The impact of flue gas cleaning technologies in coal fired power plants on CCN distribution and consequently clouds in Germany

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Motivation

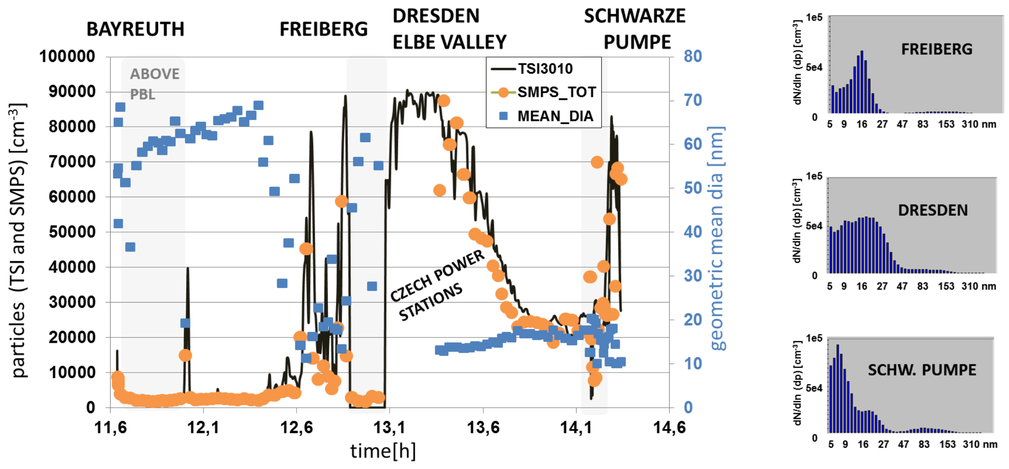
Airborne measurements showed **high number concentrations** (≈ 50 000 cm−3) of ultra-fine particles (< 50 µm) a few km **downwind of modern coal-fired power plants**.

Because this high number concentrations occur almost **independent of the daytime and are not found downwind of older coal-fired power plants** in comparable measurements, Junkermann et al. 2011 [3] concluded that **this is due to nucleation inside modern coal-fired power plants.**

We present a combination of observation, process- and regional-scale simulations to investigate the impact on particle distribution, CCN and cloud properties.

Airborne Observations

Ultrafine particle plumes encountered during a research flight with D-MIFU in Germany. **Plumes originate** from Freiberg (distance ~30 km) and Schwarze Pumpe (distance ~15 km) **power stations** as well as from several Czech power stations south of the border with subsequent transport via the Elbe valley. Size indicates that Dresden is not the source.



Nucleation inside power plants

The simulation tool AerCoDe [8] is used to **simulate the formation of sulphuric acid aerosol droplets inside the flue gas cleaning devices** (wet flue gas desulfurization).

- One-dimensional mass and energy balances
- Gas-liquid heat and mass transfer
- Aerosol population balance including classical nucleation theory (with hydrate formation [6]) and growth by condensation
- Polydisperse modeling with multiple droplet classes
- Subsequent polydisperse coagulation calculations (residence time of 20s up to stack exit)

T inlet [°C]	120	120	160	160
H_2SO_4 inlet [mg/m³] (STP)	3	10	3	10
c_N outlet WFGD [cm³]	3.81E+07	2.28E+09	2.62E+09	2.11E+09
c_N after 20 s [cm³]	**3.54E+07**	**4.36E+07**	**3.43E+07**	**4.1E+07**
D_p [nm]	**49.06**	**90.08**	**41.49**	**78.35**
H_2SO_4 outlet [mg/m³] (STP)	0.9	3.6	0.59	2.54

→ H_2SO_4 droplet **concentrations** c_n **at stack exit ~4E+07 cm^{-3}**

→ Droplet **sizes increase with higher inlet concentrations** of H_2SO_4.

References

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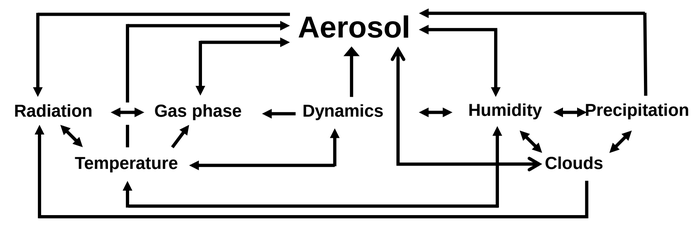
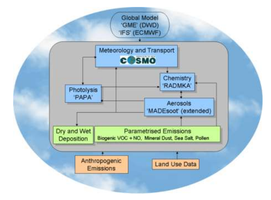
Regional Model Framework

Considered feedbacks



Online coupled model system **COSMO-ART** [7]



Aerosol

- Explicit simulation of **mass and number of 11 aerosol modes**
- **Köhler theory** to calculate diagnostic CCN(0.1%)

Gases

- Comprehensive photochemistry

Clouds Processes [1]

- Activation [2] using **updraft PDFs**
- Comprehensive full **two-moment cloud microphysics** [4]

Emissions

- Detailed anthropogenic emission data [5]
- Natural emissions parameterized online

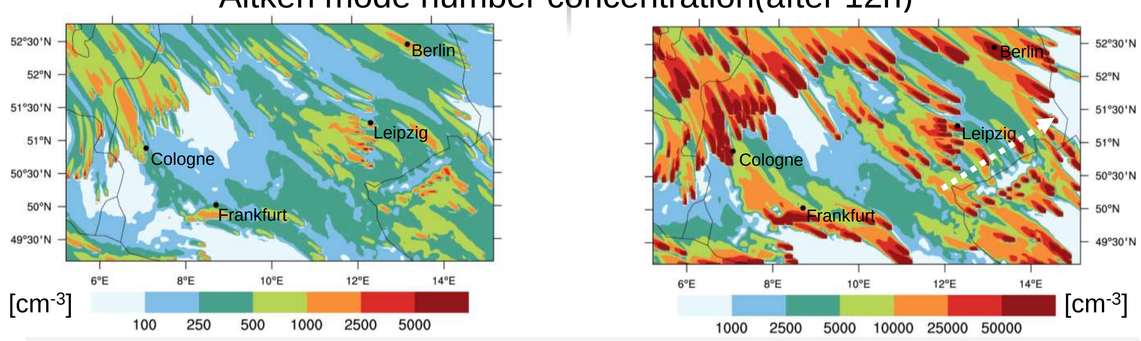
Regional Simulations (16-19.11.2011)

Setup: 2.8 km grid mesh size, 50 vertical levels, nested in a simulation of Europe with 7km grid mesh size starting 2 days before

Direct H_2SO_4 particle emissions from power plants (1.5% of SO_x)

(A) **5.5E+15 s^{-1}** particles per plant based on AerCoDe simulations | ***(B)*** **2E+18 s^{-1}** particles per plant derived from airborne observations

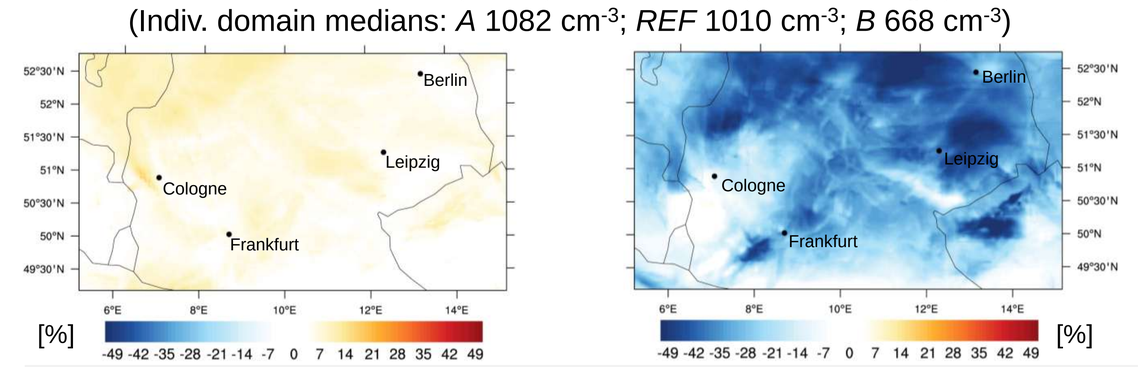
Aitken mode number concentration(after 12h)



→ Simulated **particle number concentrations in *(A)*** based on in-plant nucleation simulations **differ by a factor of >10 to *(B)*** and the observations. **What is the source of the additional particles?**

Difference in CCN(0.1%) to referenz (68h average)

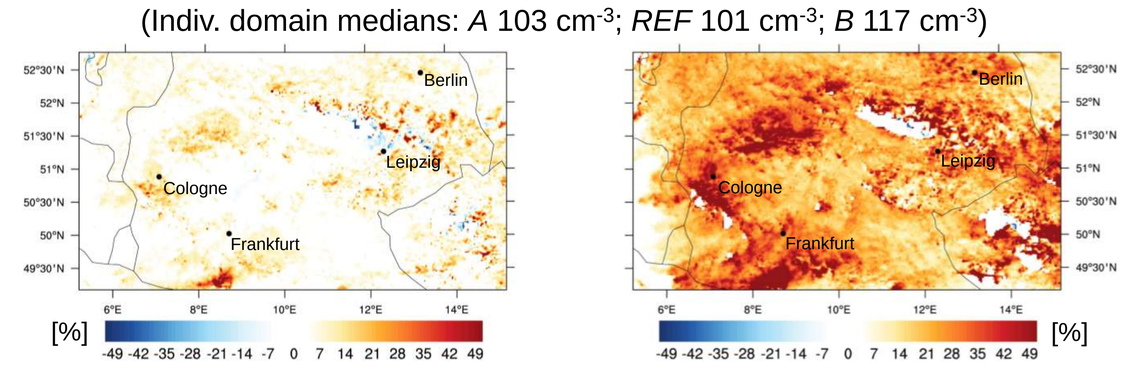
(Indiv. domain medians: *A* 1082 cm^{-3}; *REF* 1010 cm^{-3}; *B* 668 cm^{-3})



→ **In case *(A)* CCN(0.1%) are increased** up to 20% due to the additional particles. But, **CCN(0.1%) are decreased** up to 50% **in case *(B)*** due to the strong decrease in median particle diameters (< 50nm)

Difference in cloud droplet number to referenz (68h average)

(Indiv. domain medians: *A* 103 cm^{-3}; *REF* 101 cm^{-3}; *B* 117 cm^{-3})



→ **Cloud droplet numbers are increased in both cases.** With a **stronger increase up to 50% in case *(B)*** caused by **activation of small particles** at the upper part of the updraft PDF (s>0.1%!).