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

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(1) Motivation

(1) **High aerosol loadings** were often observed in megacities. Does this result in **more droplets** in the air?
(2) 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 ?

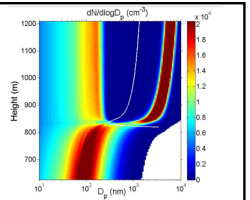
(2) Cloud Parcel Model Description

- Condensation growth equation :

$$\frac{dm}{dt} = \frac{4\pi r (s_\infty - s_{eq})}{\left(\frac{L_V}{R_V T} - 1\right)\frac{L_V}{K^* T} + \frac{R_V T}{e_{s,w}(T) D^*}}$$

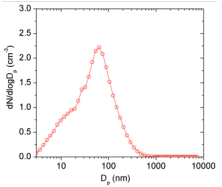
- Start at 95% RH, stop at 8 g/kg LWC
- S_{eq} calculated by κ- Köhler equation, in which κ represented the **hygroscopicity** of particles

$$S_{eq} = \frac{D_w^3 - D_d^3}{D_w^3 - D_d^3(1-\kappa)} \exp\left(\frac{4\sigma_s M_w}{RT\rho_w D_w}\right)$$

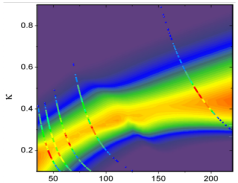


Activation of aerosols in one simulation

(3) Input (Measurement Data)

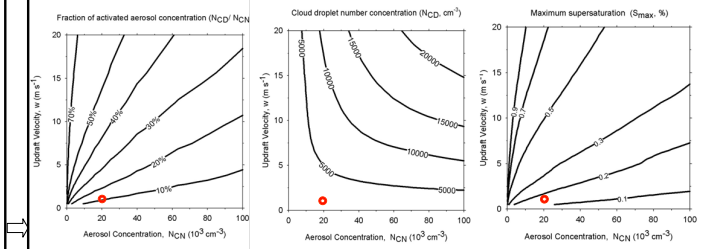


Average Size Distribution at Yufa site during CAREBEIJING 2006 campaign



Distribution of size resolved ***hygroscopicity κ*** *(Lines show measured data points, while the contour plots show interpolation from the measurements)*

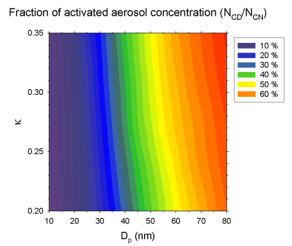
(4) Regimes of Cloud Droplet Formation (Modeling Results)



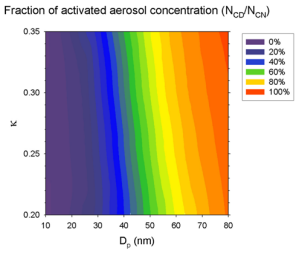
- Based on average size distribution and κ values, numerous simulations were made by varying N_{CN} and w.
- Three different regimes of cloud droplet formation were found depending on the (w/N_{CN}):
  - Aerosol-limited regime
    High w/N_{CN}, N_{CD} depends on N_{CN}
  - Updraft-limited regime
  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

(6) Cloud Parcel Modeling VS Constant *S*

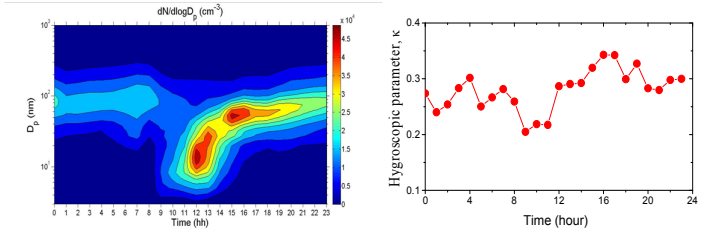
Constant updraft velocity (10 m s^{-1})



Constant Supersaturation (0.79 %)



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



- Particle **size** and **composition** (**hygroscopicity**) changed during each event
  - **Size**: from 10 nm to 80 nm (12:00 - 16:00)
  - **Hygroscopic parameter** κ: from 0.2 to 0.35 (12:00 - 16:00)
- 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 κ while **91%** was caused by change in **size**.

(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**.

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