Simulation of the visibility in presence of anthropogenic aerosol on the regional scale with COSMO-ART

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Motivation

- The visibility is of great interest on short term with respect to air and surface traffic and on long term also for tourism.

- The presence of aerosol causes a higher turbidity in the atmosphere and therefore a reduction of the visibility due to the scattering and absorption of light.

- In industrialized and due to the lifetime of the particles in the atmosphere even in the remote areas the visibility is remarkably modified by anthropogenic aerosol particles.

- Current weather prediction models are forecasting the visibility based on standard atmospheric variables as humidity and on assumed climatological aerosol distributions. The model system COSMO-ART gives the possibility to simulate the influence of the variability of anthropogenic aerosol on the visibility.
Methods

- Simulation of concentration fields of gas phase and particle phase species and the optical properties of particles (extinction) with COSMO-ART in a nested version.

- Calculation of the visibility using
  a) the Koschmieder equation (constant extinction coefficient)
  b) the contrast reduction of a dark object against the horizon (horizontally varying extinction coefficient)

- Comparison of the two methods with measurements
COSMO – ART (ART=Aerosols and Reactive Trace Gases)
Aerosol-Module MADE$_{SOOT}$

- MADE$_{SOOT}$ uses the method of moments for solving the chances of the particle size distribution.

- For the closure of the equation system the particle population is divided in several Modes, where each mode is approximated by an analytical function.

- Included aerosol dynamic processes:
  - nucleation
  - condensation and evaporation of gas phase species and water on particles
  - coagulation
  - diffusion, advection and convection of particles
  - sedimentation, dry and wet deposition

- Particle sources:
  - emissions of natural and anthropogenic primary particles
  - emissions of natural and anthropogenic gas phase species $\rightarrow$ secondary particles

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The aerosol population is represented by 12 overlapping modes.

Each mode is approximated by log normal functions ($\sigma_g = \text{const.}$)

2 modes containing $\text{SO}_4^{2-}, \text{NO}_3^-, \text{NH}_4^+, \text{H}_2\text{O}, \text{SOA}$, internally mixed

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1 mode pure SOOT

1 mode containing primary PM10 emissions (only transport)

3 modes for Mineraldust

3 modes for Seasalt particel

+ Pollen

Vogel et al., 2006;
Riemer et al., 2003;
Hoose, 2004
Lundgren, 2006

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- Time period: August 16th-20th, 2005 → 120h

- Model domain: South-West Germany and Switzerland 343 km x 546 km

- Grid resolution: 7 km

- Initialisation and boundary values: nesting COSMO-ART in COSMO-ART for meteorology, gas phase and particle phase
- **Lateral boundaries:**
  nesting in COSMO-ART simulations over Europe (grid resolution 14 km)

- **Lower boundaries:**
  anthropogenic emissions (Pregger et al. IER UNI Stuttgart)
  biogenic emissions
calculation from landuse data
The optical properties of the aerosol depend on the particle size distribution, the chemical composition (soot, water on particles) and the wavelength of light.

**aerosol extinction coeffizient:**
\[ b_{\text{ext}, \text{aero}, \lambda} = \sum_{i=1}^{\text{mode}} b_{\text{ext}, i, \lambda} + b_{\text{ext}, \text{gas}, \lambda} \]

**gas phase extinction coefficient:**
\[ b_{\text{ext}, \text{gas}, \lambda} = \text{const.} \]

**particle extinction coeffizient:**
\[ b_{\text{ext}, i, \lambda} = \int_{0}^{\infty} \frac{\pi}{4} d_{p} n_{i} (d_{p}) Q_{e} (d_{p}, \lambda) dd_{p} \]

To obtain \( Q_{e} \) after Mie theorie (Mie 1908) is very expensive in computational costs.

→ Parametrisation for the online calculation

\[ \sum_{i=1}^{1} b_{i, \text{ext}, \lambda} = a_{i} \cdot m_{i} (d_{p})^{c_{i}} \quad \text{Bäumer et al. (2004)} \]
Calculation of the visibility

**Method 1:** Koschmieder (1929)

\[ L_v = \frac{-\ln C_{\text{min}}}{b_{\text{ext}}} = \frac{3.91}{b_{\text{ext}}} \quad \text{minimal contrast } C_{\text{min}} = 0.02 \]

- The visibility depends only on the local extinction coefficient

**Method 2:** the reduction of the contrast (Riemer 2002)

\[ C(\bar{x}_0, \bar{r}, k \cdot \Delta x) = C_0 \cdot \exp \left( - \sum_{i=0}^{k} b_c (\bar{x}_0 + (i \cdot \Delta x) \cdot \bar{r}) \cdot \Delta x \right) \]

- The visibility depends on the horizontal distribution of the extinction coefficient.
  → yields a direction depending visibility
Results
PM 10 and visibility Karlsruhe 17.08.2005 - 20.08.2005

PM 10

visibility

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- The optical properties especially the aerosol extinction coefficient were simulated using the comprehensive mesoscale model system COSMO – ART.

- The extinction coefficients show a strong spatial and temporal variation.

- The visibilities were investigated using the Koschmieder equation with local extinction coefficients and due to the reduction of the contrast under consideration of the horizontal variability of the extinction coefficient.

- The comparison of both methods shows great differences for high visibilities.

- The comparison of calculated visibility under consideration of the horizontal variability of the extinction coefficient shows a good agreement with measurements when the aerosol is simulated correctly.
Thank You!