Enviro-HIRLAM sensitivity to the wet and dry deposition

Iakov Gontsov

ABSTRACT

Dry deposition is the removal of gaseous and particulate nuclides or other pollutants from the atmosphere to the earth surface by vegetation or other biological or mechanical means. In wet deposition, there are always some atmospheric hydrometeors which scavenge aerosol particles. Usually the wet deposition is treated in a standard way with a wash out coefficient for a bellow-cloud scavenging and a rainout coefficient for incloud scavenging. The washout coefficient is strongly depends on the particle size. This dependence, however, is not included in most atmospheric models. Therefore, a revised formulation of the wet deposition parameterizations of particles of different size is suggested. Possible ways to implement different parameterization of the dry and wet deposition are observed.

Main Aim:

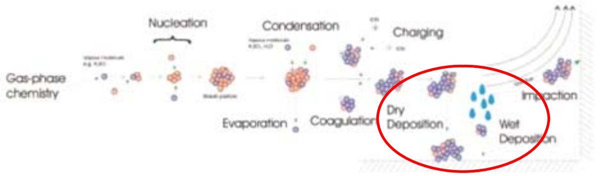
➢ Sensitivity to deposition mechanisms of the Enviro-HIRLAM

Objectives:

➢ Implementation and code improvement of the Enviro-HIRLAM modeling system
➢ Considering one case study scenario, based on the Chernobyl accident (or some other, e.g., Algeciras or ETEX)
➢ Analysis of different parameterizations of the dry deposition and gravitation settling.
➢ Analysis of different parameterizations of the wet deposition (rainout and washout mechanisms).
➢ Sensitivity study of the atmospheric deposition and airborne transport on particle size, density, etc.
➢ Links the rainout mechanism with cloud characteristics in Enviro-HIRLAM and comparison with off-line runs (e.g. 3D clouds vs. precipitation only).

Deposition:

- aerosol particles are removed from the atmosphere by deposition (dry and wet deposition)
- in dry deposition, particles touch/hit a surface (soil, ground, water) and remain there
- dry deposition the most important removal pathway for coarse (2.5 мм < Dp < 10 мм) and ultrafine (Dp < 0.1 мм) particles
- in wet deposition, particles are removed from the atmosphere by rain or fog
- wet deposition is the most important removal pathway for fine particles, especially particles in the size range 0.1-1 мм



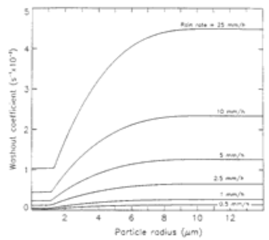


Figure 1

Dependence of the washout coefficient on particle radius and rain intensity.

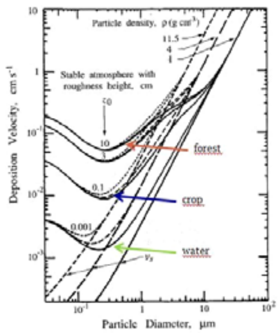


Figure 2

Close to the surface deposition flux

$$F = -v_d C$$

Deposition velocity v_d is most strongly affected by particle size and the roughness of the surface

Here the following effects can be distinguished:

❖**– Suppression of drizzle is part of the cloud lifetime effect** as being shown most clearly from ship track studies, e.g., Ferek et al. (1998). However, one remaining problem is that most climate models suggest an increase in liquid water when adding anthropogenic aerosols, whereas newer ship track studies show that polluted marine water clouds can have less liquid water than clean clouds (Platnick et al., 2000; Coakley Jr. and Walsh, 2002; Ackerman et al., 2004).

❖**– Aerosols may change the occurrence and frequency of** convection and thus could be responsible for droughts and flood simultaneously.

❖**– Aerosols may cause reductions in the net solar radiation** reaching the surface. In particular the direct sunlight is reduced. Thus, even in a (greenhouse gas induced) warmer climate the evaporation could decrease and the hydrological cycle could be expected to slow down.

❖**– Aerosol induced cooling can have consequences in** other parts on the world. It is believed that the cooling of the Northern Hemisphere causes a southward shift of the intertropical convergence zone, which could have been partly responsible for the Sahelian drought.

❖**– Anthropogenic aerosols could influence mixed-phase** clouds by retarding the onset of freezing due to their smaller size (thermodynamic process), by acting as ice nuclei in the different freezing modes and hence speeding up the Bergeron-Findeisen process (glaciation effect) and by the reducing the riming process (see also Table 1). These aerosol influences are not studied well enough to predict their sign yet. However, these aerosol effects may suggest a mechanism for a decreasing cloud water content with increasing aerosol load.

Future plans:

- Feedbacks – simple direct / simple indirect
- Sensitivity of advection scheme
- Model code sensitivity analysis
- Effects of urbanization pollutants (transport, transformation and deposition) could be linked with feedbacks

Conclusions:

We are entering a new area of aerosol research by investigating the interactions between aerosols and the hydrological cycle. Research in this area started with cloud seeding research, as summarized in the overview article by Bruintjes (1999). Investigations in cloud seeding research could benefit from satellite-based microphysical retrievals that can be combined with in situ cloud sampling to monitor the effects of natural and anthropogenic aerosol or hygroscopic seeding material on cloud droplet size evolution, and the effects of ice-forming nuclei on ice-particle concentrations, both of which determine the efficiency of precipitation formation. The cloud seeding community, however, has traditionally not been interested in the climate impact of anthropogenic aerosols or their effect on the global hydrological cycle, but has focused on the influence of aerosols on precipitation on a local to regional scale. Thus, a knowledge exchange between the two research communities would be beneficial.

Our knowledge about aerosol effects on clouds and the hydrological cycle is still very rudimentary. The observations for the hydrological cycle are less complete than for global mean temperature and the physical constraints are weaker so that it will be substantially harder to quantify the range of possible changes in the hydrological cycle (Allen and Ingram, 2002). Therefore, clearly more research in terms of field experiments, laboratory studies and modeling efforts is needed in order to understand and quantify the effect of anthropogenic aerosols on clouds and the hydrological cycle. This is especially important because cloud feedbacks in climate models still represent one of the largest uncertainties.

References

Br´eon, F.-M., Tanr´e, D., and Generoso, S.: Aerosol effect on cloud droplet size monitored from satellite, Science, 295, 834–838, 2002.

Bruintjes, R. T.: A Review of Cloud Seeding Experiments to Enhance Precipitation and Some New Prospects, Bulletin of the American Meteorological Society, 80, 805–820, 1999.

U. Lohmann and J. Feichter: Indirect aerosol effects: a review, Atmos. Chem. Phys. 5, 715-737, 2004

Gorbunov, B., Baklanov, A., Kakutkina, N., Windsor, H. L., and Toumi, R.: Ice nucleation on soot particles, J. Aerosol Science, 32, 199–215, 2001.