

COSMO-ART – The Impact of Aerosol Particles on Warm Clouds and Precipitation on the Regional Scale

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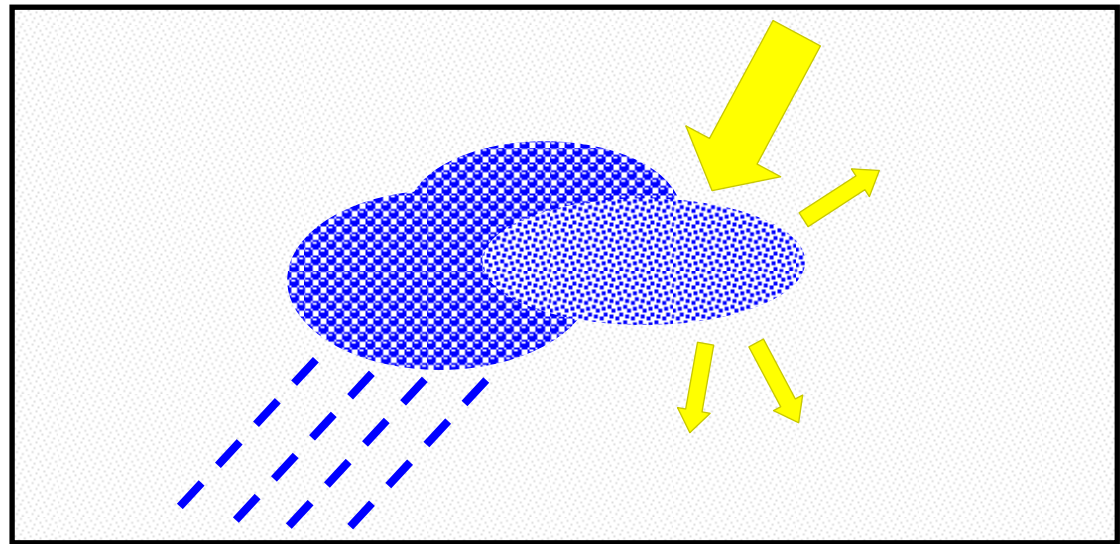
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Interaction of Aerosol Particles with the Atmosphere

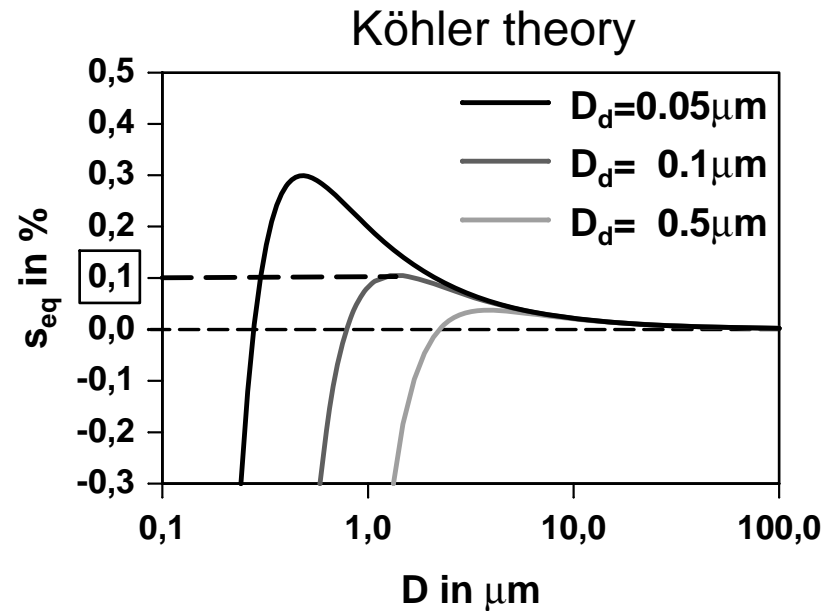
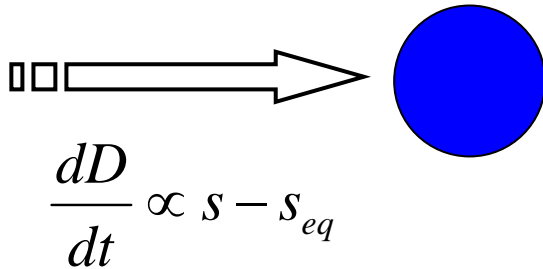
Radiation



Clouds and Precipitation



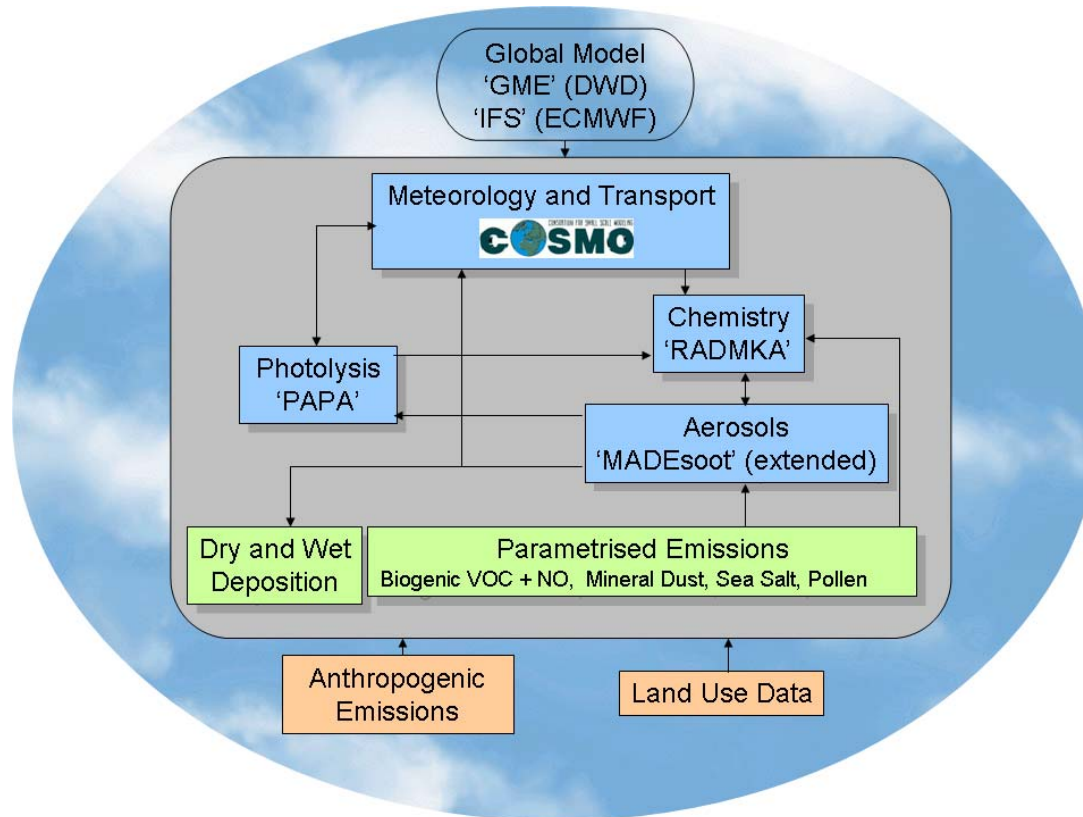
Activation of Aerosol Particles



The activation of an aerosol particle is a nonlinear function of:

- the supersaturation s ,
- the dry size D_d and the chemical composition of the aerosol particle.

COSMO-ART

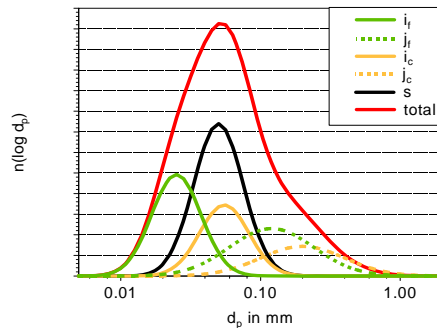


Aerosol and Cloud Representation

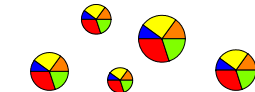
MADE_{soot}

Budget equations for number and mass.

Five Modes with log-normal distributions.



2x SO_4^{2-} , NO_3^- , NH_4^+ ,
 H_2O , SOA



1x Soot



2x SO_4^{2-} , NO_3^- , NH_4^+ ,
 H_2O , SOA, Soot



Processes:

nucleation, condensation, and coagulation.

hydci_pp

Budget equations for the mass fractions of:

Water vapor
Cloud water
Rain
Cloud ice
Snow

Autoconversion (Seifert &
Beheng, 2001):

Cloud water → Rain

Coupling of Aerosol and Clouds

Activation of the particles:

- **Parameterisation of the maximum supersaturation** as a function of vertical velocity, aerosol size distribution and aerosol chemical composition (Abdul-Razzak & Ghan, 2000)
- **Integration of the aerosol size distribution** based on the Köhler theory to determine the number of CCN for a specific supersaturation
- **Activation of particles** is restricted to the transport of cloud free air into the cloud base:

$$AKT = -\frac{\partial}{\partial z} CCN_w + \frac{\partial}{\partial z} K \frac{\partial}{\partial z} CCN$$

Warm cloud microphysics:

- **Additional budget equation for cloud droplet number** using the parameterisation of Seifert & Beheng (2001) for autoconversion and selfcollection:

$$\frac{\partial}{\partial t} N_c = ADV + DIFF + AKT - AU - SC - MIKRO$$

- **Autoconversion for number and mass fractions** depending on cloud droplet number.



Impact of aerosol on warm precipitation

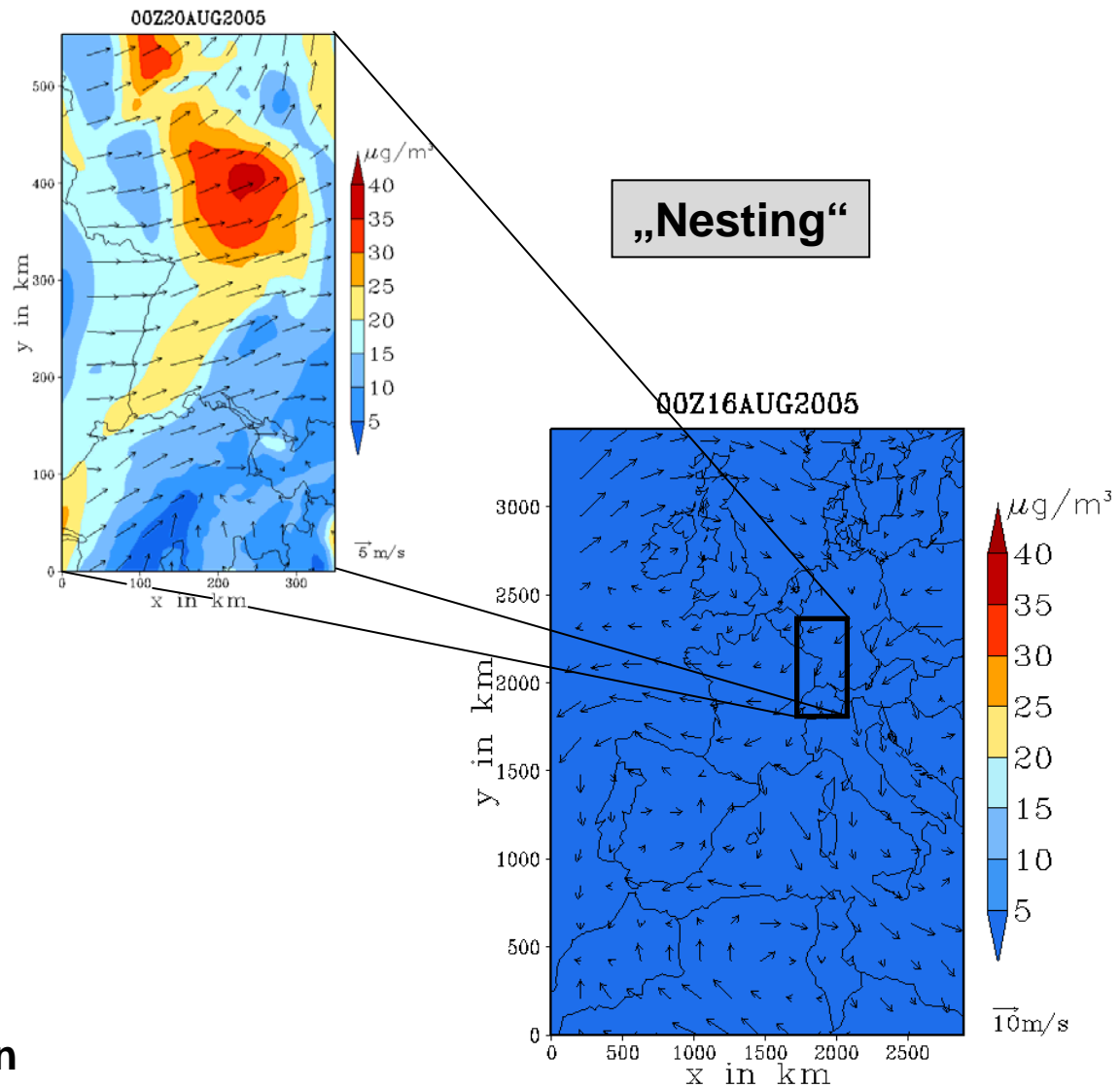
Simulations

16.-20. August 2005:

- 16.-18. Aug.
High pressure
- 19.-20. Aug.
Low over the North Sea
- 19 Aug. 20 UTC
A weak front system
reaches the model domain

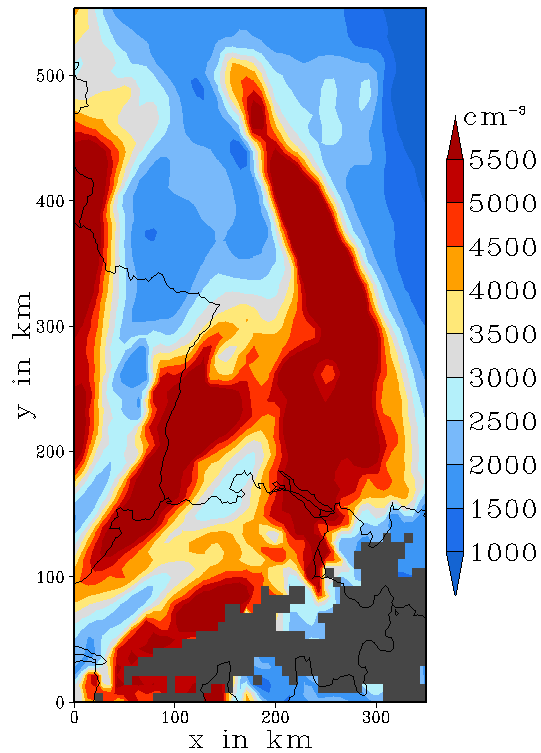
Setting:

- 7 km resolution, 10s timestep
- No convection parameterisation

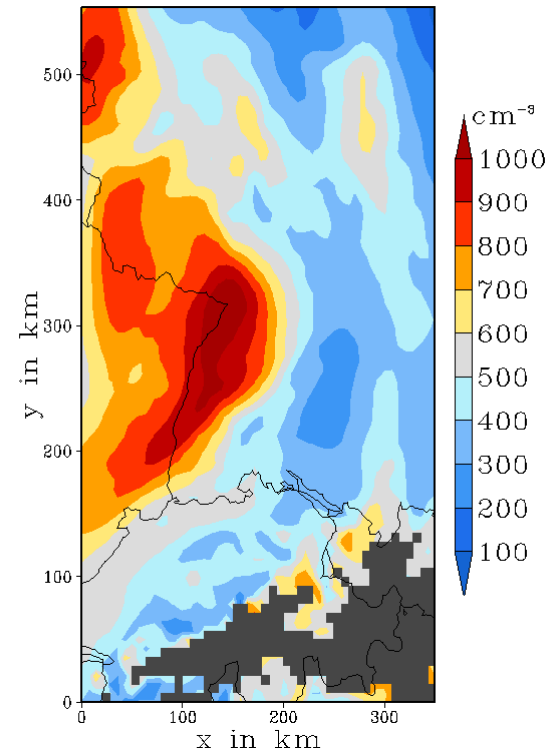


Distribution of CCN

Aerosol number density



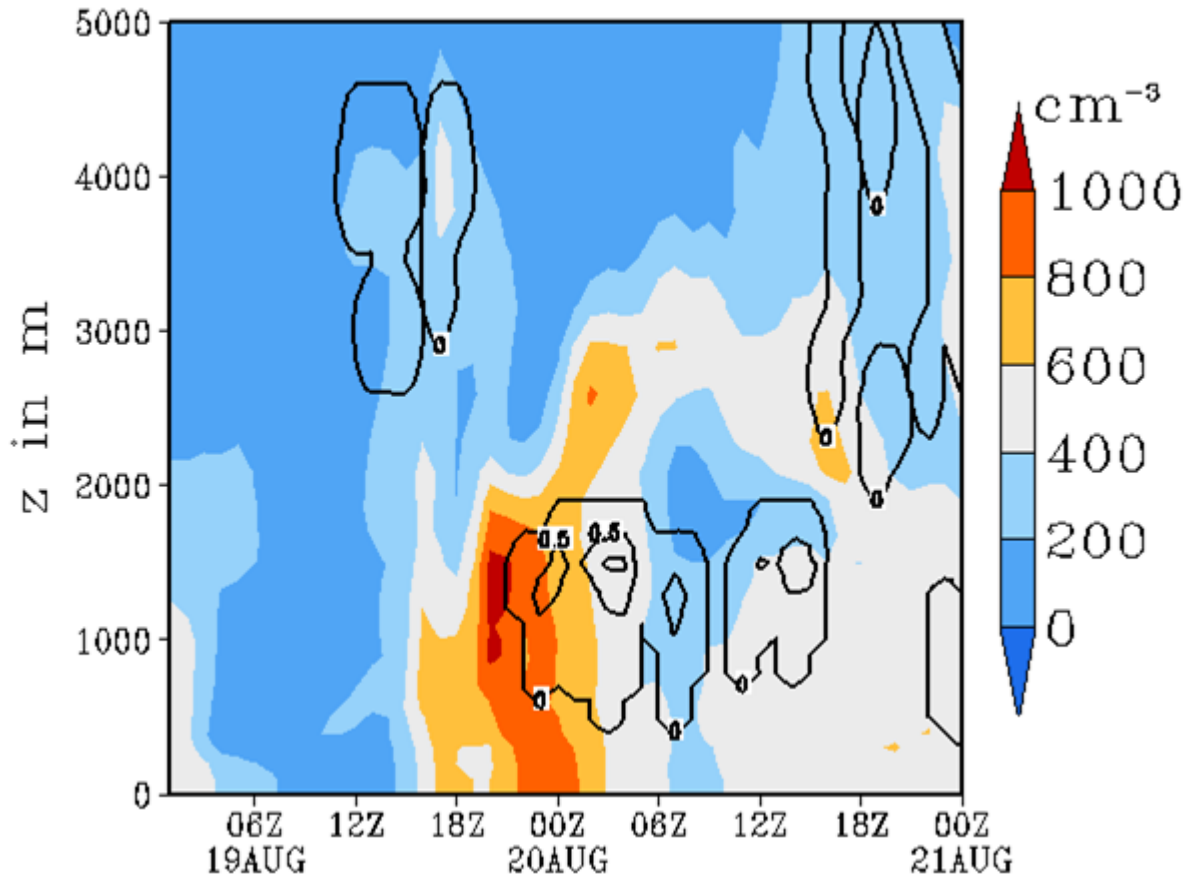
CCN number density



20 UTC 19. Aug.
Height: 1500 m

CCN shown for
0.1% supersaturation

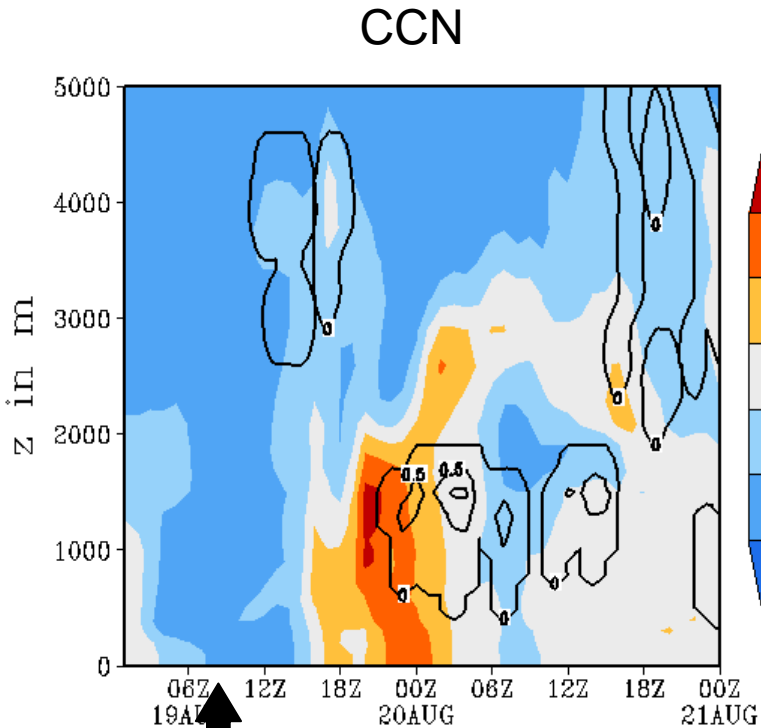
CCN and Cloud Water at Karlsruhe



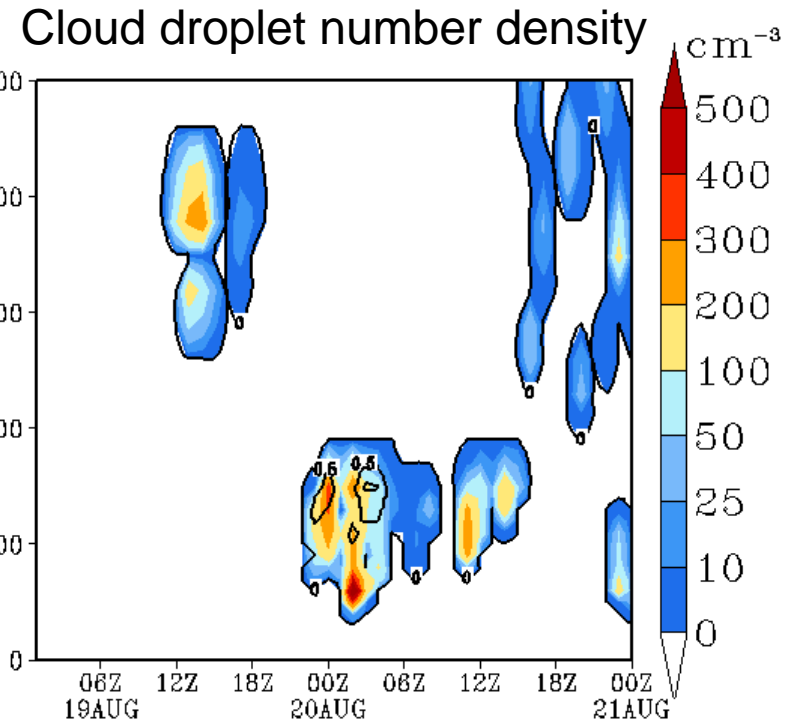
CCN shown for
0.1% supersaturation

Simulation of Cloud Droplet Number

Karlsruhe

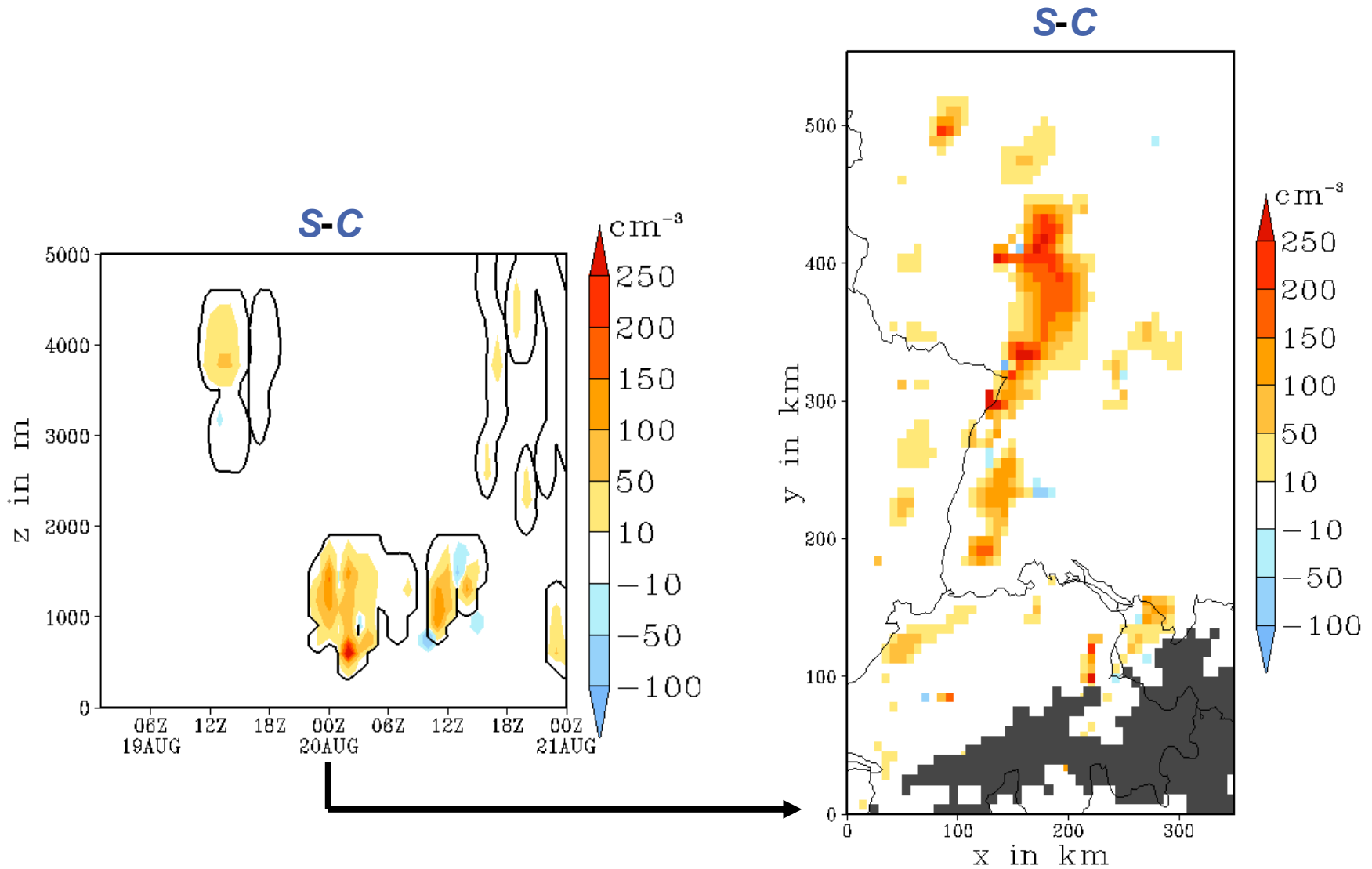


Simulation C



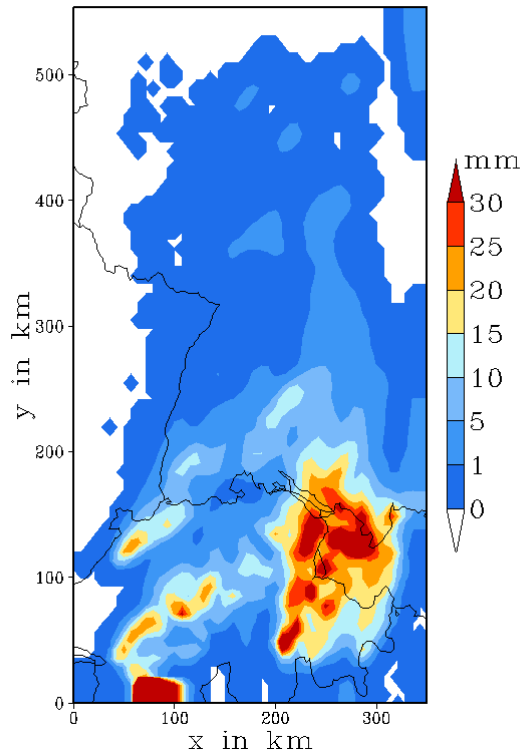
Simulation S

Difference in Cloud Droplet Number



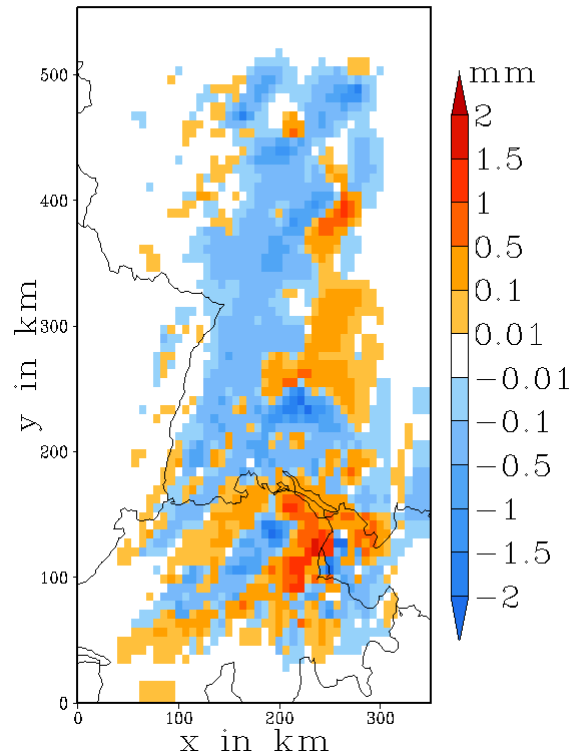
Impact of Aerosol on Total Precipitation

12 h total precipitation



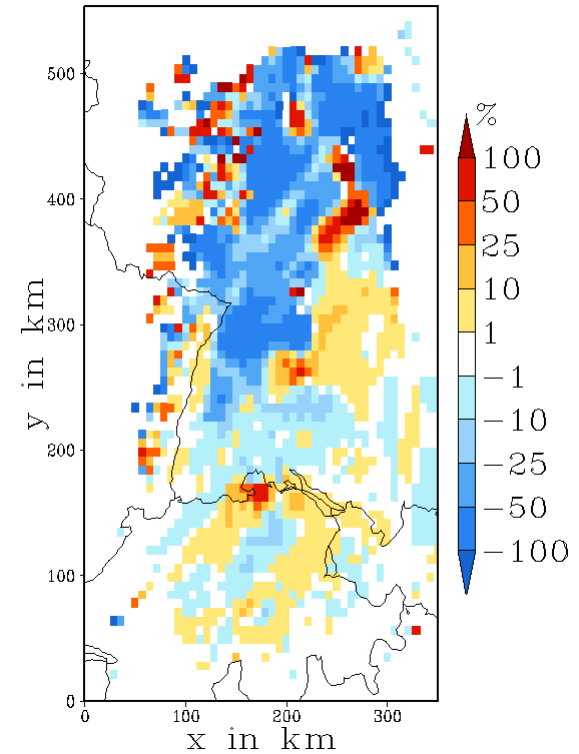
C

Difference in precipitation



S-C

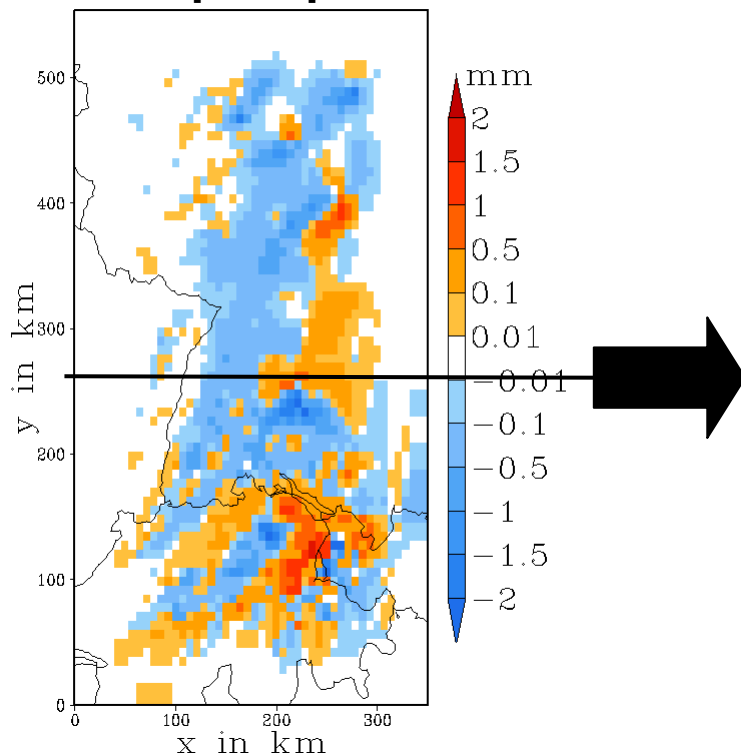
Relative difference in precipitation



(S-C)/C

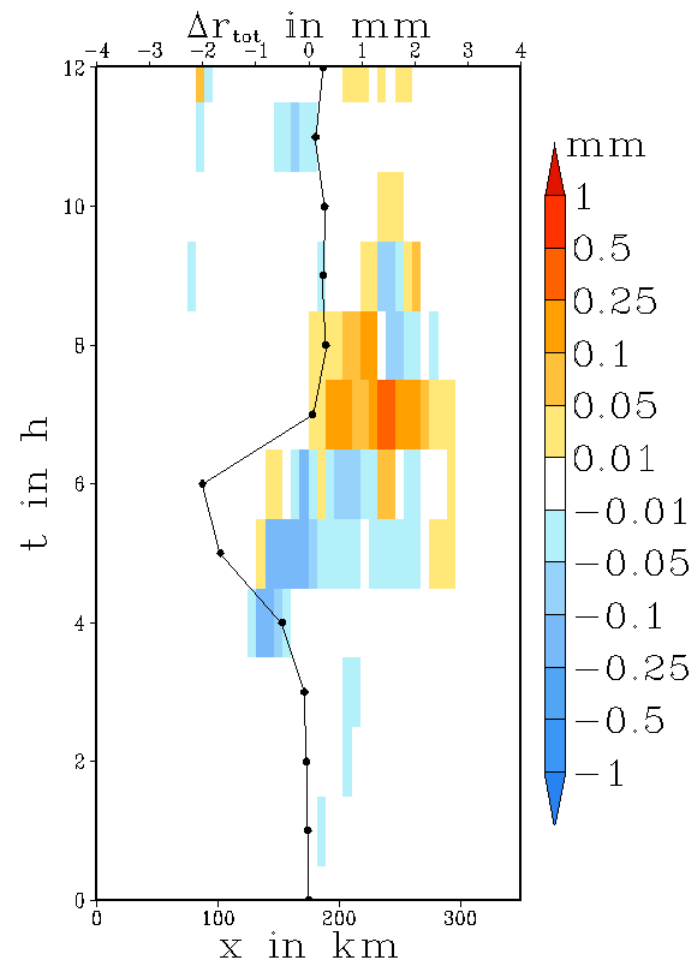
Impact on Development of Precipitation

Difference in total precipitation



S-C

Difference in hourly precipitation



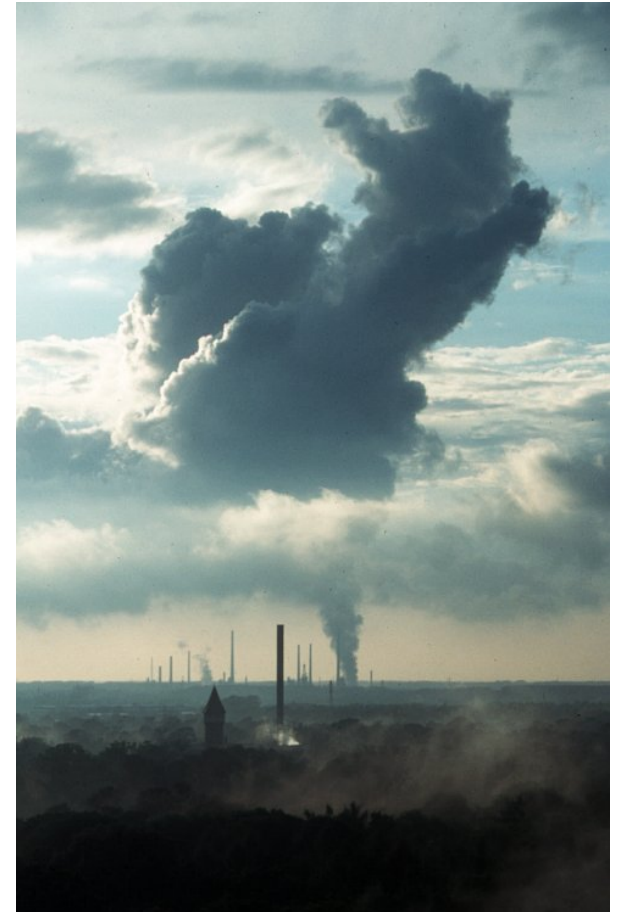
Summary

■ COSMO-ART

- Simulation of cloud condensation nuclei.
- Influence of aerosol on cloud droplet number.
- Impact of aerosol on precipitation formation.

■ First Results

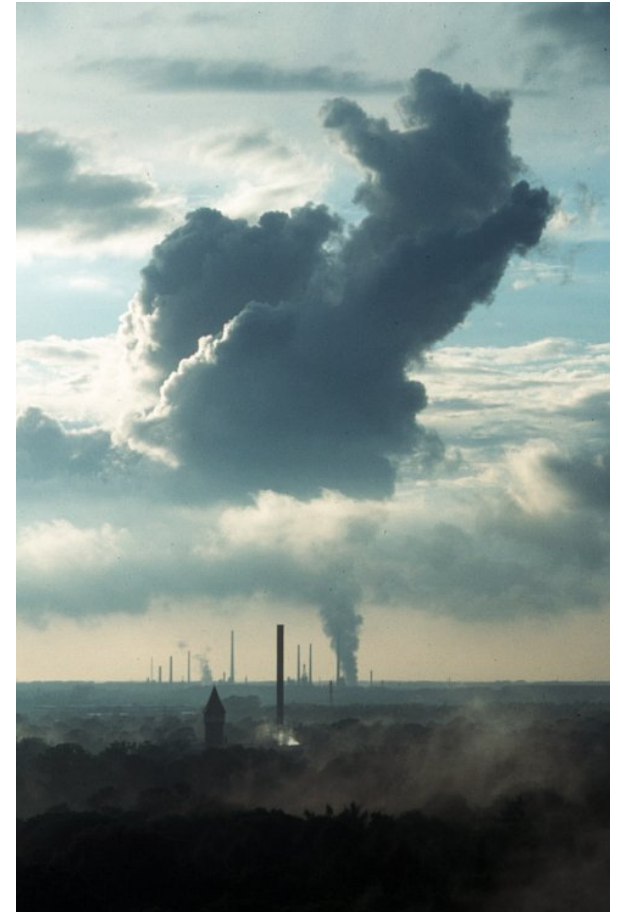
- CCN-distribution is very variable in space and time.
- Distribution of CCN and clouds are strongly related especially at higher altitudes.
- Spatial and temporal shifts in precipitation due to the variations in the CCN-distribution.
- Modification of precipitation most significant for drizzle.



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Outlook

- **Case studies for Europe.**
- **Modification of Aerosol particles inside clouds.**
- **Modification of cloud optical properties.**
- **Investigation and quantification of feedback processes.**



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Thank You!

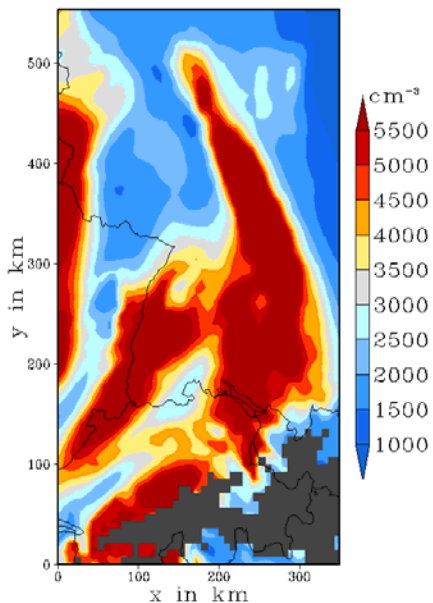


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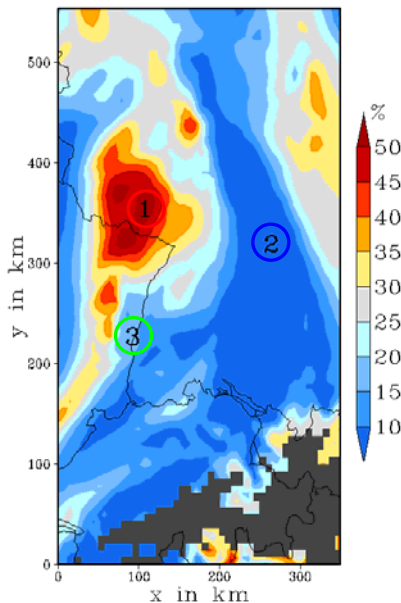


Distribution of CCN

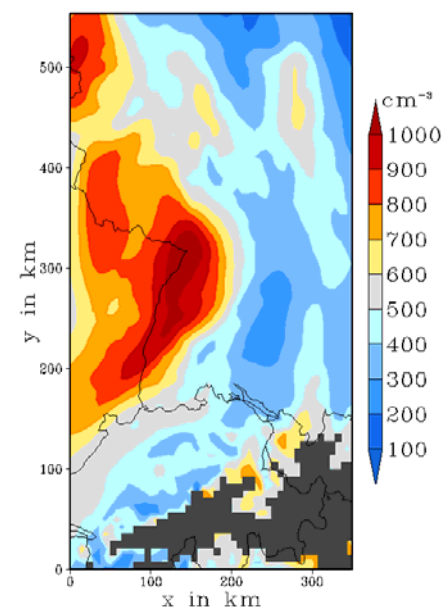
Aerosol number density



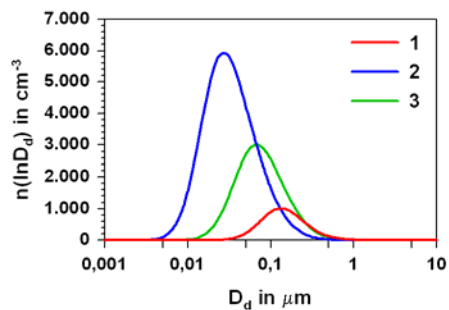
Fraction of CCN



CCN number density



Aerosol size distribution:

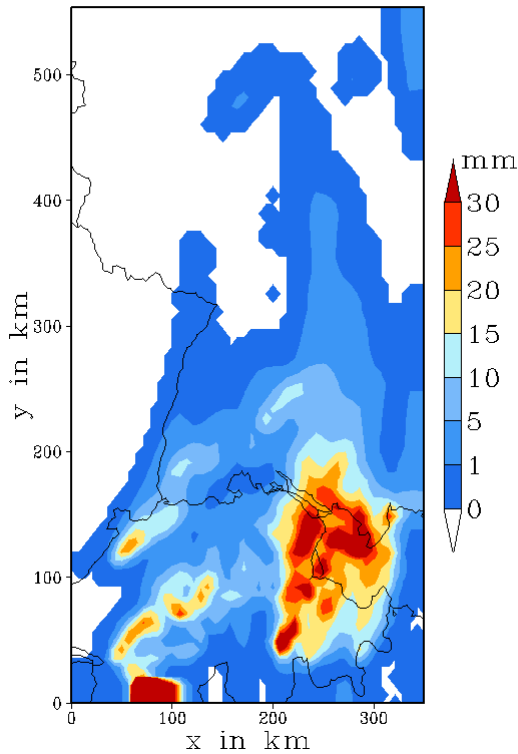


**CCN shown for
0.1% supersaturation**

**20 UTC 19. Aug.
Height: 1500 m**

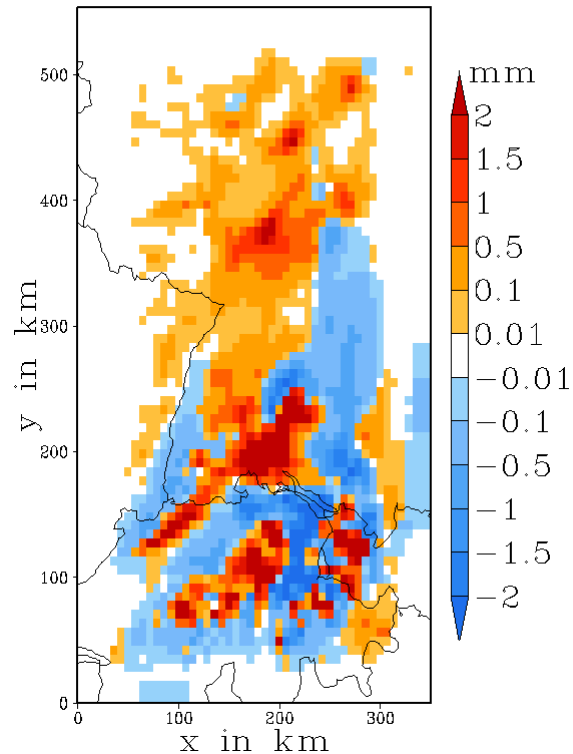
Difference to operational COSMO

12 h total precipitation



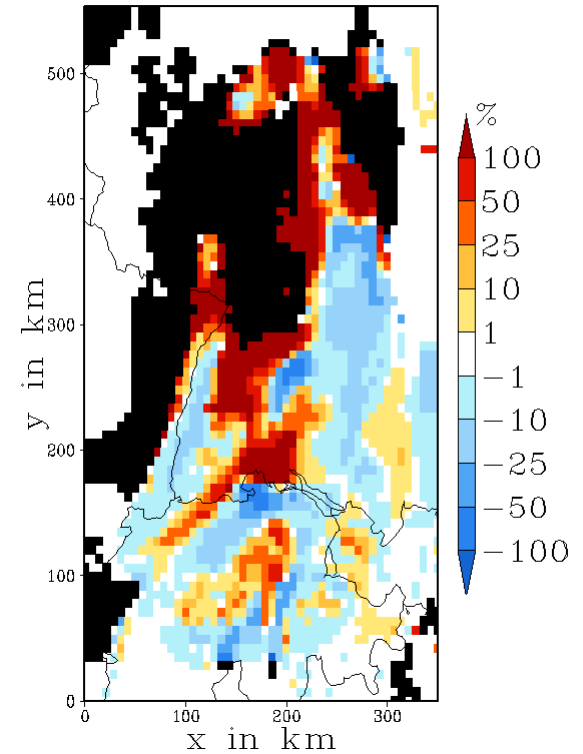
C

Difference in precipitation



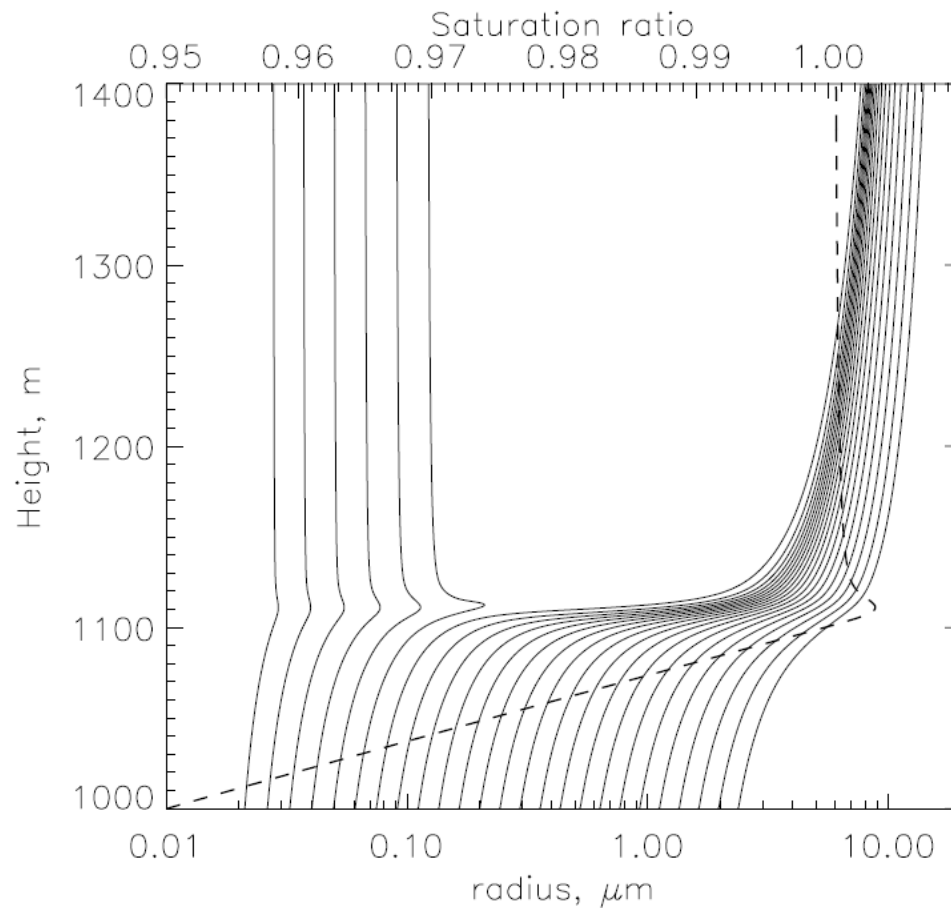
S-O

Relative difference in precipitation



(S-O)/O

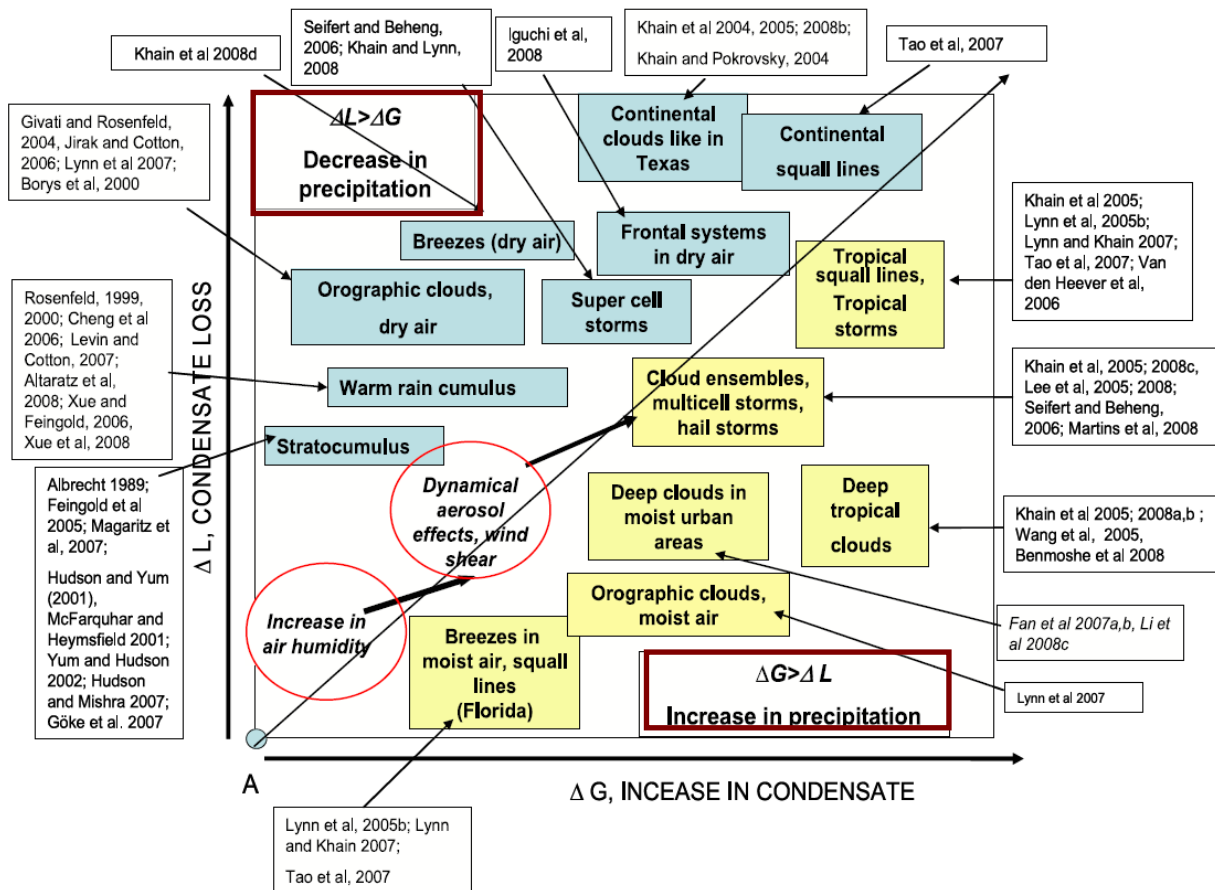
Activation of Aerosol Particles



McFiggans, 2006

Impact of Aerosol on Precipitation

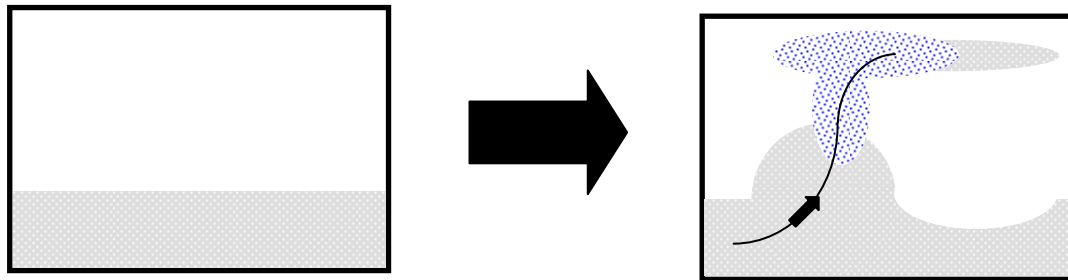
Impact of an enhanced aerosol particle number



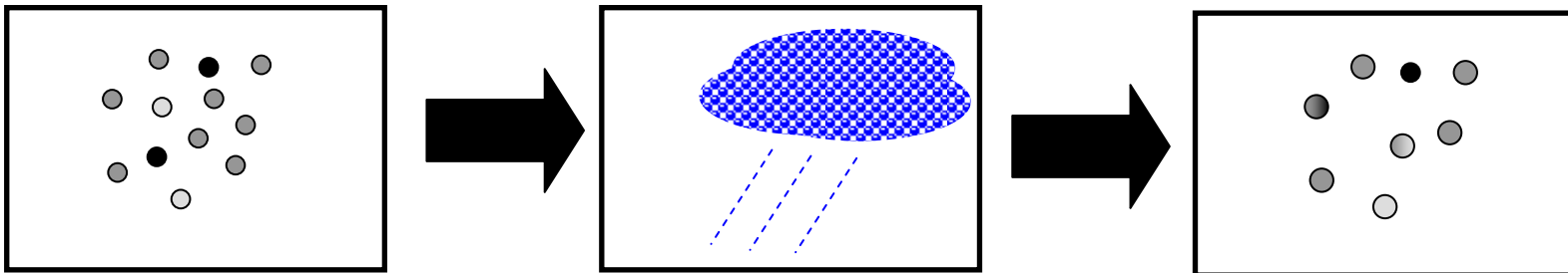
Khain, 2009

Impacts of Clouds on the Aerosol

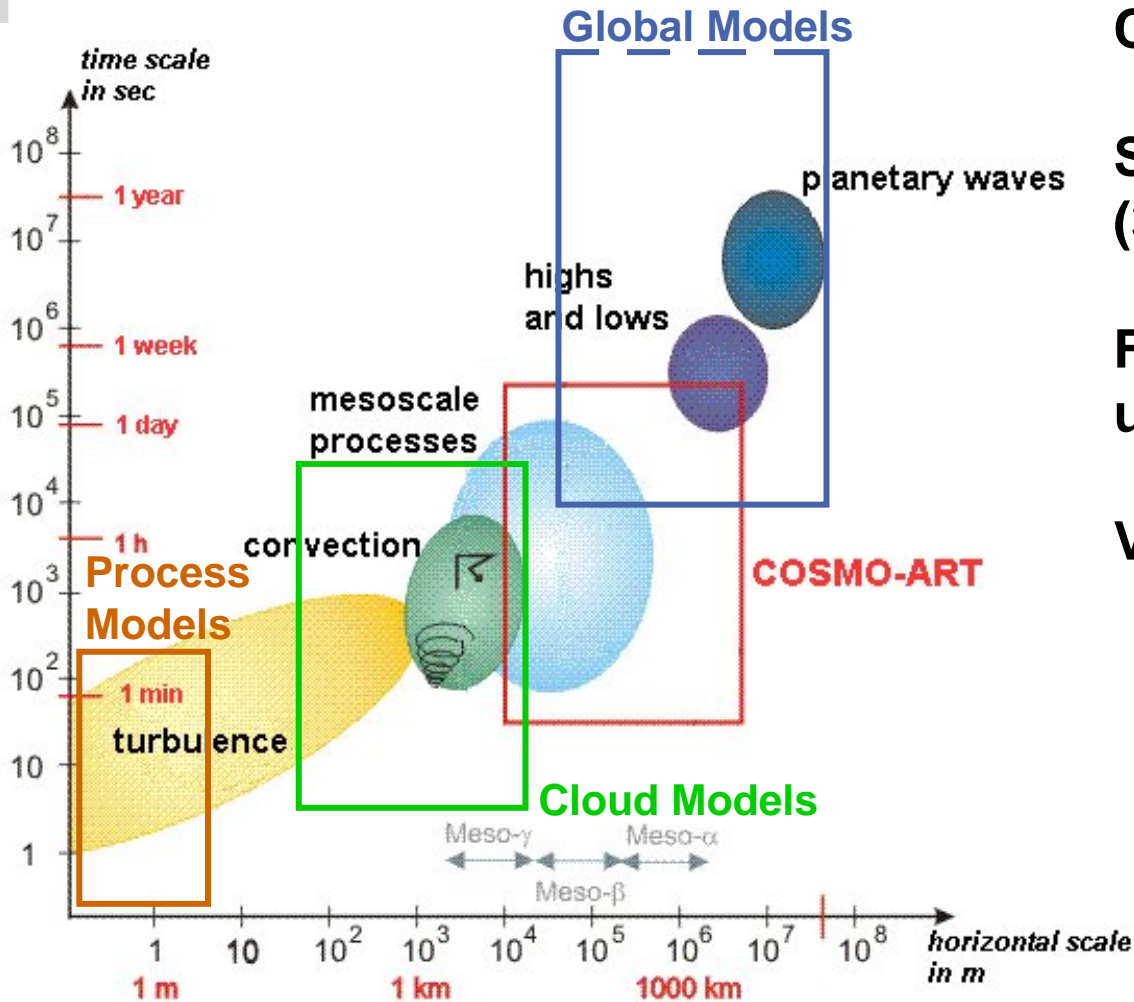
- Clouds are dynamical systems which modify the spatial distribution of aerosol particles especially in the vertical.



- The scavenged aerosol particles were modified inside the cloud due to microphysical and chemical processes.



Typical Scales of numeric Models treating Aerosol-Cloud-Interactions



COSMO-ART:

Spatial Resolutions:
(3 km) 7km 14 km

**Focus on regional
up to continental scales.**

Various domains:
South-West Germany,
Europe,
Africa,
Mediterranean Sea,
....

Some Equations

■ **Supersaturation:**

$$\frac{ds}{dt} = \alpha w - \gamma \frac{\partial q_c}{\partial t}$$

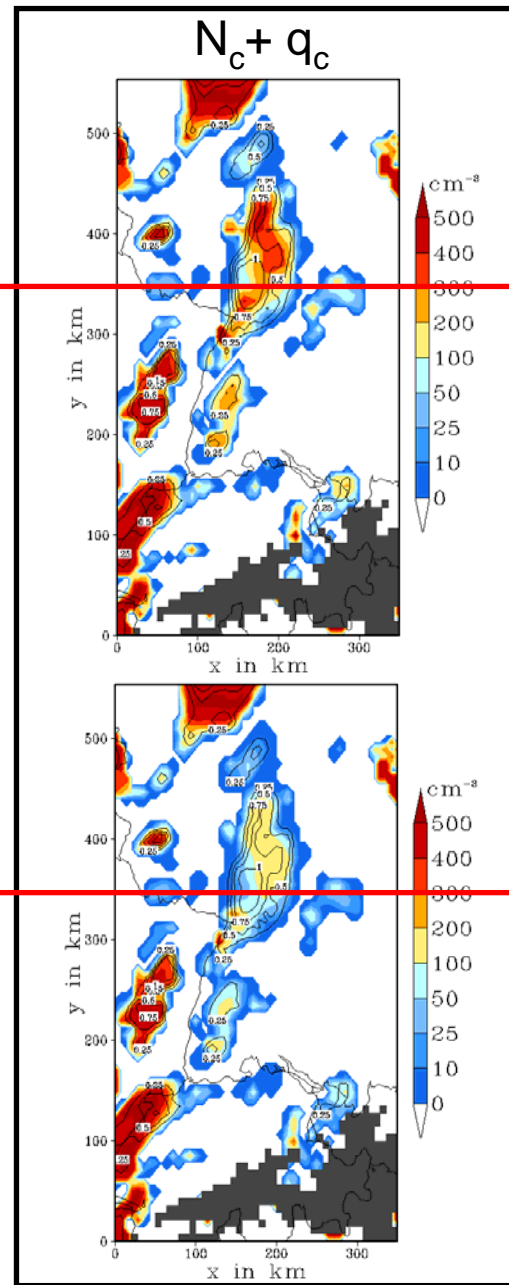
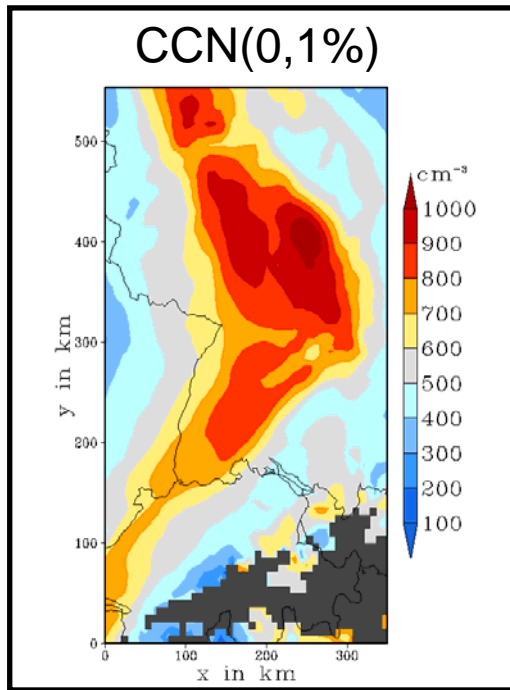
■ **Minimum Diameter:**

$$D_l^*(s) = \left(\frac{4A^3 \rho_w M_s}{27\nu_s \rho_s M_w s^2} \right)^{1/3}$$

■ **CCN Integration:**

$$CCN = \sum_l \int_{D_l^*}^{\infty} n_l(D) dD$$

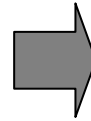
S



0 UTC 20. Aug.

C

CCN(0,1%)
200 cm⁻³



Impact on Cloud Water and Radiation

05 UTC 20. Aug.

