Fully coupled aerosol-radiation-interaction with LM-ART

D. Bäumer, B. Vogel, H. Vogel, T. Stanelle, R. Rinke,
M. Bangert, Ch. Kottmeier

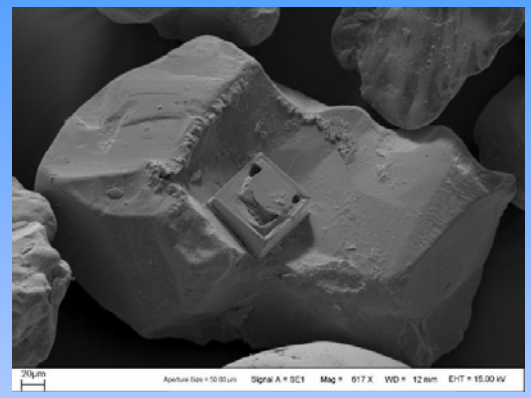
Langen, 05.03.2007

Institut für Meteorologie und Klimaforschung, Forschungszentrum Karlsruhe,
Germany

Outline

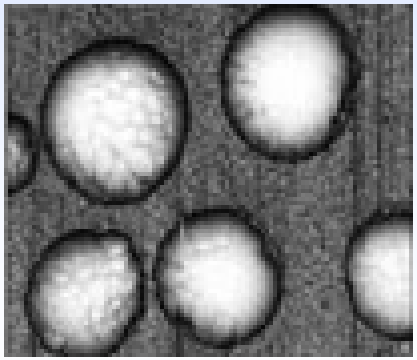
1. Case Study: Saharan Mineral dust event

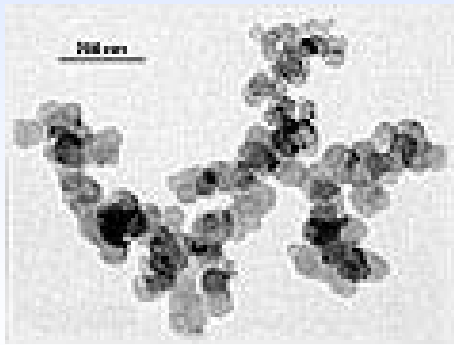
    - Full dust-radiation-emission coupling



2. Towards fully coupled anthropogenic aerosol – radiation - interaction

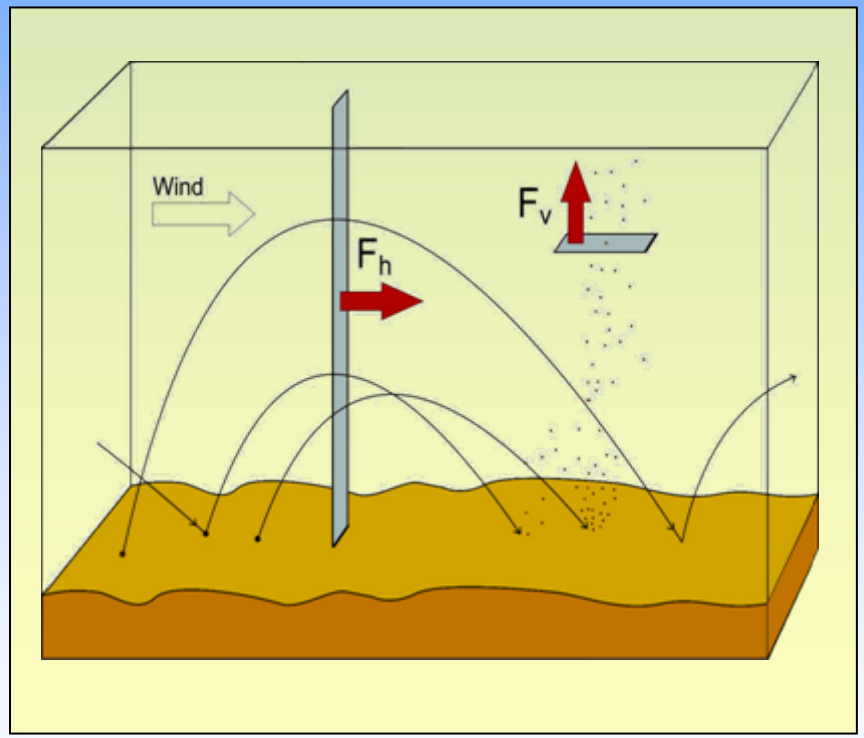
    - South-West Germany and adjacent areas





Source: PSI

Aerosol Model MADEdust



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

COSMO LM – ART

Soil properties
(von B. Marticorena)

Calculation of dust particle emission

u_*, soil humidity

Refractive index of mineral dust

- Assumption of constant composition
- (98 % Kaolinite, 2% Hematite)

Mie Calculations

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

Transport, Sedimentation, Deposition

LM

Dust concentration

New Routine in LM-ART:

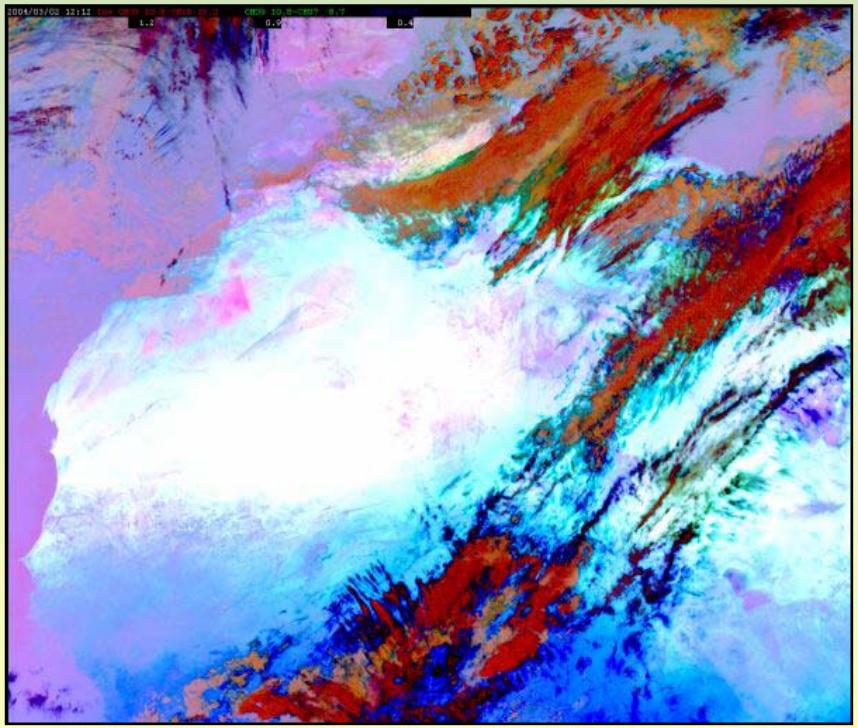
Computation of ω, b, g for prevailing dust concentration

ω, b, g

Modified radiation in LM:

Substitution of climatological optical properties based on current dust concentrations

Case Study: *Mineral dust over West Africa in March 2004*



Meteosat-8 Image, 2. – 3. März 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

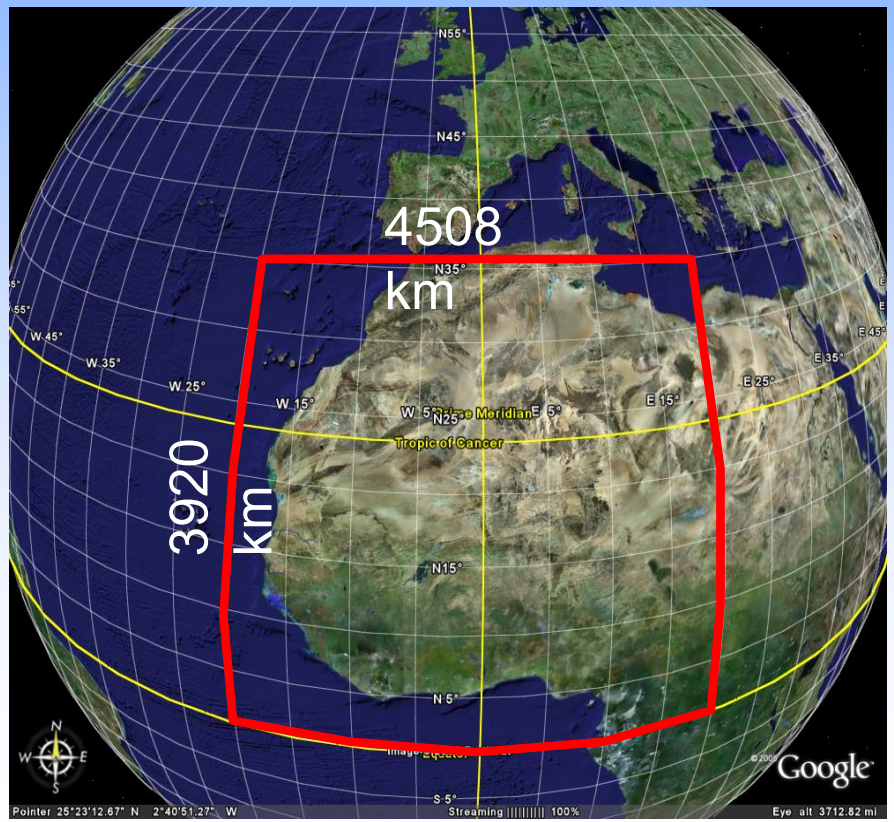
Horizontal resolution: 0.25° (≈ 28km)

Simulation period: 1.3. – 7.3.2004

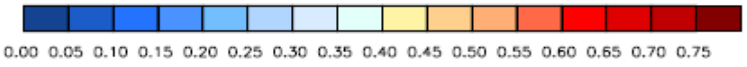
Simulation A : Interaction of radiation and mineral dust, climatology removed

Simulation B : No interaction, climatology removed

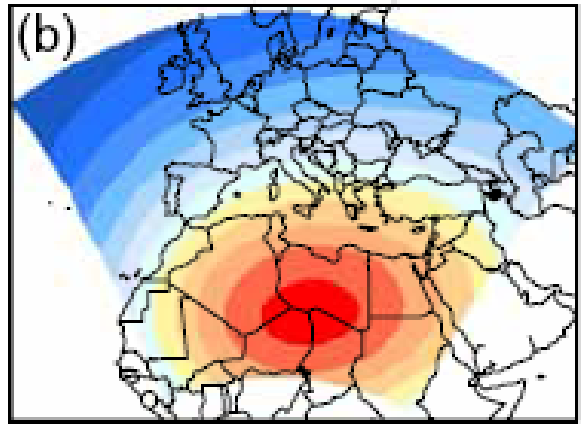
Simulation C : Climatology of mineral dust (original LM)



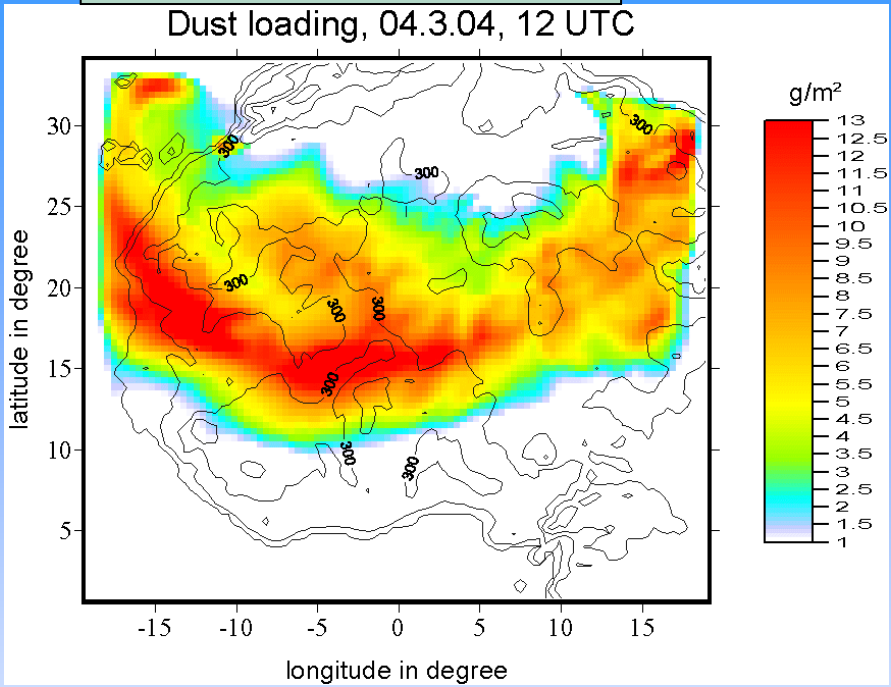
Climatology (from Helmert et al., 2006)



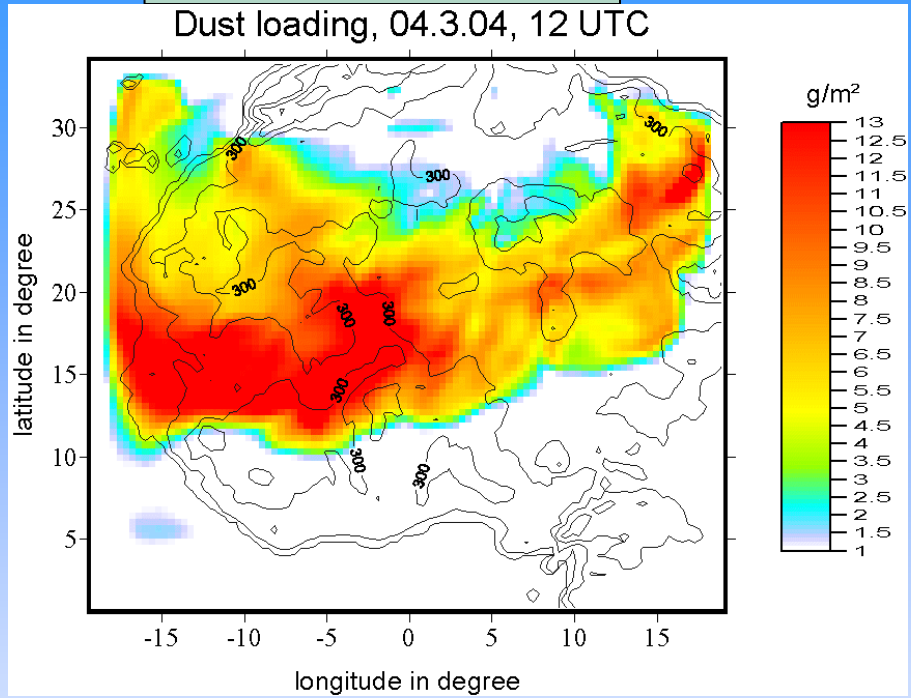
Optical thickness τ(550 nm)

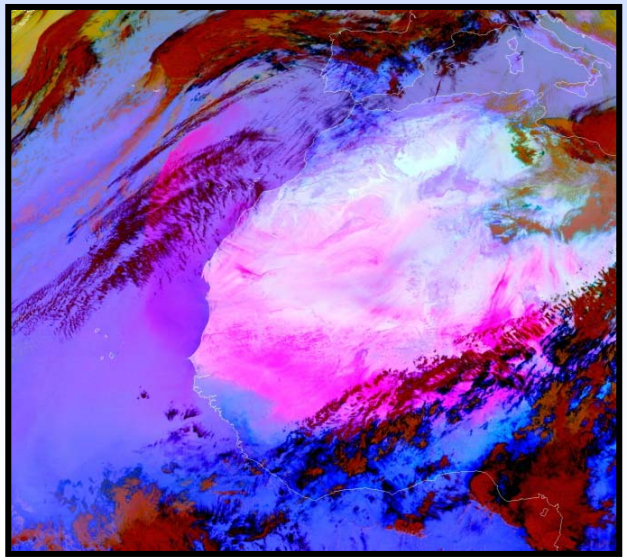


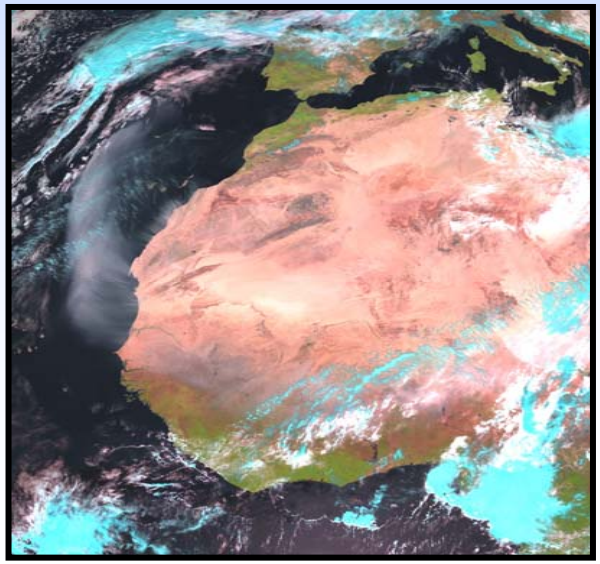
(B) Without interaction



(A) With interaction

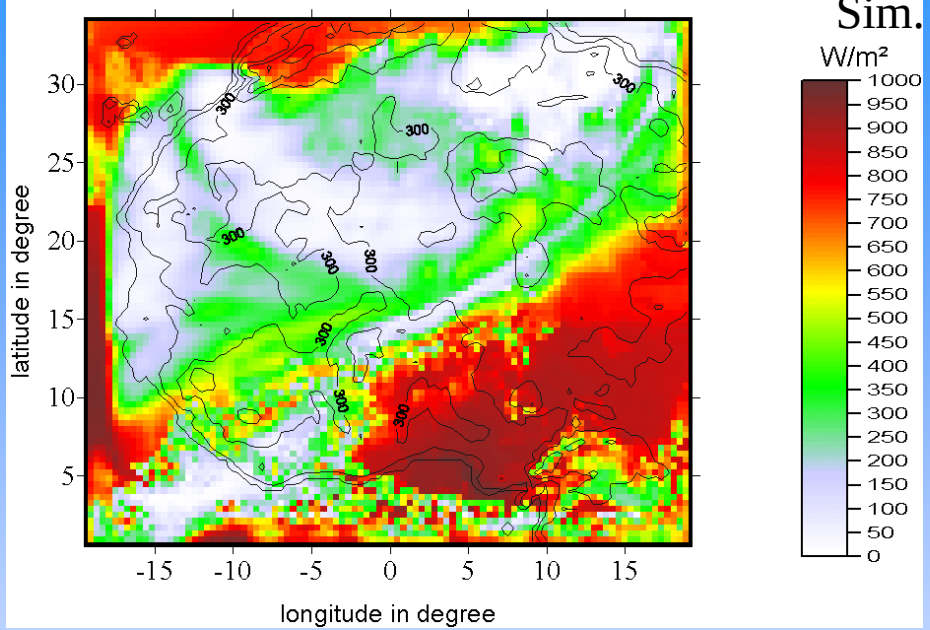




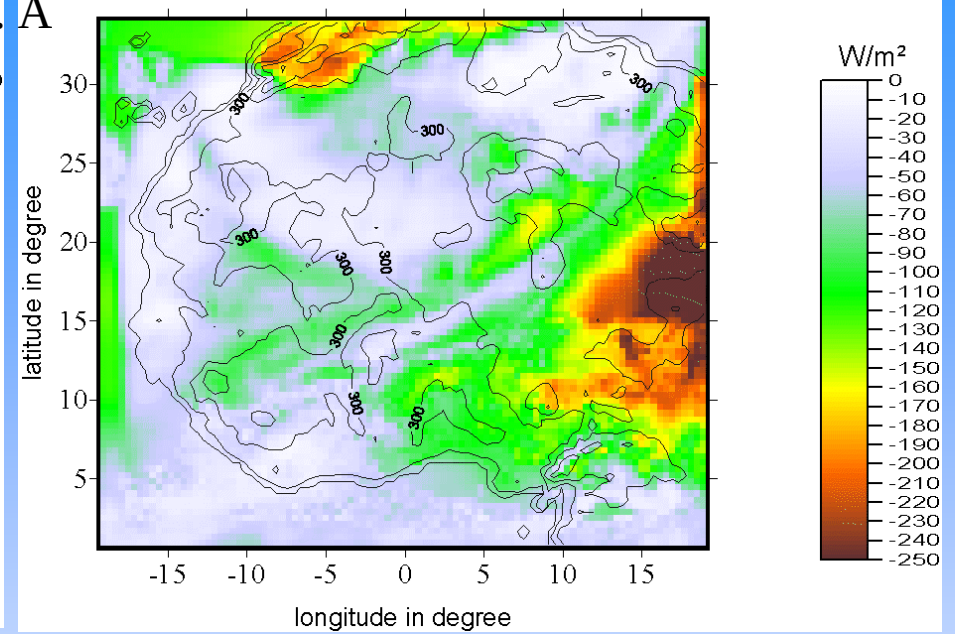


Net shortwave radiation (surface), 03.03.2004, 12UTC

Sim. A

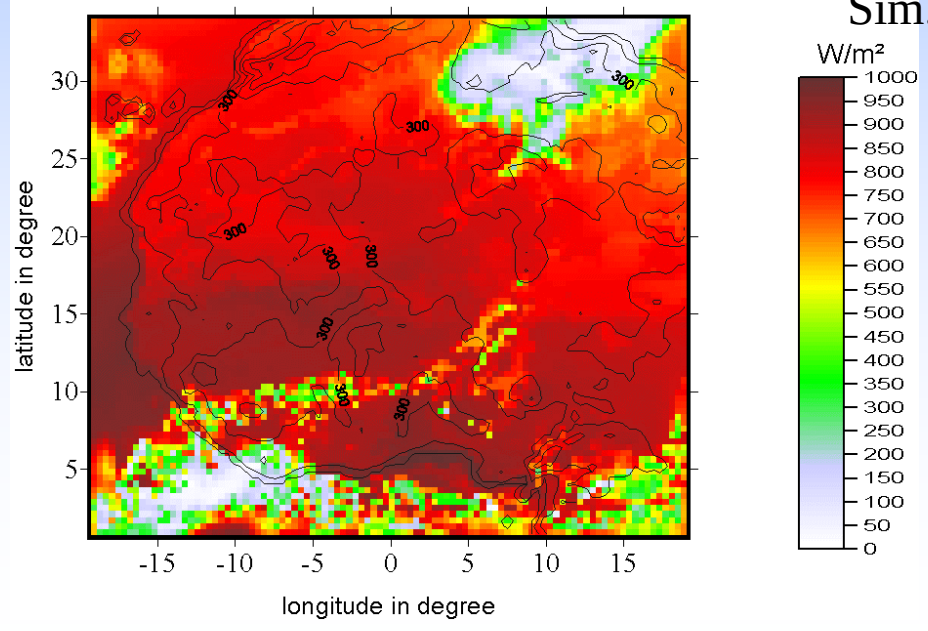


Net longwave radiation (surface), 03.03.2004, 12UTC

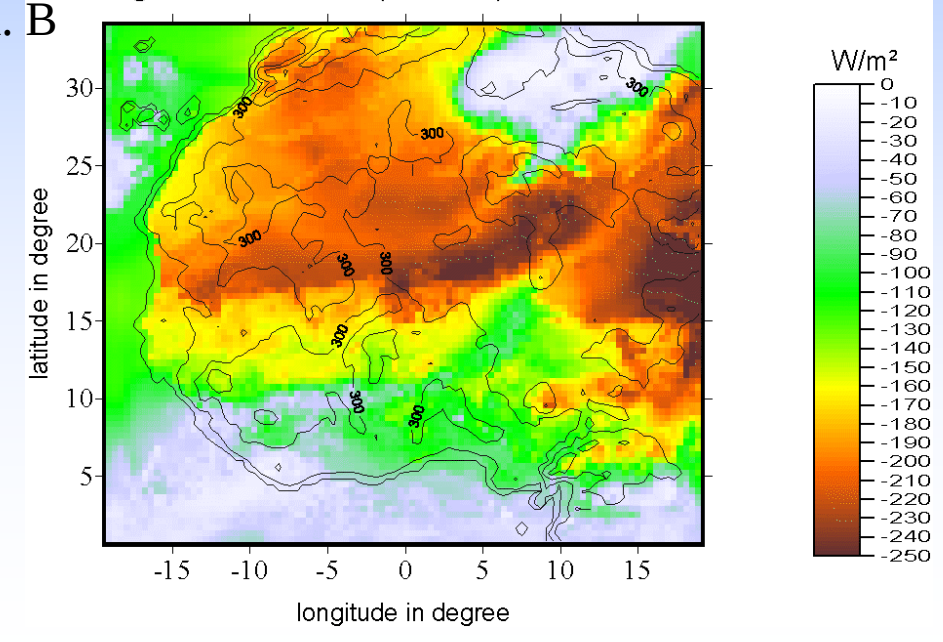


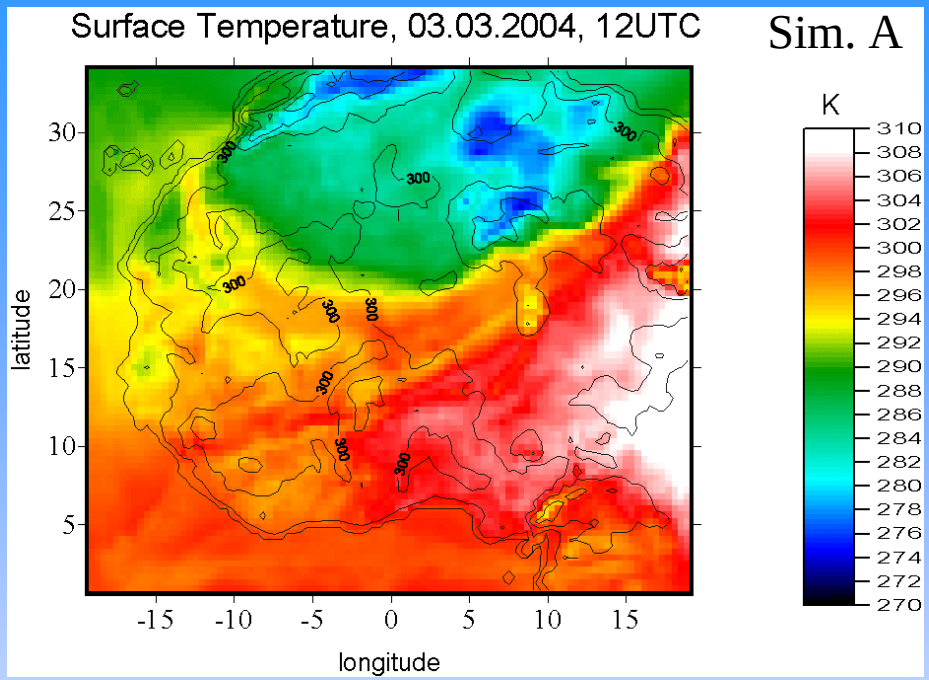
Net shortwave radiation (surface), 03.03.2004, 12UTC

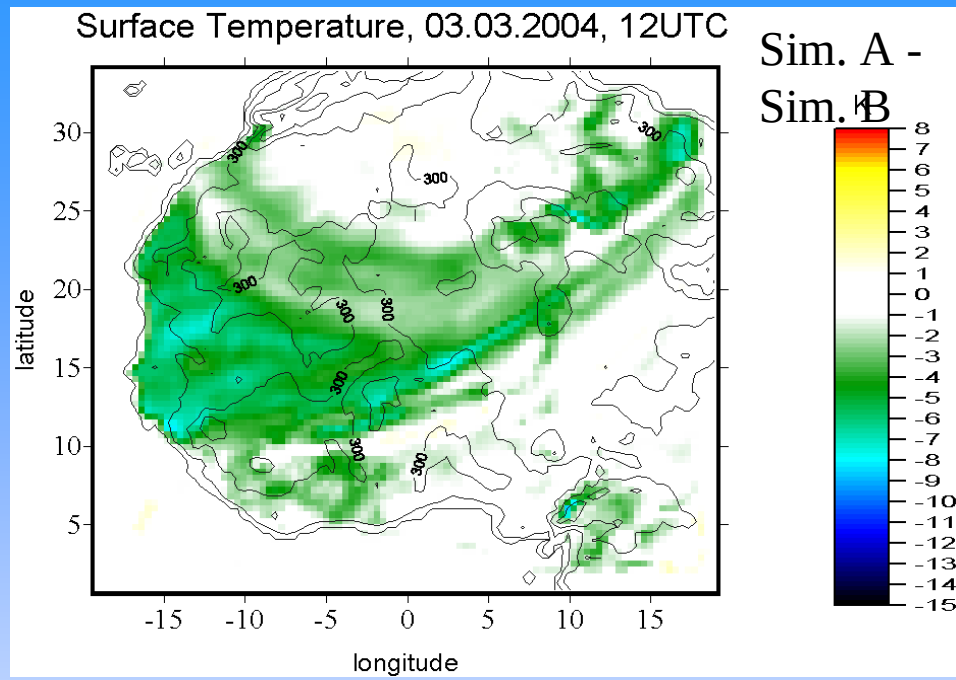
Sim. B

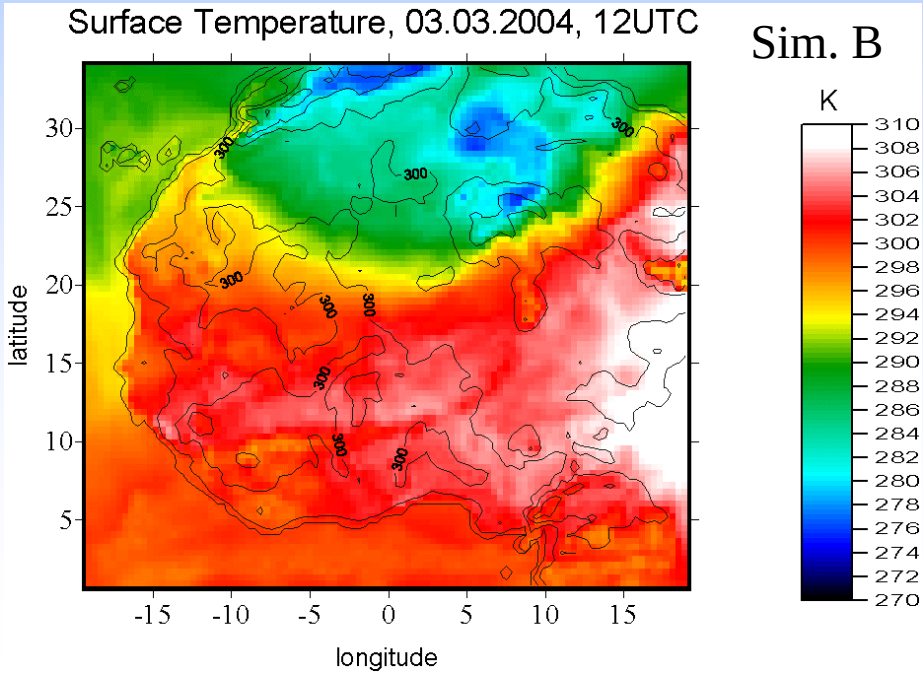


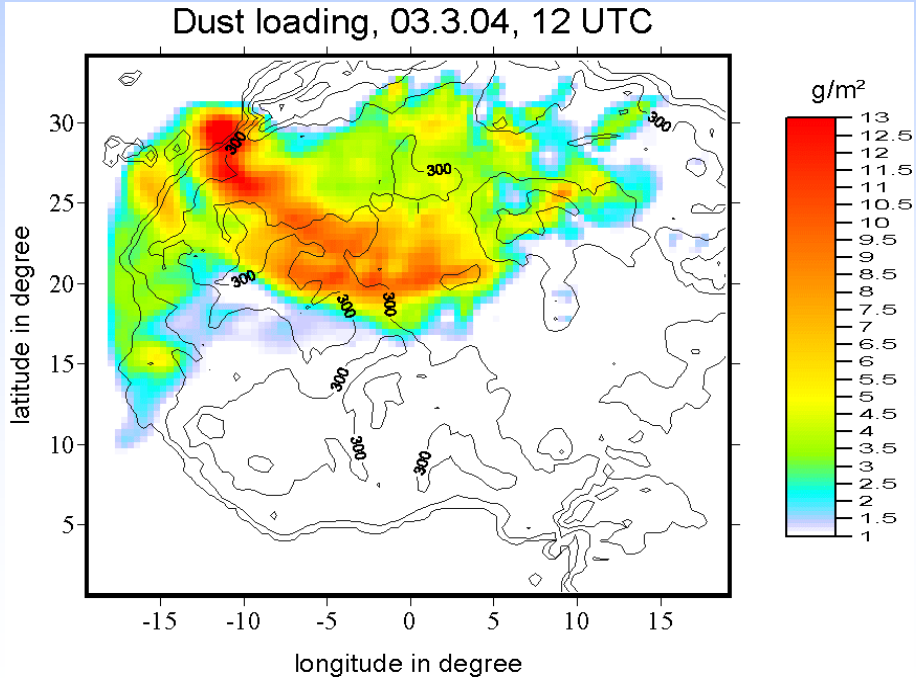
Net longwave radiation (surface), 03.03.2004, 12UTC



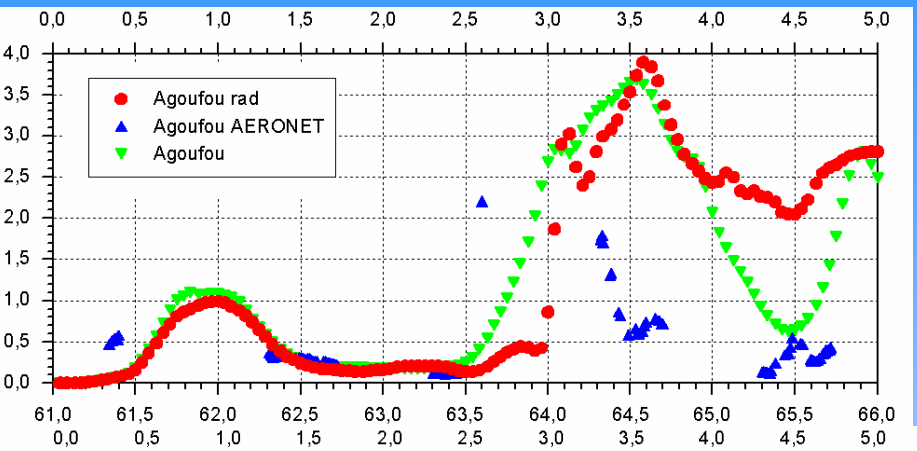

Surface Temperature, 03.03.2004, 12UTC
Sim. A
K
310
308
306
304
302
300
298
296
294
292
290
288
286
284
282
280
278
276
274
272
270
latitude
longitude
30
25
20
15
10
5
-15
-10
-5
0
5
10
15
300

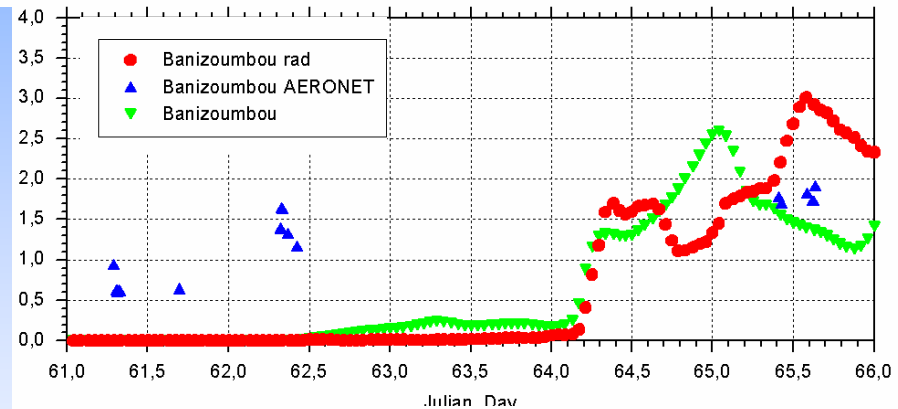

Surface Temperature, 03.03.2004, 12UTC
Sim. A - Sim. B
K
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
latitude
longitude
30
25
20
15
10
5
-15
-10
-5
0
5
10
15
300

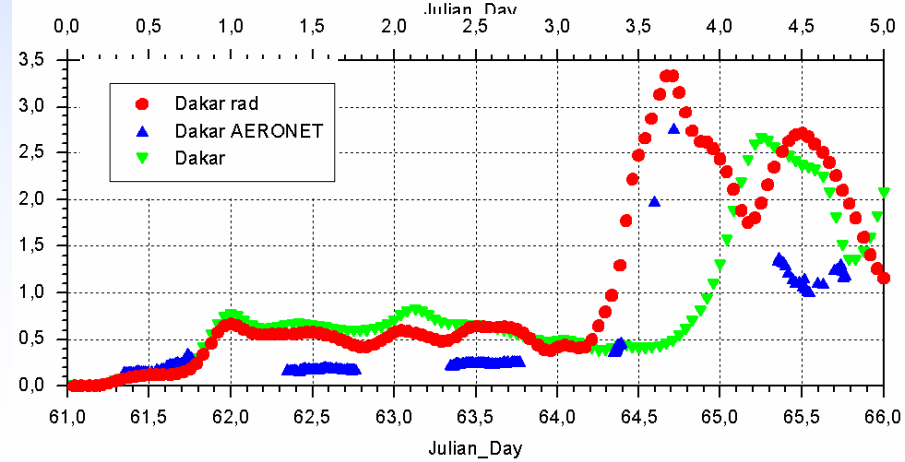

Surface Temperature, 03.03.2004, 12UTC
Sim. B
K
310
308
306
304
302
300
298
296
294
292
290
288
286
284
282
280
278
276
274
272
270
latitude
longitude
30
25
20
15
10
5
-15
-10
-5
0
5
10
15
300

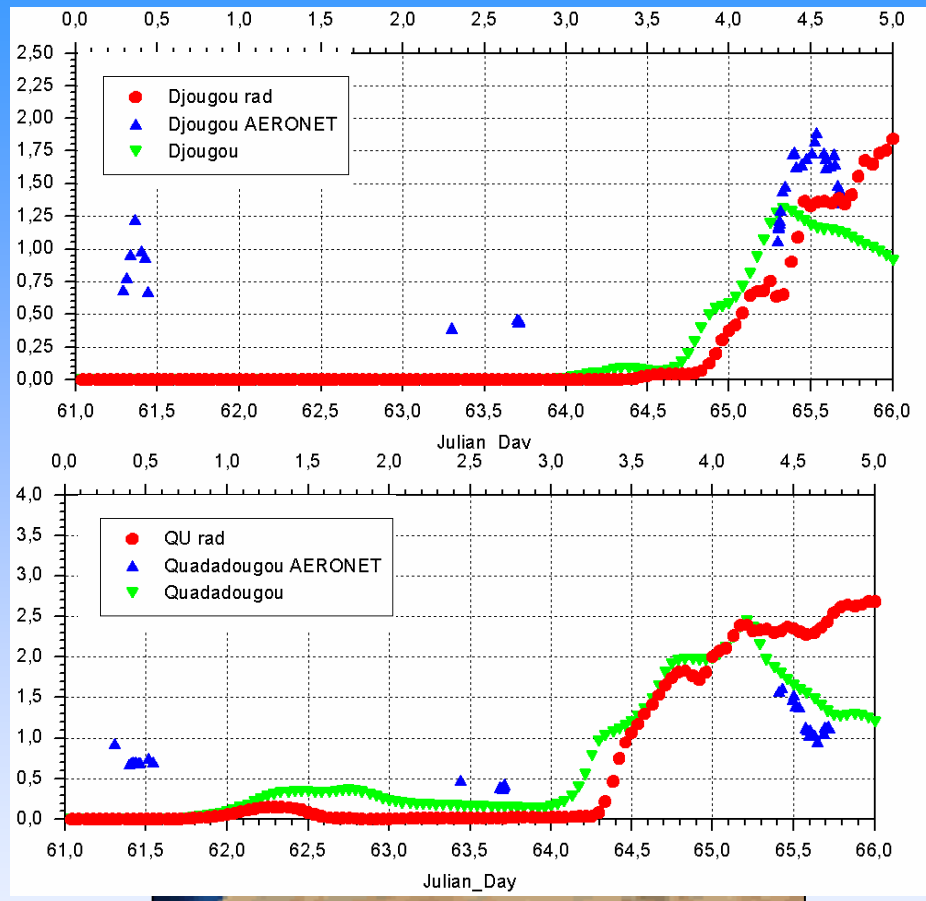

Dust loading, 03.3.04, 12 UTC
g/m²
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
latitude in degree
longitude in degree
30
25
20
15
10
5
-15
-10
-5
0
5
10
15
300

Comparison AOT Model and AERONET sun photometers

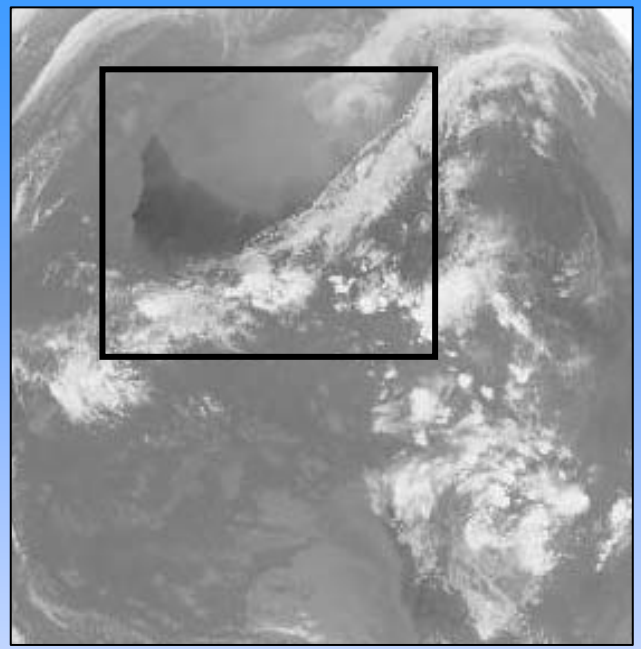




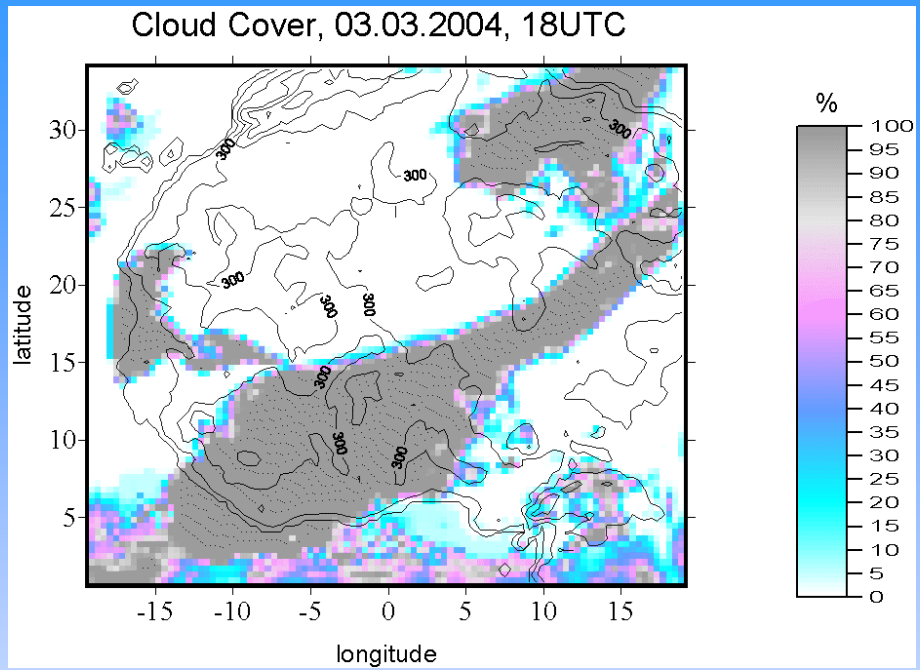




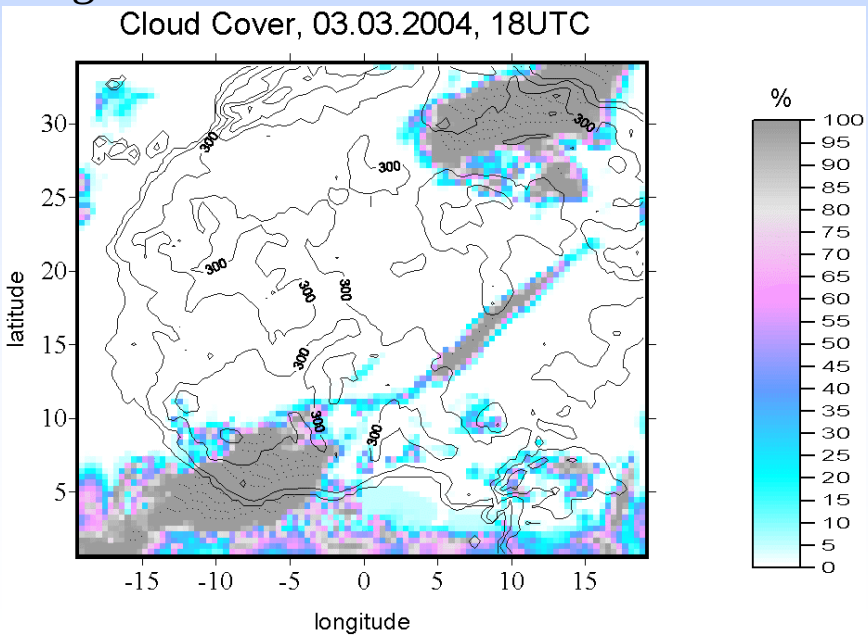
Eumetsat



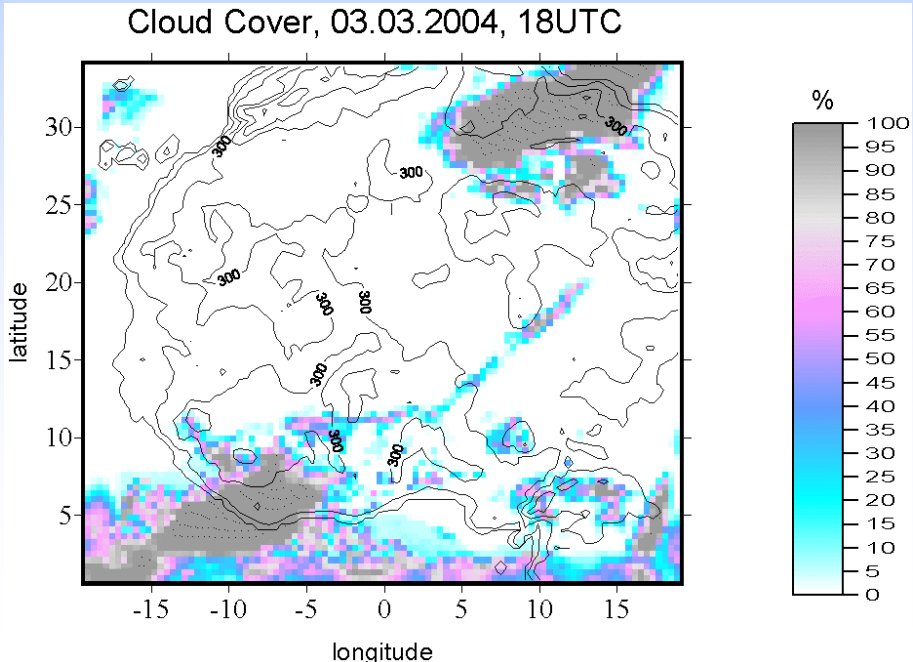
With interaction



Original LM



Without interaction



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)

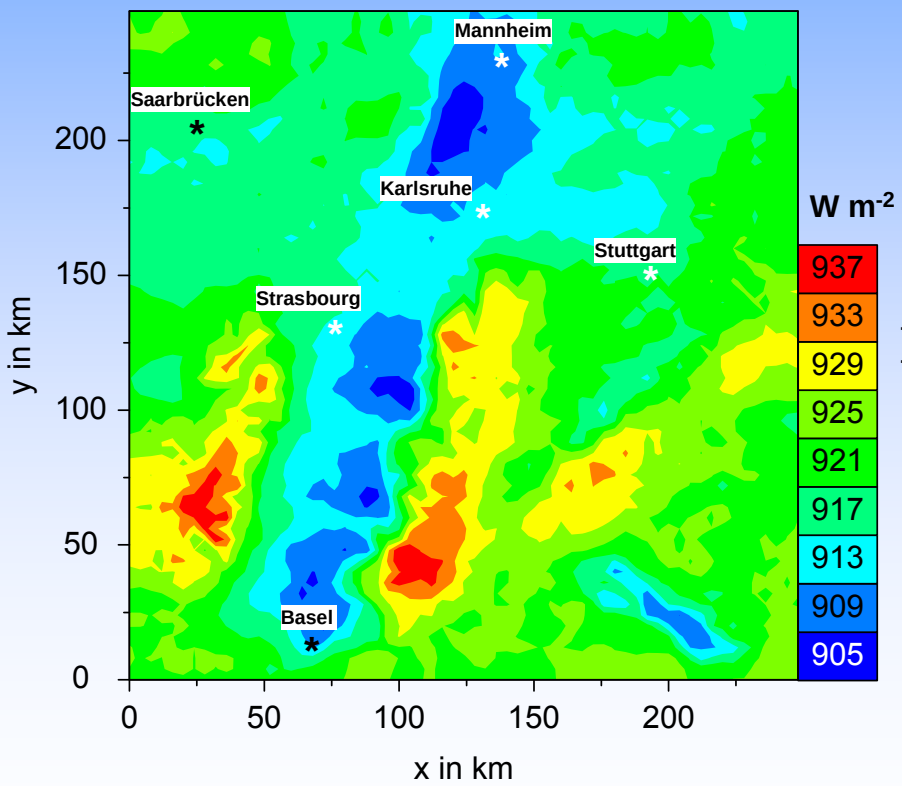
Outlook (1):

- 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

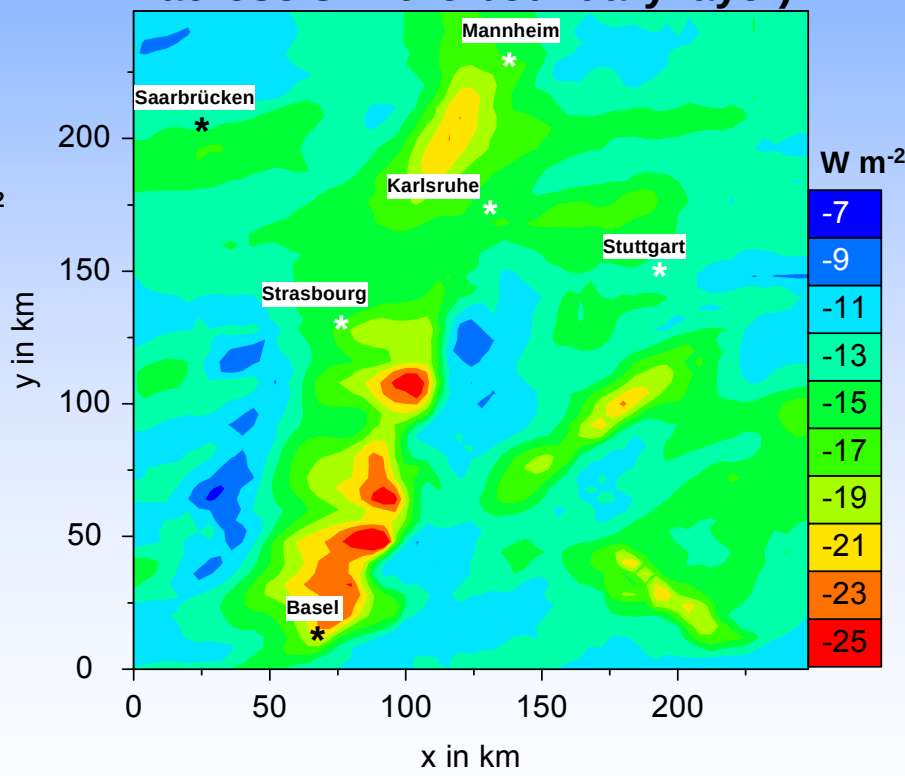
2. Anthropogenic aerosol radiation interaction

Former results (non-coupled)

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



ΔF_{d1} (reference case – no aerosols in the boundary layer)



Riemer et al., 2003,

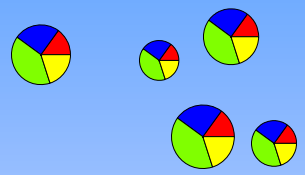
(using the radiation transfer model LibRadtran, Mayer et al., 1997, offline)

The Aerosol Model MADE$_{SOOT}$

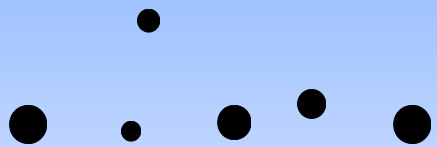
(Riemer et al., JGR, 2003)

- **Five** modes represent the aerosol population:

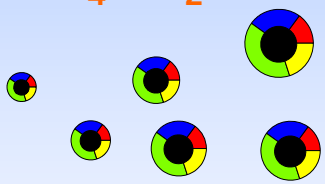
Two modes for SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, internally mixed:



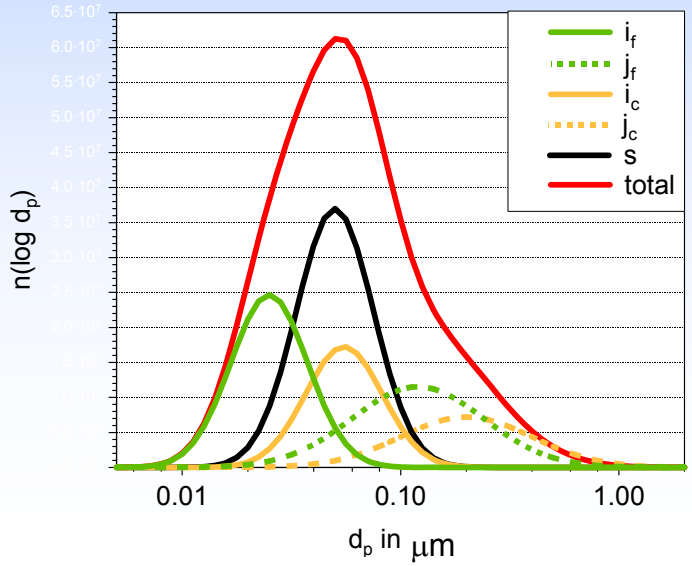
One mode for **pure soot:**



Two modes for SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, **soot**, internally mixed:

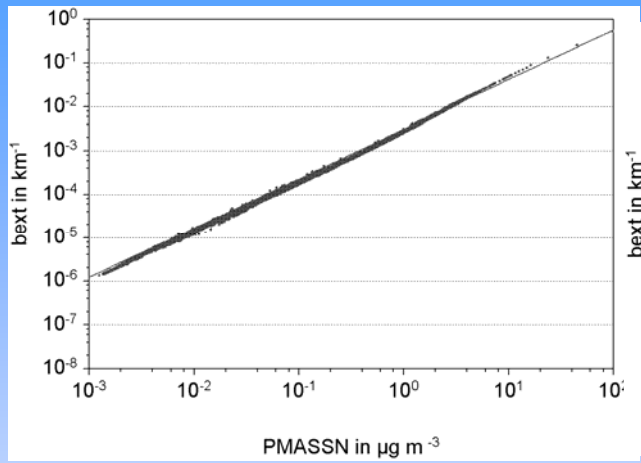


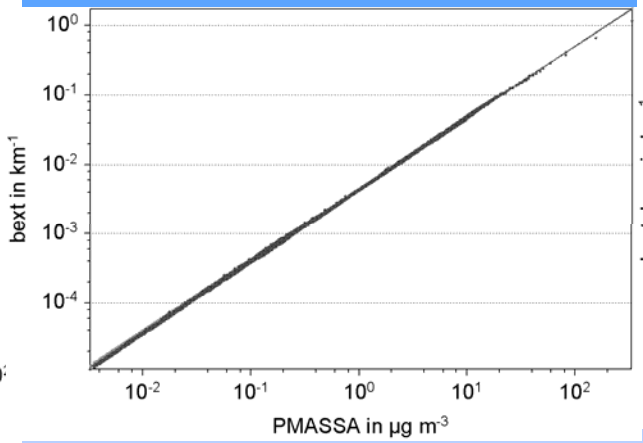
Each mode is represented by a log-normal distribution.

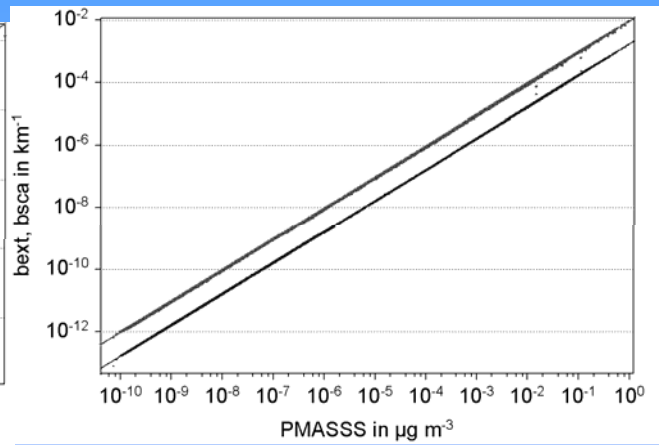


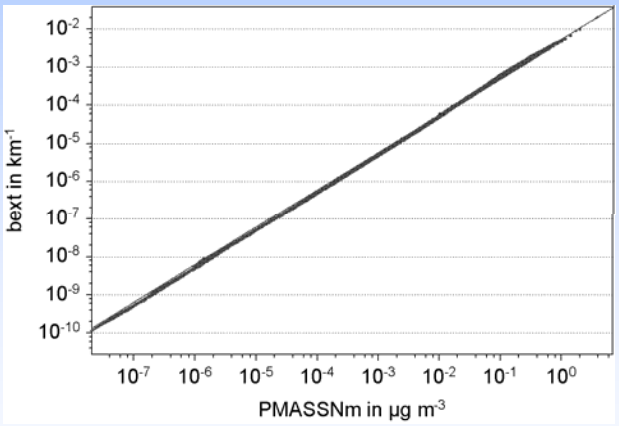
Parameterization of optical properties based on Mie theory

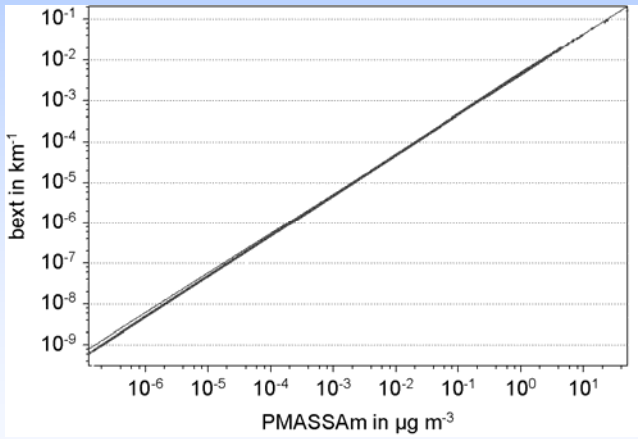
Extinction coefficients of the 5 modes as a function of mass density of each mode averaged over the visual band









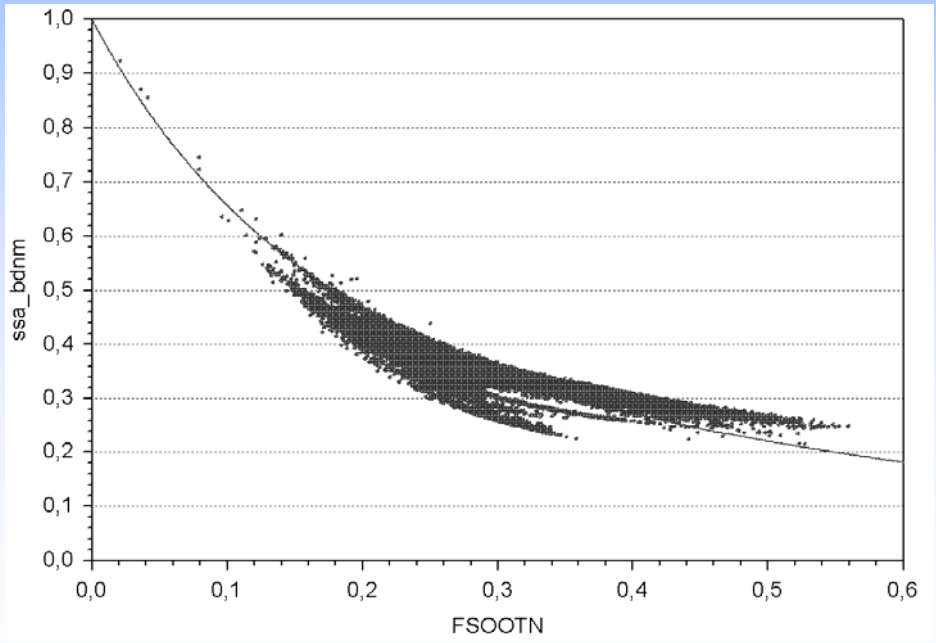


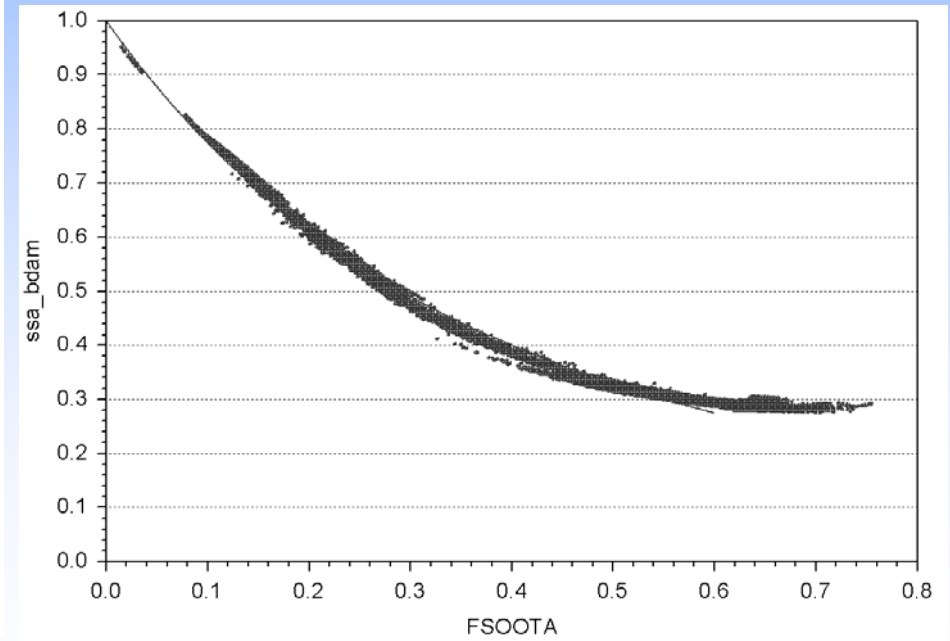
For a clear dry summer day easy functions of the form $y=a\,x^b$ can be used to approximate the extinctions coefficients of each mode in the visual band as a function of mass density in the model domain.

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

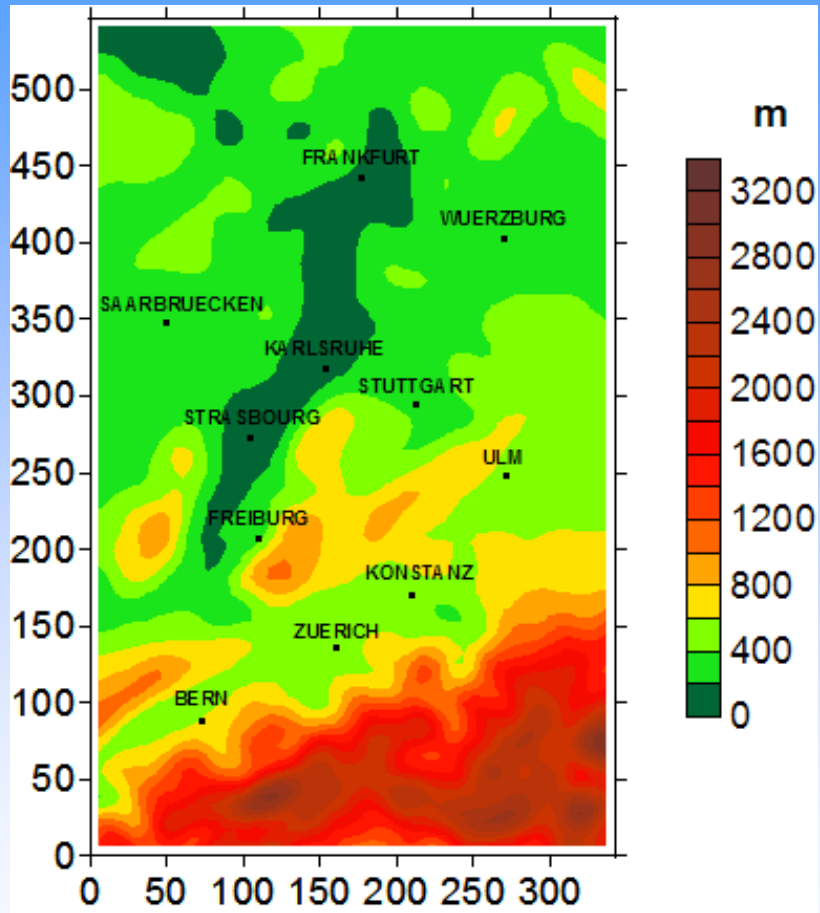
Horizontal Resolution 7km x 7km

Input data:

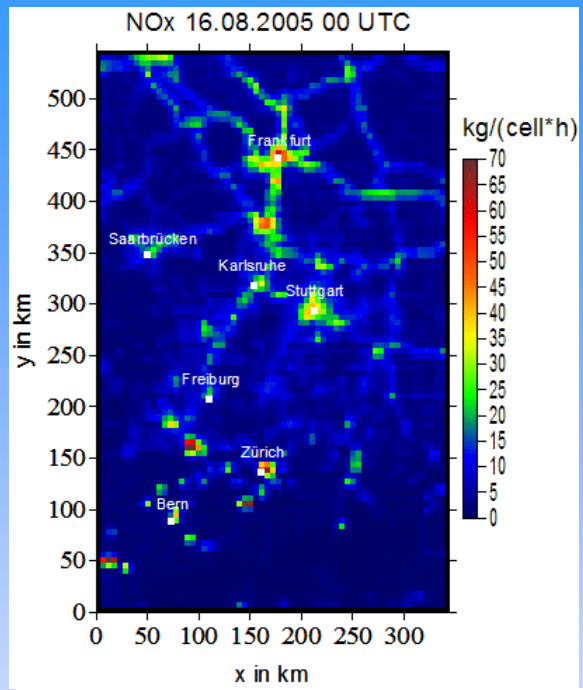
- Meteorology: GME Reanalysis (DWD)
- Emission data (IER,Stuttgart)
- Land use (JRC-IES,Ispra)

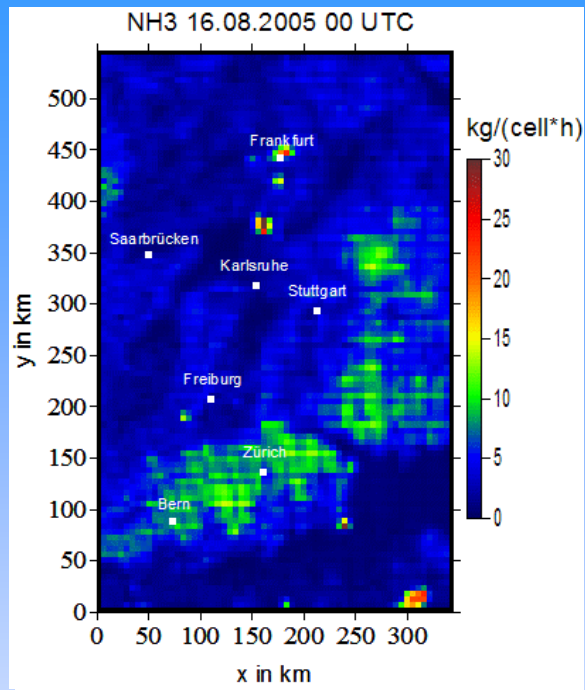
Strategy:

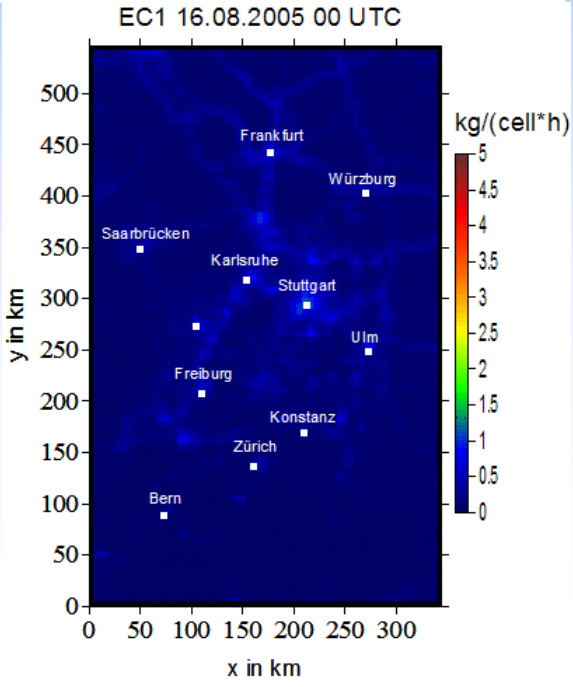
Runs with and without aerosol radiation interaction.

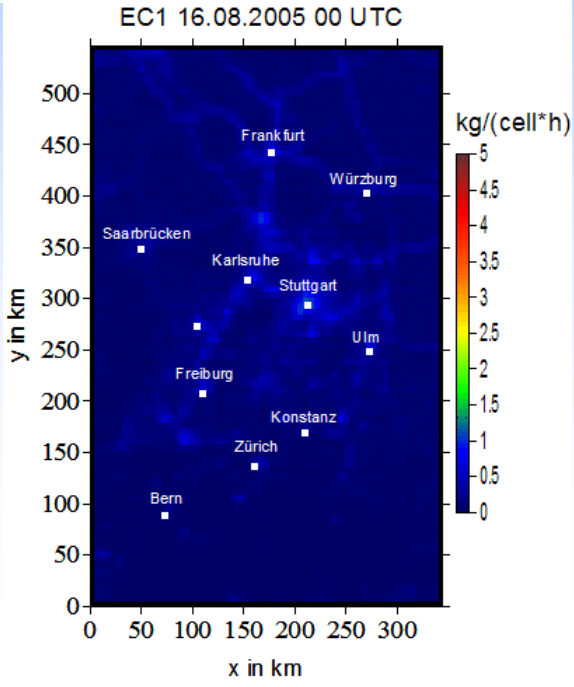


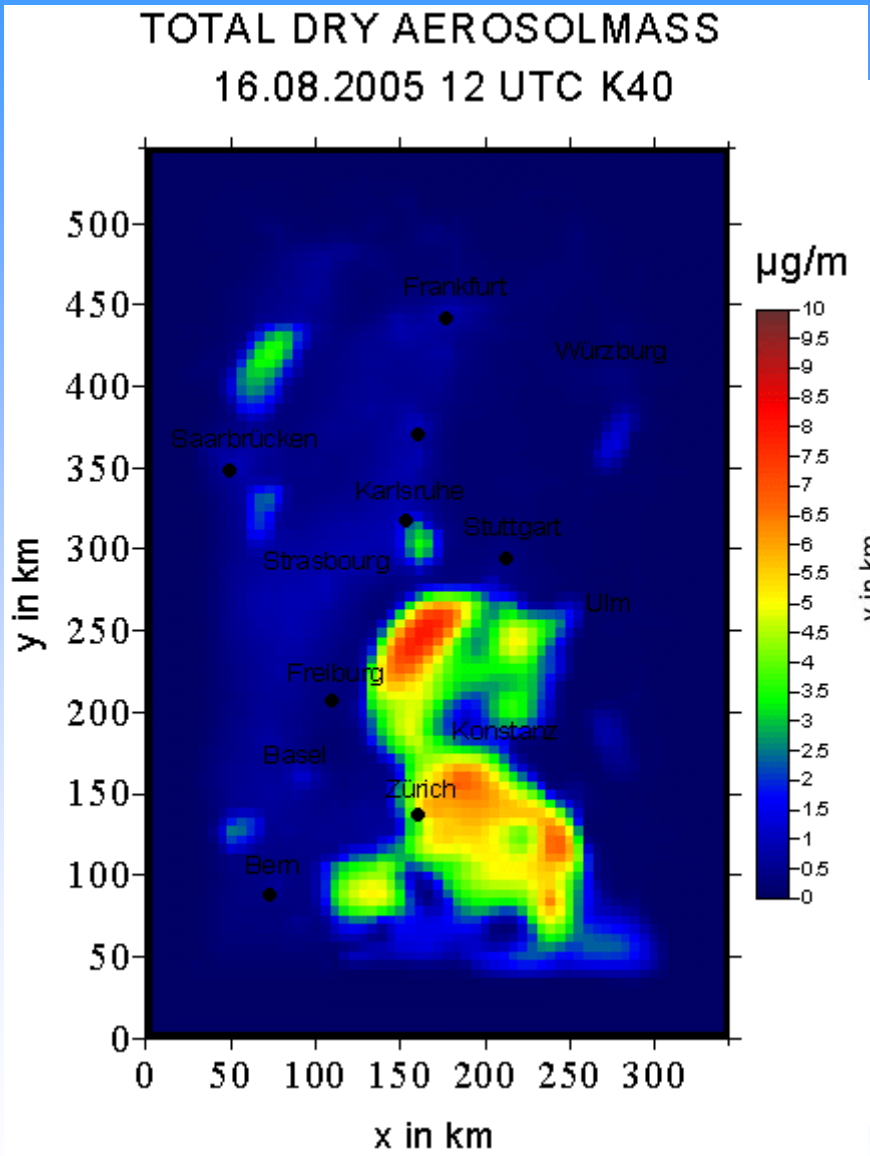
Emissions (IER Stuttgart)



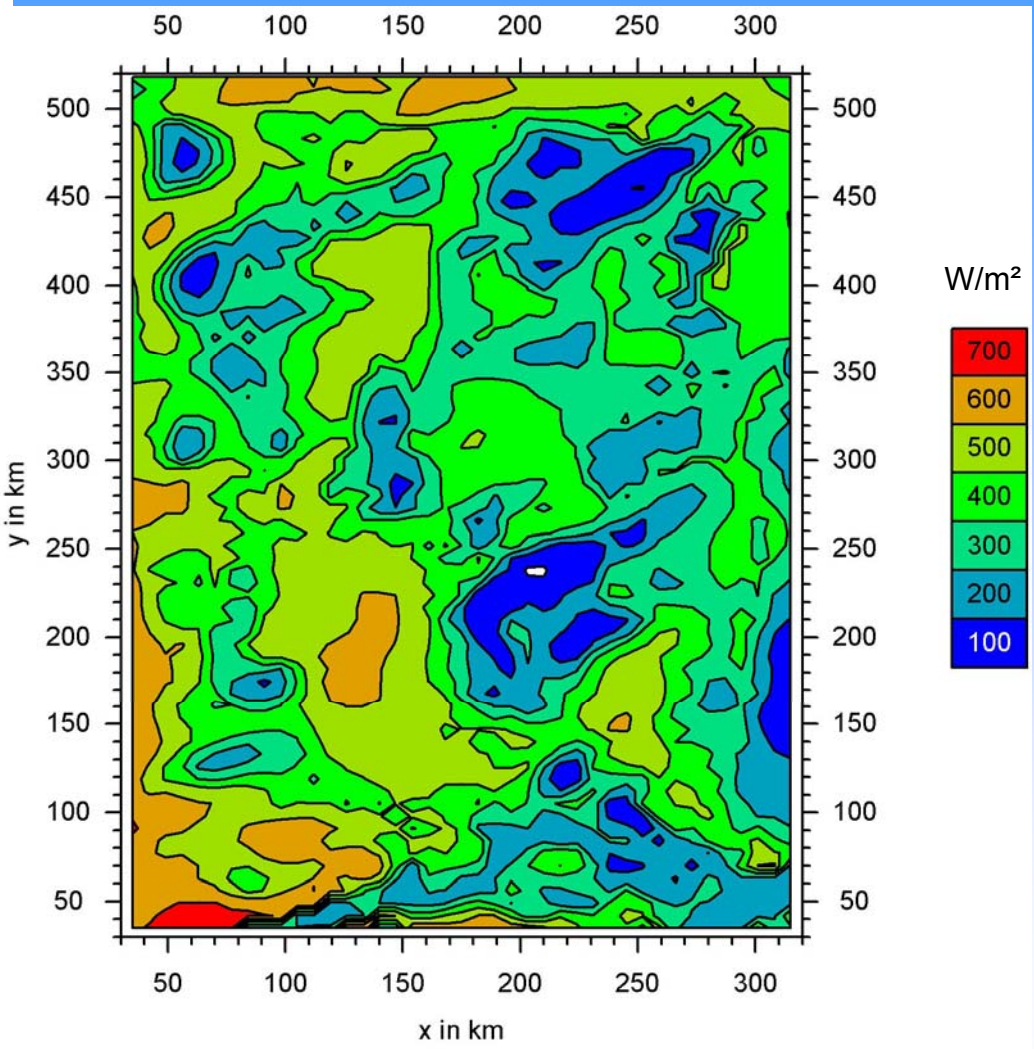








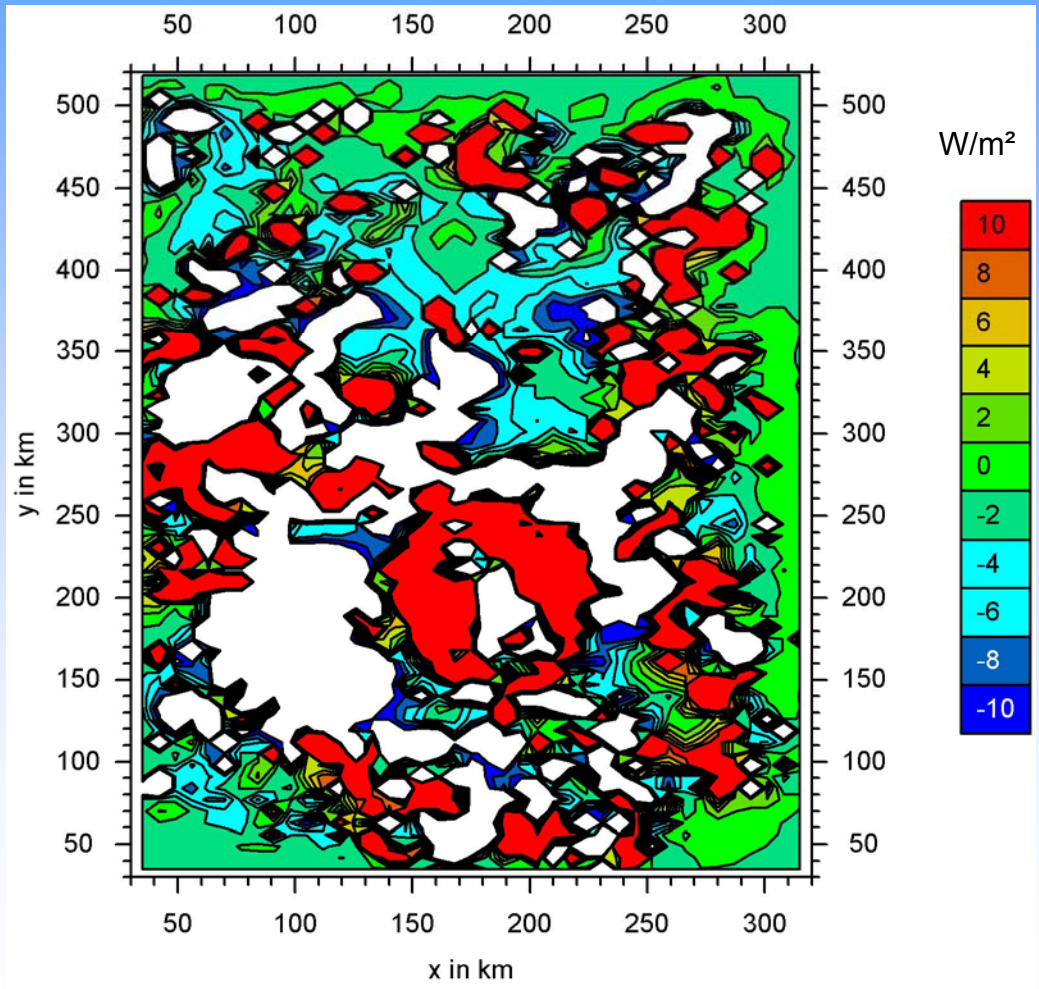
Shortwave radiation balance surface



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)

12 UTC	-2.61
13 UTC	-1.17
14 UTC	-1.90
15 UTC	-1.64
16 UTC	-1.25
17 UTC	-0.42
18 UTC	-0.03

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