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Interactions between aerosol particles and stratocumulus clouds in different airmass types

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Introduction

Beside other factors the microphysical and dynamical processes in the clouds play key role on climate change. Nowadays the effect of aerosol particles comes into view in the researches. It is justified by the fact that the size, the shape and the chemical composition of aerosol particles have an effect on global climate. Moreover the aerosol particles modify the clouds structure in complex way and about this effect has a large uncertainty (IPCC, 2007). Despite the difficulties the effects of aerosol particles are confirmed by some measurement and model results.

The aerosol particles not only affect the atmospheric processes but it characterise the pollution of atmosphere. Measurement results prove that how a significant effect have the presence of an industry area or an air corridor to the composition of atmosphere. These emission sources determine the concentration and chemical composition of aerosol particles and so have an effect to the cloud formation, the radiation balance and the precipitation formation. Not only the aerosol particles have an effect to cloud formation but also the clouds and precipitation affect to the properties of the aerosol particles.

The purpose of my research to simulate this complex interaction between aerosol particles and stratocumulus clouds, which can be observe relative frequently in the air and hence has a significant role to the cycle of the aerosol particles.

Purpose of the research

In our research we have focused on the aerosol – cloud interactions that occur in stratocumulus clouds. Not only the role of the aerosol particles in the precipitation formation was investigated, but also how the water insoluble aerosol particles are washed out. We also studied the regeneration of the aerosol particles in the subsaturated regions.

These processes were investigated in stratocumulus clouds due to their relatively simple dynamics. The weak convective updrafts generate shallow, horizontally extensive cloud layers due to the overlaying drier and stable air that blocks the vertical development of the air mass. Stratocumulus clouds play an important role in climate change due to their high albedo, which causes a significant negative contribution to the overall radiative forcing.

Description of the model

The microphysical processes that occur in a stratocumulus cloud were simulated in a dynamic framework of the idealized two-dimensional kinematic model. The two-dimensional domain includes both updraft and downdraft regions. The updraft and downdraft regions were characterized with two different maximum velocities. The horizontal and vertical extensions of the domain were 2000 m and 750 m, respectively. The resolution was 20 m in horizontal direction and it was 15 m in vertical direction.

Detailed microphysical scheme was used in the research. The size distribution of water drops and wet aerosol (haze) particles were divided into 55 bins and the aerosol particles were divided into 36 bins. The aerosol particles were divided into two categories: the water soluble and water insoluble ones. On the base of these observation the ratio of the number concentration of soluble aerosol particles and the total aerosol particle concentration was chosen to be 0.5 when the radius of the aerosol particles was less than 0.012 μm (in the first 10 bins), and this ratio was 0.7 in case of the larger sizes. The purpose of using external mixture was to investigate the different scavenging mechanism. The aerosol particles contained water soluble fraction can be washed out mostly by water drop formation (nucleation scavenging). The water insoluble aerosol particles can be collected by water drops through other different scavenging mechanism (Brownian, phoretic and gravitational collection).

In this study the following microphysical processes were taken into consideration: (i) drop formation on water soluble aerosol particles; (ii) and condensational growth/evaporation of water drops; (iii) collision - coalescence of water drops; (iv) and aerosol particles collection by water drops due to Brownian-, phoretics- and gravitational motion. Some theoretical studies suggest that the turbulence enhance the water drops – aerosol particles collection efficiency. But efficient turbulent collection was found for collector drops larger than 200 μm in combination with particles with diameter of 2 – 4 μm (Zhang and Vet, 2006). Because in the stratocumulus clouds the drops size generally less than 200 μm, the effect of turbulent collision was not taken into account in this study. The water soluble aerosol particles were transferred into the water drop category, if the relative humidity was larger then 90 %. The transfer of dry aerosol particle to wet aerosol particles due to vapor diffusion starts at subsaturated condition. In the case of small water soluble particles (< 0.1 μm) this process occurred at relative humidity larger than 95%, at larger particles size the transfer occurred at

90 %. If the mass of the water in a wet aerosol particle decreased to be equal to the mass of the aerosol inside, the wet aerosol particles were transferred to the dry aerosol particle category. Thirty minutes of cloud life time was simulated using 1 s time step.

Results and conclusions

The aim of our research was to study the cycle of aerosol particles in stratocumulus clouds using a detailed microphysical scheme in the case of maritime, rural and remote continental air mass types and at different dynamic conditions. In this study we focused on the following processes:

1. The size distribution of the wet aerosol particles was mostly affected by the nucleation scavenging, which mechanism does not change the size of the particles inside of water drops. In the stratocumulus clouds the collision – coalescence of the water drops hardly affected the size distribution of the regenerated aerosol particles. Thus after the evaporation of water drops the sized distribution of the regenerated water soluble aerosol particles was similar to the initial size distribution. This result proves that model simulates well the life cycle of the water soluble aerosol particles.

2. By the end of the simulation more than 93% of the water soluble aerosol particles and more than 99% of the mass of the water soluble aerosol particles were depleted due to the formation of water drops independently to the intensity of the updraft. The scavenging of these particles by collision with water drops was negligible.

3. The water insoluble aerosol particles were scavenged by collision with water drops by Brownian, phoretics and gravitational forces. In case of smaller updraft velocity the particles were scavenged only inside of clouds. In case stronger updraft the particles were washed out in the clouds and the downdraft core too. The highest collection rate in the remote continental air mass was the consequence of the largest total surface area of the droplets in a unit volume of the air.

4. The Brownian, phoretics and gravitational collision play a significant role in the scavenging of water insoluble particles. The scavenging efficiency depends on the size of the aerosol particles. Due to the Brownian and gravitational collision the aerosol

particles radius smaller than 0,1 µm and the particles radius larger than 1µm were scavenged efficiently. Corresponding the concentration change of particles due to updraft the concentration increase be caused by convergence near the surface was not compensated by scavenging in size range 0,3-2 µm Our results supports the observations, which show that the particles in size range of 0,1-1 um have the longest lifetime in the atmosphere.

Further purpose of research

The purpose of further research to investigate physical and transport processes of aerosol particles, for gain more information about effect of aerosol particles to clouds and climate. Participation in AEGEAN_GAME science project gives an opportunity to follow the research.

The propose of this project to investigate the physical and chemical processing of polluted air transported over the Aegean troposphere during the Etesian winds, and to evaluate the representation of these processes in models of atmospheric composition and transport. The experiment will involve flights of long legs; near surface and close to PBL top, along the direction from Lesvos to Crete to sample the spatial structure of the atmospheric parameters and of the chemical concentrations. Deep profiles exceeding the PBL top and including 30 minute closed legs at two different levels will provide information regarding radiation balance and flow divergences and fluxes. The interpretation of the airborne measurements will be enriched by the analysis of in situ continuous air pollution and meteorological measurements on the islands of Lesvos and Crete. Furthermore, measurements using instruments onboard commercial vessels commuting across the Aegean Sea will be used.

The measured physical parameters and chemical/aerosol concentrations will be compared with model predictions to assess their ability to capture various processes in the atmosphere over the Aegean Sea. This database will provide an excellent tool for further development of parameterization schemes.

List of publication

1. Papers related to the dissertation

1. **Szabó–Takács B**. 2011: *Numerical simulation of cycle of aerosol particles in stratocumulus clouds with a two-dimensional kinematic model*. Időjárás, vol. 115, No. 3., pp. 147–165, (probable IF is about 0.6)

2. **Takács B**., Geresdi I. 2009: *A légköri aeroszolrészecskék kialakulása, hatásai és azok vizsgálatai*. In: Szabó–Kovács B.–Tóth J.–Wilhelm Z.: Környezetünk természeti-társadalmi dimenziói. Tanulmánykötet Fodor István tiszteletére. Publikon Kiadó, Pécs, pp. 79-89

3. **Szabó – Takács B**. 2009: *Cirrus felhőkben végzett repülőgépes felhőfizikai mérések és ezek kiértékelése*. Légkör, 54, pp. 15–20

4. Geresdi I**., Takács B.** 2008: *Numerical study of atmospheric aerosol scavenging by water drops.* Geographia Pannonica Nova III. Imediars Publisher, pp. 315–321

1.2. Publications in conference proceedings

1. **Takács B.** 2007: *Szilárd halmazállapotú aeroszol részecskék kimosódása a légkörből*. In. Máté Csongor [et. al.]: III. Kárpát-medencei Környezettudományi Konferencia, Kolozsvár, pp. 80–85

2. **Takács B.** 2007: *Numerical simulation of atmospheric aerosol collection efficiencies of water drops*. In.: Lehoczky L. – Kalmár L. (eds.): 6th International Conference of PhD Students, Miskolc, pp. 139–143

3. **Szabó-Takács B.** 2011**:** *Csapadékképződés hatása az aeroszol részecskék körforgására*, In. Szappanyos Melinda: IX. Grastyán Konferencia, PTE Grastyán Endre Szakkollégium, Pécs, pp. 430–435

2. Papers not related to the dissertation

1. **Takács B.** Geresdi I. 2008: *Részvétel az EUFAR Phd iskolán A 2008 április 23-i repülőgépes mérés eredményei*. Egyetemi Meteorológiai Füzetek, No. 22, pp. 180–184

2. Clavo A., Blackett M., Chou C., Frey W., Markakis K., **Takács B**. 2008: EUFAR Summer school, 16 – 24 April 2008, Utrecht, Flight mission B359 (22 – April – 2008), Group B Final Report. In http://bo.eufar.net/document/project/1253271950486b2aecb61c1:t.pdf

3. Bolbasova L., Fiori E., Katzwinkel J., Mallaun C., **Szabo-Takacs B**. 2010: TETRAD Scientific report - Group 3 – Flight 53, Turbulence and aerosol (TAA) project.In: http://bo.eufar.net/document/project/TETRAD_scientific_report_group3_20110105115845.pdf