LONG-TERM MODEL CALCULATIONS OF PARTICULATE MATTER AND PHOTO-OXIDANTS FROM REGIONAL TO LOCAL SCALE WITH FOCUS ON NORTH-RHINE WESTPHALIA


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OVERVIEW

1. Motivation
2. EURAD Model
3. Results
   • Comparison with measurements
   • Emission Scenarios
4. Conclusions and future plans
Focus on air pollutants relevant for EU-DD (health effects, effects on vegetation)

Near surface layer:
PM$_{10}$, SO$_2$, NO$_2$, CO, NO$_x$, O$_3$

More available from 3D-CTM:
VOCs, NH$_3$, particle size and composition
Deposition, vertical resolution
EURAD-SYSTEM

- Meteorology: MM5, input from ECMWF or NCEP

- Emissions: EEM, input from available emission data (e.g. TNO, EMEP, local, EDGAR)

- Chemistry: EURAD-CTM, MADE, Cloud chem. (aq.), RACM or RADM2, RACM-MIM

- Nesting option for local application
MODEL DESIGN

Horizontal grid resolution (km): 125 – 25 – 5 – 1

23 layers from the surface to the upper boundary

Near surface-layer about 40 m thick

15 layers below 3000 m

Upper boundary about 16 km (100 hPa)

Annual run for 1997: 125 – 25 – 5 km
Vertical: 23 layers
Lowest layer: about 40 m
Upper boundary: about 15 km

Chemica Weather forecast
www.eurad.uni-koeln.de
Sept. 30, 06 UTC, 1997

High pressure system
Over Central Europe

PM\textsubscript{10} concentration more than 150 µg/m\textsuperscript{3}

PM\textsubscript{10}

ANABEL-Projekt LUA NRW
Nitrogen Oxides – N3 (1 km)

NO \left[ g/(s^{*}km^{**2}) \right]

NOx 30.09.97 1800 UTC [ppbV]

Layer 1 (ca. 0 - 36 m)
**NO\textsubscript{x} – PM\textsubscript{10} – ANNUAL**

**NO\textsubscript{x}:** annual average 1997

**PM\textsubscript{10}:** number of days > 50 [µg/m\textsuperscript{3}]

**NO\textsubscript{x} limit value:** 30 µg/m\textsuperscript{3}

**PM\textsubscript{10} limit value:** 35 days

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SCATTER DIAGRAMM PM10

Daily average
Based on hourly values
PM10 from NRW stations only
PM10 = 0.83*TSP
Underestimation in summer
(Nest 2 results, 5 km grid res.)
Emission Scenario

No anthropogenic Emissions in NRW (noNRW)

Sept. 29, 1997

Left: Base Case
Middle: noNRW
Right: Difference

Wind turns from Southeast to Southwest

PM$_{10}$
Emission-Scenario noNRW

NO\textsubscript{x}

PM\textsubscript{10}
COMPOSITION

DAILY AVERAGE

APA N2, TSP Nettetal


Observed

ANTH
BSOA
ASOA
EC
OC
NO₃⁻
NH₄⁺
SO₄²⁻

Jan.
Feb.
March


CTM apa N2: xko = 9.44, yko = 26.59, lev = 1

height = 49 m
lat = 51.33
lon = 6.20

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Emission-Reduction $\text{NH}_3$ (local)

12.04.2002, 12 UTC

Sensitivity, Change in %

50nh3–apa [%]

NH$_3$

APA 50nh3
TIME: 12.04.02 12.00 UTC

50nh3–apa [%]

PM$_{10}$

APA 50nh3
TIME: 12.04.02 12.00 UTC

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PM$_{10}$: Changes (%) 2002 – 2005 - 2010

ANNUAL AVERAGE PM10: 2005 - 2002

ANNUAL AVERAGE PM10: 2010 - 2002

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PM$_{10}$: 2002 - 2005 - 2010

NUMBER OF DAYS WITH DAILY AVERAGE > 50 µg/m$^3$
PM$_{10}$: 2002 – (2005) - 2010

2002


NUMBER OF DAYS WITH DAILY AVERAGE > 50 µg/m$^3$
HEMISPHERIC SIMULATION

- 29 layers
- Upper boundary: 10 hPa
- Hor. grid size: 100 km
- EDGARV3.2 emission data
- Meteorology: MM5

Ozone, lowest layer, August 13, 1997, 12 UTC
Verification: Germany: 09 August 2003
Ozone (µg/m³), daily Maximum

Observation (UBA)

Forecast (EURAD)
SUMMARY

• In general good agreement between observation and model for „PM$_{10}$“ (but: underestimation in summer)

• Problems with incomplete and/or not harmonized emission data

• Long range transport is important for background concentrations

• Composition of particles has not been investigated in detail yet, but: secondary aerosols are important

• Lack of information in the vertical (LIDAR, satellite)
FUTURE PLANS

• Long-term calculations for 2002, 2005, 2010
• Hemispheric version (long-term, forecast)
• Data assimilation to improve air pollution forecast
• General improvement of model numerics, physics and chemistry
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NCEP
German Weather Service (DWD)

CITY-DELTA INITIATIVE
Aerosol Chemistry in MADE

Modal Aerosol Dynamics Model for EURAD/Europe
(Binkowski et al., 1995, Ackerman et al., 1998, Schell et al, 2001)

Aerosol dynamics (included)
Coagulation, nucleation, condensation-evaporation
Cloud-aerosol interaction
Diffusion, advection
Dry deposition, sedimentation

\[
\frac{dM_i^k}{dt} = nuk_i^k + \text{coag}_{ij}^k + \text{coag}_{ji}^k + \text{cond}_{ij}^k + \text{sink}_{ij}^k + \text{emi}_{ij}^k
\]

\( M_i^k := k^{\text{th}} \) Moment of i\(^{\text{th}}\) Mode
OBS – MODEL: COMPOSITION

Observation from EMEP

Ammonium
Nitrate
Sulfate
TSP
Emission-Reduction NH$_3$

NH$_3$ (red)/NH$_3$(Basis) [%]

PM$_{10}$ (red)/ PM$_{10}$ (Basis) [%]

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PM$_{10}$: 2002 – (2005) - 2010

MAX. DAILY AVERAGE: PM$_{10}$ - 2002

MAX. DAILY AVERAGE PM$_{10}$ - 2010

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PM$_{10}$: Changes (%) 2002 – 2005 - 2010

MAX. DAILY AVERAGE PM10: 2005 - 2002

MAX. DAILY AVERAGE PM10: 2010 - 2002

HARMO, Garmisch, 01.06.2004
PM$_{10}$: 2002 - 2005 - 2010

NUMBER OF DAYS WITH DAILY AVERAGE $> 50$ µg/m$^3$
FUTURE PLANS

- Extension of the modelling system to hemispheric scale to treat the intercontinental transport of pollutants
- Coupling of models with satellite data (4DVar-data assimilation including aerosols)
- Gaps in observation (vertical, composition)
- Improvement and harmonization of emission data
- Process-oriented model evaluation, composition, size
- Multiphase chemistry
- Modal → sectional
- Coupling of clouds and aerosols