Modelling direct aerosol effects on radiation in urban areas

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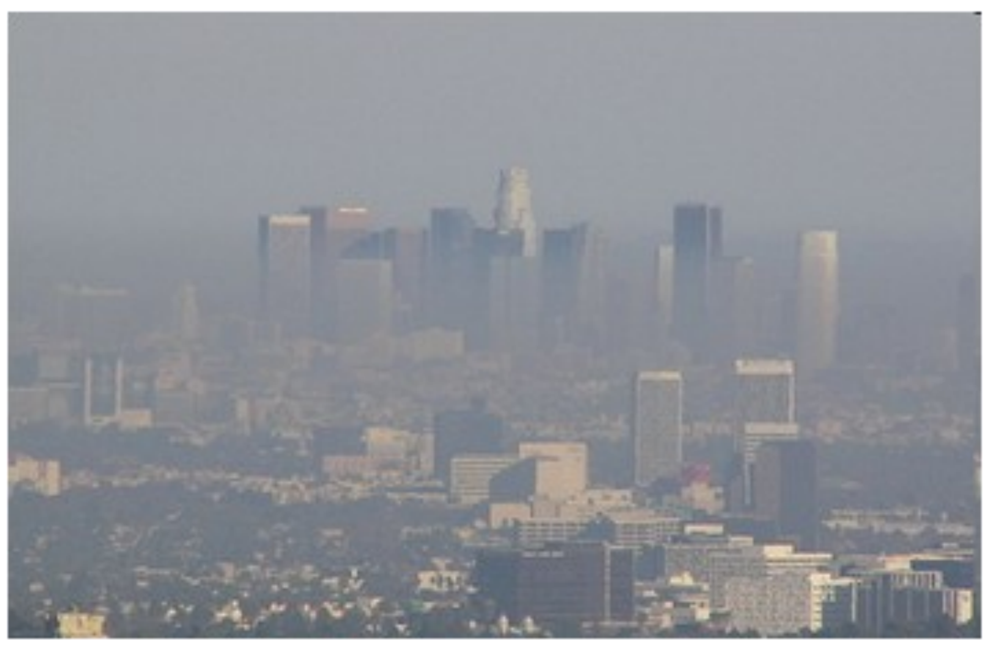
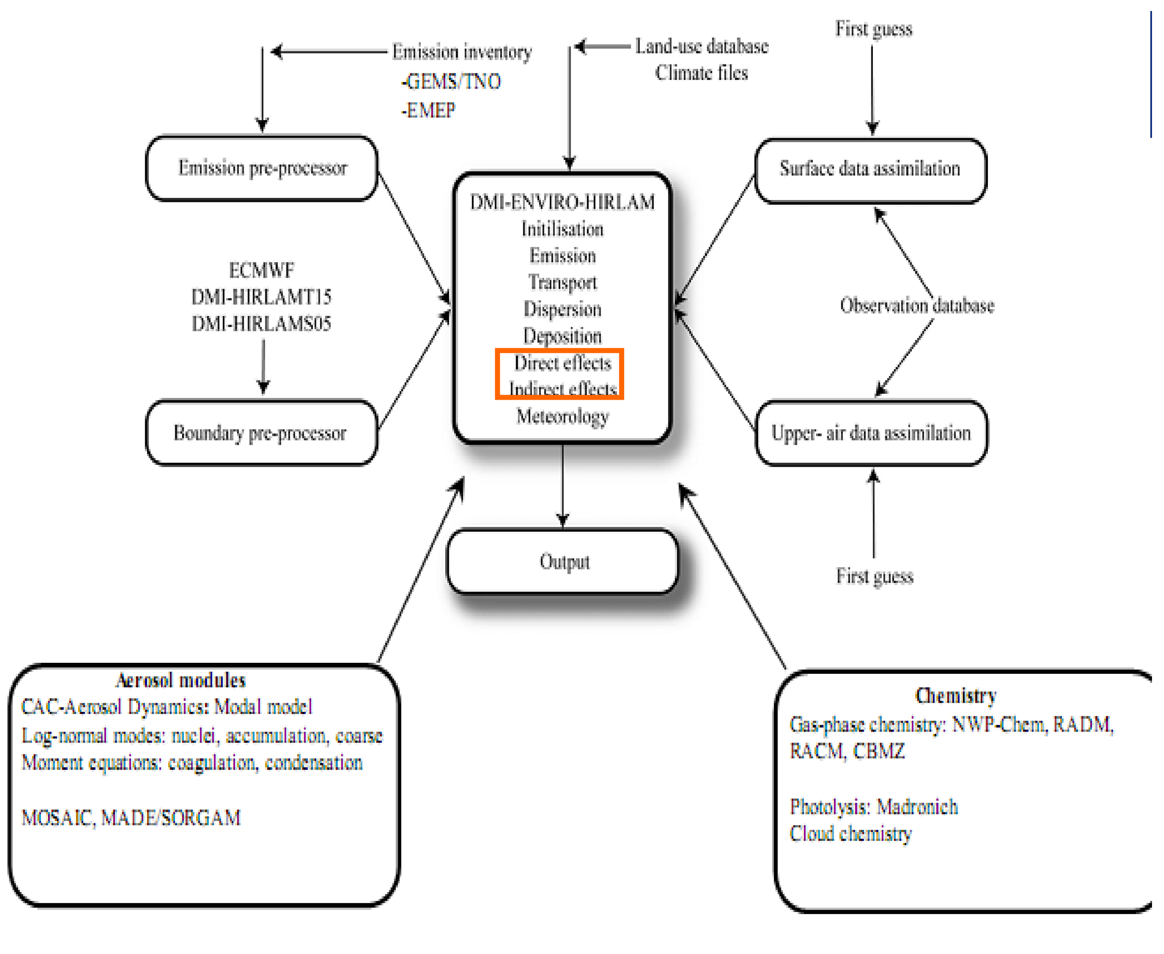
Abstract

Atmospheric aerosols are significant source of direct radiative forcing. The research is devoted to the problem of modelling of direct aerosol effect and its implementation to the radiation scheme into the online coupled meteorolology-chemistry Enviro-HIRLAM model for more accurate radiation assessment. Absorptance, transmittance and reflectance of the atmosphere for different cases of 10 main aerosol loads were calculated and can be used for solar radiation estimation. To evaluate this optical properties compiled into the Global Aerosol Data Set (GADS) were used.





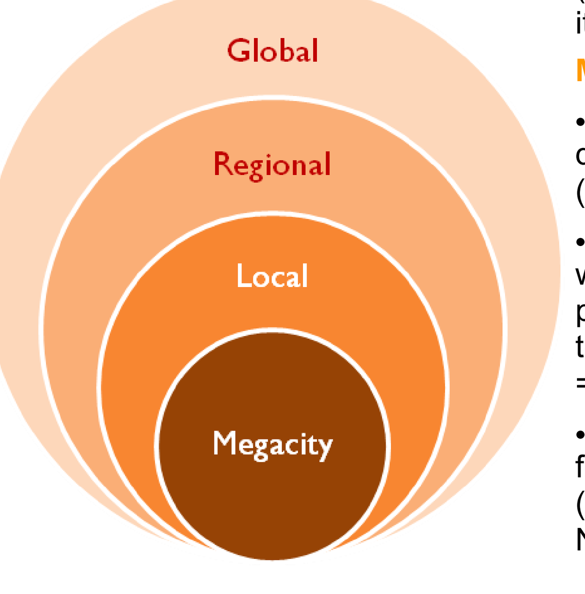
Introduction

Aerosol is one of the important components of the atmosphere in addition to absorbing gases which affect on radiative transfer at all scales.

There are a great variety of aerosols which differ by their properties. Based on their formation processes, aerosols are either primary - are directly emitted to the atmosphere - , or secondary – are formed in atmosphere by gas-to-particle conversion. Based on their sources, aerosols can be natural or anthropogenic. Natural aerosols are emitted as a result of processes of nature (windblown dust, sea salt, volcanic emission, pollen, etc.) and anthropogenic ones is related to human activities (fossil fuel burning, traffic, agricultural activities, etc.). The size range of the aerosols extents from nanometer size secondary produced molecular clusters to primary particles of tens of micrometers. Size affects both the lifetime and physical and chemical properties. Aerosol life time estimates in second-years (in the troposphere – typically hours-days). Distributions are generally uneven horizontally and vertically and high concentrations are encountered when there are nearby sources. These peculiarities of aerosols make the aerosol effect estimations task not trivial and even more difficult than estimations of greenhouse gases effect (*Jacobson et al., 2002*).

Urban areas characterized by mixture of primary emissions from industry, transportation, power generation, and natural sources and secondary aerosols through gas-to-particle conversion, number concentration dominates by ultrafine particles and mass has two dominating modes: coarse and accumulation (*Seinfield and Pandis, 1998*).

Aerosols, both natural and anthropogenic, can reduce of downward solar radiation by absorption and scattering (direct effects) and affect radiation budget by interaction with clouds serving as a cloud condensation nuclei (indirect effects). At the global scale it is considered that impact of anthropogenic aerosols on shortwave radiation compensates part of the heating caused by greenhouse gases. Understanding of aerosol effect at the regional scale especially in urban areas contains large uncertainties. These uncertainties are due to the greater temporal variability, heterogeneity of the distribution of aerosols comparing to greenhouse gases, as well as the existence of feedbacks between chemical processes in the atmosphere and the surface layer of the underlying surface (*Baltensperger at al.,2003*). Estimations of aerosol effects obtained by different authors depend on the assumptions and empirical formulations used in models; and recently the problem of a proper parameterization scheme is still unresolved.



Aerosol effects are traditionally neglected in meteorology and air quality modelling due largely to historical separation of meteorology, climate, and air quality communities as well as our limited understanding of underlying mechanisms. The current state of computer technique development and modelling makes possible on-line coupling of meso-scale meteorological models and atmospheric chemical transport models, which helps to consider different feedback mechanisms, e.g. aerosol forcing (*Korsholm et al., 2008*).

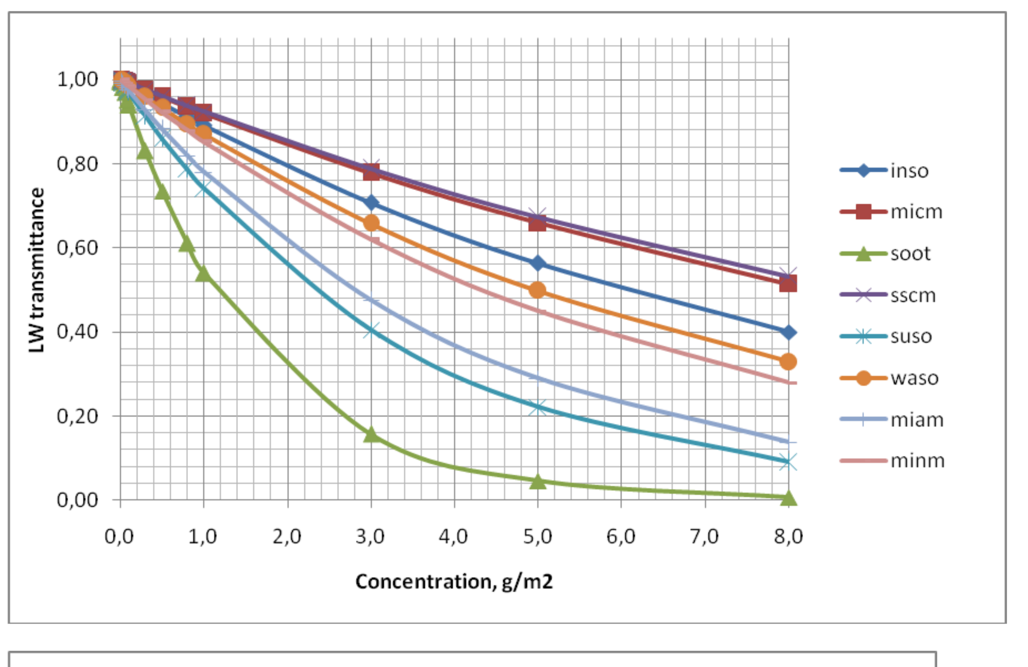
The main goal of this work is

- to study the optical properties of aerosols which determine their radiative effects and
- to test a subroutine for calculation of these properties for further implementation into the radiation scheme of regional online coupled model Enviro-HIRLAM (Environment-High Resolution Limited Area Model).

Methods

- Realization depends on the radiation scheme used in the model (Savijärvi,1990)
- Calculation of spectrally weighted aerosol inherent optical properties (optical depth, single scattering albedo, asymmetry factor) =>Look-up table
- And transmittances at horizontal fields and absorption optical depth (subroutine was written by Kristian P. Nielsen, DMI)

1.



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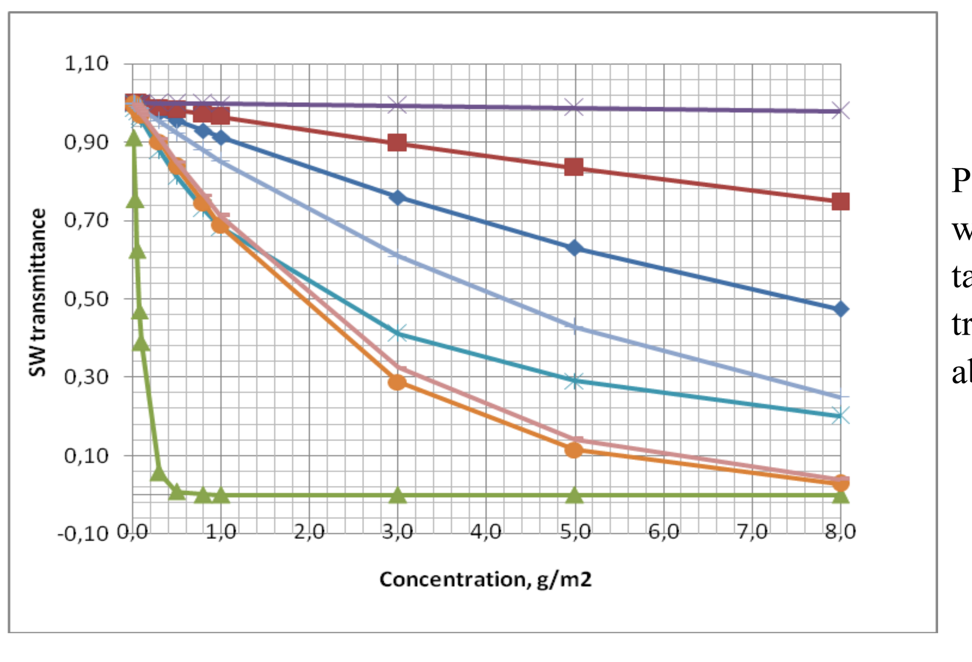
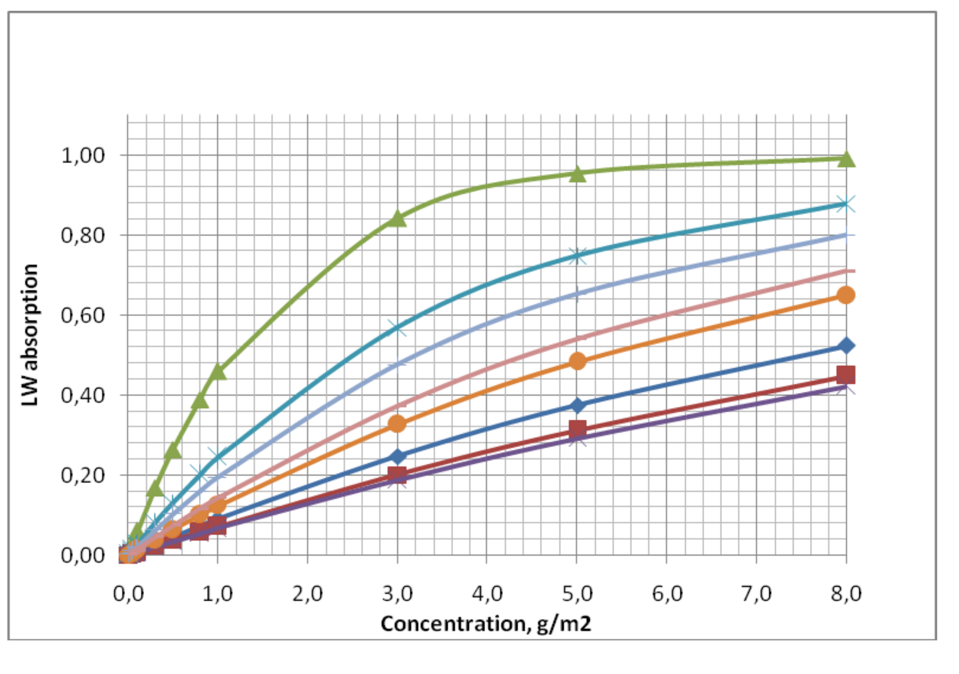


Pic. 1 – 3 Short-wave transmittance, long-wave transmittance and absorptance

Soot is a product of the combustion of fossil fuels and one of the key aerosol component in urban areas with respect to effects on radiation

2.



Global Aerosol Data Set (GADS, MPI Hamburg, *Koepke at al.,1998*)=>10components:

- waso—water soluble (organics, sulfates, nitrates),
- inso—water-insoluble (dust-like particles, clay),
- soot,
- suso—sulfate droplets (stratospheric!),
- sscm, ssam—sea-salt (2 size classes) and
- miam, minm, micm, mitr—mineral (desert dust, 4 size classes)

Future steps:

Implementation in HIRLAM 1D

Testing, validation and radiation forcing assessment (for summer 2010, fires)

Implementation into Enviro-HIRLAM (3D)

Models Inter-comparison (HARMONIA, MM5/WRF-Chem)

Results

The obtained results are shown on the pictures 1-3. It can be seen that for the short-wave radiation sea salt is almost fully transparent for the radiation, but for soot particle concentration of 0,5 g/m2 the atmosphere becomes non-transparent. In the long-wave region, sea salt are partly absorbing and soot is completely absorbing. The second and third absorbing aerosols are sulfate droplets and accumulation mode of mineral aerosols. There is non-linear dependence between the size of mineral aerosols and the transmittance/absorptance ability of the atmosphere. It has been noticed that soot properties are not varied with relative humidity (not shown here), because in the GADS soot is externally mixed.

Conclusions

- Soot is one of the key aerosols, especially in urban areas, as far as the traffic emissions have a significant impact on the soot fraction
- Direct radiative impacts due to anthropogenic aerosols are more pronounced (soot, waso, inso)
- Sea salt doesn't have a large impact at least on direct radiative forcing
- Testing shows realistic results, so further steps can be made (see table on the left side)

Thanks to Dr. Kristian P. Nielsen and other colleagues of the Danish Meteorological Institute for providing the model and help with the simulations.

References

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