Cloud parcel modeling of CCN activation in megacity air based on observations from Beijing


(1) Max Planck Institute for Chemistry, Biogeochemistry Department, Mainz, Germany, (2) Johannes Gutenberg University Mainz, Institute for Atmospheric Physics, Mainz, Germany
(3) Leibniz Institute for Tropospheric Research, Leipzig, Germany, (4) College of Environmental Sciences and Engineering, Peking University, Beijing, China

Contact: hsu@mpch-mainz.mpg.de

(1) Motivation

High aerosol loadings lead to more droplets in the air? Both the aerosol (a) size distribution and its (b) chemical composition changed during the particle growth events. Which characteristic matters more for cloud-nucleation ability of aerosol particles?

(2) Cloud Parcel Model Description

Condensation growth equation:

\[ \frac{dn}{dt} = \frac{4 \pi r (s - s_{eq})}{R_T T} \]

Start at 95% RH, stop at 8 g/kg LWC

\[ S_{eq} \text{ calculated by } \kappa \text{ Köhler equation, in which } \kappa \text{ represented the hygroscopicity of particles} \]

Activation of aerosols in one simulation

(3) Input (Measurement Data)

Average size distribution at Yufa site during CAREBEIJING 2006 campaign

Distribution of size resolved hygroscopicity \( \kappa \)

(4) Regimes of Cloud Droplet Formation (Modeling Results)

- Based on average size distribution and \( \kappa \) values, numerous simulations were made by varying \( N_{CN} \) and \( w \).
- Three different regimes of cloud droplet formation were found depending on the \( \kappa w/N_{CN} \):
  - Aerosol-limited regime
  - Updraft-limited regime
  - Intermediate regime
- Median \( N_{CN} \) depends on both \( w \) and \( N_{CN} \)
- Beijing lies in the updraft-limited regime (red circles in the figures):
  - \( N_{CN} \) - 20\( \times 10^{3} \) cm\(^{-3} \), updraft velocity \( w = 0.5-2.0 \) ms\(^{-1} \)

(5) Particle Growth Events at Yufa Site, Beijing (Measurement Data)

- Particle size and composition (hygroscopicity) changed during each event
- Two methods were used to compare the contribution of changes in size and composition to CCN activity:
  - Constant supersaturation, mostly used in CCN measurements
  - Constant updraft velocity, parcel model simulation, counting the competition of water vapor.
- About 9% of the increase was caused by change in \( \kappa \), while 91% was caused by change in size.

(6) Cloud Parcel Modeling VS Constant \( \kappa \)

Constant updraft velocity (10 m s\(^{-1} \))

Constant supersaturation (0.79%)

Fraction of activated aerosol concentration \( \frac{N_{CN}}{N_{CN}} \)

(7) Conclusions

Megacities lie in the updraft-limited regime of CCN activation. High aerosol loadings lead to a significant decrease in LWC largely depressing the CCN activation process.

Evidence from parcel model simulations and CCN measurements shows that the increase of aerosol sizes in particle growth events is more important than the increase of the hygroscopicity for their cloud-nucleation abilities.

Acknowledgement

This work was funded by the Max Planck Society (MPG) and the European integrated project on aerosol cloud climate and air quality interactions (EUCAARI). The authors gratefully acknowledge support by the hosts, organizers, team, and funding agencies of CAREBEIJING2006.

References