar-Jun [cm^{-3}]

height [m]

CCN [cm^{-3}]

Legend:
- COSMO-MUSCAT perturbed mean
- COSMO-MUSCAT perturbed 25-75%
- COSMO-MUSCAT control mean
- COSMO-MUSCAT control 25-75%
- LIDAR 2013 mean
- LIDAR 2013 25-75%

Costa Surós et al., ACP, 2020
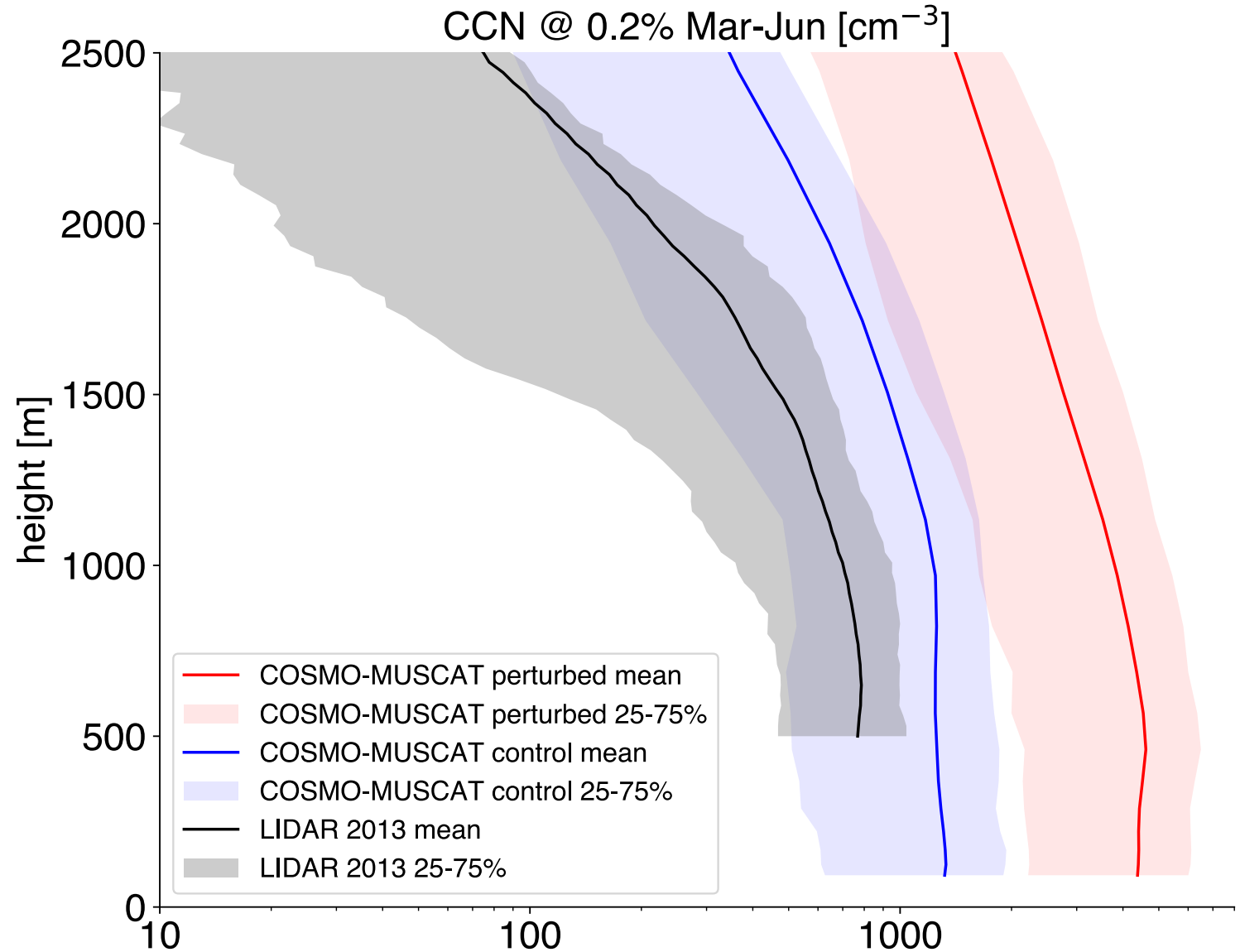
Summary

- Aerosol composition and CCN concentration in mid 1980's over Europe was simulated with COSMO-MUSCAT and compared to 2013

- In boundary layer: aerosol mass ~5 times and CCN ~2-3 higher in1980's compared to 2013

- Comparison to available observations in both time periods (AOD) reveals reasonable agreement

- Today's CCN concentrations by up to factor of 2 underestimated

- Overall, a size resolved treatment of aerosols is promising to prove the findings of this work

References

Costa-Surós, M., Sourdeval, O., Acquistapace, C., Baars, H., Carbajal Henken, C., Genz, C., Hesemann, J., Jimenez, C., König, M., Kretzschmar, J., Madenach, N., Meyer, C. I., Schrödner, R., Seifert, P., Senf, F., Brueck, M., Cioni, G., Engels, J. F., Fieg, K., Gorges, K., Heinze, R., Siligam, P. K., Burkhardt, U., Crewell, S., Hoose, C., Seifert, A., Tegen, I., and Quaas, J.: Detection and attribution of aerosol-cloud interactions in large-domain large-eddy simulations with ICON, Atmos. Chem. Phys., https://doi.org/10.5194/acp-2019-850, 2020.

Genz, C., Schrödner, R., Heinold, B., Henning, S., Baars, H., Spindler, G., and Tegen, I.: Estimation of Cloud Condensation Nuclei number concentrations and comparison to in-situ and lidar observations during the HOPE experiments, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-742, in review, 2019.