Fully coupled aerosol-radiation-interaction with LM-ART

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Outline

1. Case Study: Saharan Mineral dust event
   - Full dust-radiation-emission coupling

2. Towards fully coupled anthropogenic aerosol – radiation
   - interaction
   - South-West Germany and adjacent areas

Source: PSI
Aerosol Model MADE_dust

Parameterization of the horizontal and vertical saltation and emission flux (Vogel et al, 2006)

3 different Modes (d = 1.5, 6.7, 14.2 μm)

Log normal distributions
Refractive index of mineral dust
- Assumption of constant composition
- (98% Kaolinite, 2% Hematite)

Mie Calculations

Single scattering albedo ($\omega$), specific extinction koefficient (b), Asymmetry Parameter (g) for 3 Modes and 8 Bands

New Routine in LM-ART:
Computation of $\omega$, b, g for prevailing dust concentration

Modified radiation in LM:
Substitution of climatological optical properties based on current dust concentrations

Soil properties (von B. Marticorena)

Calculation of dust particle emission

u., soil humidity

Transport, Sedimentation, Deposition

LM

Dust concentration

$\omega$, b, g
**Case Study: Mineral dust over West Africa in March 2004**

**Prevailing Situation:**
- Unusual
- Low temperatures and high wind speeds in the Sahara
- Heavy Precipitation in Libya
- After the mineral dust event ITC was shifted southwards

(Knippertz and Fink, 2006)
Model domain: West Africa, 19°E – 19°W, 0.5°N – 35°N
Horizontal resolution: 0.25° (≈ 28km)
Simulation period: 1.3. – 7.3.2004

**Simulation A**: Interaction of radiation and mineral dust, climatology removed
**Simulation B**: No interaction, climatology removed
**Simulation C**: Climatology of mineral dust (original LM)
Comparison AOT Model and AERONET sun photometers

[Graphs showing comparisons across different locations and timestamps]
Summary (1):
- Dust-Radiation-(…) Emission-Interaction in LM-ART
- Comparison with AERONET AOT shows a slight overestimation of the model.
- Influence on cloud cover (semi-direct effect)

Outlook (1):
- Call radiation more frequently instead of once an hour.
- Nesting of emission areas (LMart2LMart)
- Simulation of an event in March 2006 and comparison with AMMA measurements
2. Anthropogenic aerosol radiation interaction

Former results (non-coupled)

Global radiation $F_d$ (280 nm – 3.7 µm), 14:00 CEST

$\Delta F_{d1}$ (reference case – no aerosols in the boundary layer)

Riemer et al., 2003,

(using the radiation transfer model LibRadtran, Mayer et al., 1997, offline)
The Aerosol Model MADE_{SOOT}

(Riemer et al., JGR, 2003)

Five modes represent the aerosol population:

Two modes for \( \text{SO}_4^{2-}, \text{NO}_3^-, \text{NH}_4^+, \text{H}_2\text{O}, \text{SOA} \), internally mixed:

One mode for pure soot:

Two modes for \( \text{SO}_4^{2-}, \text{NO}_3^-, \text{NH}_4^+, \text{H}_2\text{O}, \text{SOA}, \text{soot} \), internally mixed:

Each mode is represented by a log-normal distribution.
Parameterization of optical properties based on Mie theory

Extinction coefficients of the 5 modes as a function of mass density of each mode averaged over the visual band

For a clear dry summer day easy functions of the form $y = ax^b$ can be used to approximate the extinctions coefficients of each mode in the visual band as a function of mass density in the model domain.
Parameterization of optical properties based on Mie theory

Single scattering albedos of the 5 modes averaged over the visual band

- Two modes without soot: \( ssa=1 \) (slight absorption neglected)
- Pure soot mode: \( ssa=0.18 \) (result of Mie theory)
- Mixed modes: \( ssa \) as a function of soot volume fraction: \( y=(ax+1)^{-b} \)
Simulation period:
16.08.05 - 22.08.05 (here 16.08., cloudy)

Simulation domain:
Southwest Germany + adjacent areas
Horizontal Resolution 7km x 7km

Input data:
- Meteorology: GME Reanalysis (DWD)
- Emission data (IER, Stuttgart)
- Land use (JRC-IES, Ispra)

Strategy:
Runs with and without aerosol radiation interaction.
TOTAL DRY AEROSOLMASS
16.08.2005 12 UTC K40

Shortwave radiation balance surface

Without (additional) aerosol radiation interaction
Difference in shortwave radiation balance at the surface:
With interaction minus only climatology (12 UTC)

Area means of difference (W/m²)

<table>
<thead>
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<th>UTC</th>
<th>Difference (W/m²)</th>
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<tr>
<td>12 UTC</td>
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<tr>
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Summary (2):
- Dust-Radiation-(…) - Interaction in LM-ART
- Very low aerosol loads cause changes in shortwave radiation balance at the ground of reasonable sign and order.
- Surprisingly strong effect on cloud pattern (semi-direct effect)

Outlook (2):
- Analyze cloud-free days with higher aerosol load.
- Nesting the domain into a European domain.
- Call radiation more frequently instead of once an hour.
- Simulate a winter case, and complete weeks.
- Horizontal Resolution 2.8 km