Clouds play an important role in the climate system and are one of the major uncertainties in general circulation models. Cloud properties are affected by aerosol particles, which serve as cloud condensation nuclei (CCN), and influence the climate by modifying the staring and dynamic of clouds. Moreover, global models incorporate different versions of these interactions between aerosol-cloud and climate; due to the difficulty in parameterizing clouds to simulate uncertainty in climate predictions there is a need to improve the large-scale cloud scheme and coupling within aerosol models.

**Model description**

**EMAC (ECHAM5-MPI) Atmospheric Chemistry Model**

The base grid resolution model is the ECHAM5 [Röseger et al., 2004] combined with the Modular Earth Submodel System (Jöckel et al., 2005, 2006). The description of the EMAC model and evaluation see Jöckel et al. (2006, 2005) or http://www.messy-interface.org.

Cloud droplet parameterization: Abdul Razak & Ghan scheme

The ARG cloud droplet scheme prognostically determines the cloud droplet number concentration and mass from a prognostic aerosol model (GMXe, ISORROPIA) implemented in the EMAC model. This approach offers a more realistic treatment of the interactions between cloud aerosol and chemistry, although explicitly calculating the aerosol activation and so prognostically derives the number of CCN and later on cloud droplet numbers. (Herlin et al. 2001 and Abdul-Razzak & Ghan, 2003, 2001).

Aerosol activation scheme: K-Köhler theory

The effective hygroscopicity parameter kappa represents the relationship between particle components and their actual solubility (Koehler theory: Kelvin effect + Raoult effect). Increasing aerosol has more potential to form cloud, but also more remaining cloud drop. It reflects the situation of smaller, or bigger growth, which is depending on the atmospheric temperature, pressure, etc. Larger aerosol with more growth will lower as the 0.4/2.2.

**Experiments**

The model was run for a year with a spectral resolution of T42 degrees and with 19 levels (Jöckel et al., 2006). Other versions of the model (ARG) with different hygroscopic properties were used.

**Global performance of the prognostic cloud droplet nucleation scheme and the effective aerosol hygroscopicity parameter in the EMAC model**

**Motivation**

The effective hygroscopicity parameter kappa represents the relationship between particle components and their actual solubility. It directly influences the distribution of cloud droplet activation, precipitation, and total radiation budget of the Earth-ocean-atmosphere system. Several uncertainties due to description of individual microphysical and chemical processes exist in the interpretation of results. New version of the model improves the understanding of the interactions between cloud, aerosols and chemistry as it explicitly calculates the aerosol activation and so prognostically derives the number of CCN and later on cloud droplet numbers (Herlin et al. 2001 and Abdul-Razzak & Ghan, 2003, 2001). Further studies: Closer investigation of sensitivities to model parameters with kappa values. Developing of combining approaches on correct cloud scheme.

**Conclusions**

Global performance of the prognostic cloud droplet nucleation scheme and the effective aerosol hygroscopicity parameter in the EMAC model

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**References**


**Table**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ARG</th>
<th>ARG_K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud droplet number concentration (cm⁻³)</td>
<td>1.28 x 10⁹</td>
<td>1.20 x 10⁹</td>
</tr>
<tr>
<td>Large-scale Liquid Water Path (g/m²)</td>
<td>30 mm/day</td>
<td>30 mm/day</td>
</tr>
<tr>
<td>Small-scale Liquid Water Path (g/m²)</td>
<td>30 mm/day</td>
<td>30 mm/day</td>
</tr>
<tr>
<td>Radiative forcing at top (W/m²)</td>
<td>Net CRF (W/m²)</td>
<td>Net LCF (W/m²)</td>
</tr>
<tr>
<td>500</td>
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<td>600</td>
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<td>-46.28</td>
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<td>-22.5</td>
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<td>-4.5</td>
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</tbody>
</table>

**Results:**

Cloud properties & AIE (Aerosol Indirect Effect)

Global distribution of Cloud effective radius (μm): two size effects on ocean and coastal regions

Cloud droplet parameterization: Abdul Razzak & Ghan scheme

Chemical composition is more sensitive on small size of aerosol mode (Aitken). This small difference impacts on radiative forcing on climate directly and indirectly.

Cloud droplet number concentration (N/cm³)

Cloud droplet parameterization: Abdul Razzak & Ghan scheme

Cloud droplet number concentration (N/cm³)

Global distribution of daily total precipitation (mm/day)

Net cloud radiative forcing at top (W/m²)

Global distribution of total cloud cover

Cloud directly influences on the radiation budget of the Earth-ocean-atmosphere system. Several uncertainties due to description of individual microphysical and chemical processes exist in the interpretation of results. New version of the model improves the understanding of the interactions between cloud, aerosols and chemistry as it explicitly calculates the aerosol activation and so prognostically derives the number of CCN and later on cloud droplet numbers (Herlin et al. 2001 and Abdul-Razzak & Ghan, 2003, 2001).

Further studies:

- Investigating the atmospheric chemistry on aerosol effects in GCMs and possibly improving the cloud parameterization schemes.

- Closer investigations of sensitivities to model parameters with kappa values.

Development of combining approaches on correct cloud scheme.

**Limitations**

- Need to evaluate these parameterizations with the quantity of the global aerosol emissions, - comparison of selected regions with observations, - several uncertainties due to description of individual microphysical and chemical processes.

Some well known aerosol species are comparably well understood, major uncertainties of the model: > BC, > black carbon (BC), and > black carbon (BC) and > black carbon (BC) and > black carbon (BC) and > black carbon (BC).

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