A scheme for particle deposition from turbulent flows above surfaces

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A new scheme for dry deposition of atmospheric aerosols is developed by the authors (2012, hereafter KS2012 scheme). Unlike earlier schemes, it is based on physical considerations and contains minimum of empirical parameters. This makes the scheme applicable in atmospheric transport models at various scales. The scheme provides simple relationships that can be tested both in laboratory and in outdoor experiments.

The scheme expresses the deposition velocity V_d – steady-state deposition flux per unit concentration at given height – through the physical properties of a species, flow, and surface. Particles are given by three basic properties: inertial relaxation time τ_p, physical size d_p, and Brownian diffusivity D. These properties can be related to diameter of a spherical particle of a given density at particular air temperature and pressure, however arbitrary particles can be handled as long as their basic properties can be expressed. This approach allows in particular to account for non-spherical particles, particle size growth with humidity, *etc*. The flow is characterized by the turbulent velocity scale at the surface. In case of thermally homogeneous flow this scale is a friction velocity u_*.

The surface properties are given only with two parameters that have clear physical meaning and can be derived from basic surface properties. One of them – aerodynamic roughness length z_0 is used to distinguish between smooth and rough flow regimes. This distinction is based on the roughness Reynolds number $u_* z_0/\nu$, where ν is air viscosity. The expression for the deposition rate onto smooth surface results from the solution of the steady-flux equation with turbophoresis term and has no tuning parameters.

Rough surfaces are characterized by z_0 and newly-introduced "collection scale" which accounts for the effective size of collectors and ratio of the velocity at the roughness top to the friction velocity. The collection scale was found to characterize the deposition with three main processes: inertial impaction, interception and Brownian diffusion, corresponding to the basic particle properties. The expressions for deposition rates are found and verified against the data of wind tunnel measurements and numerical simulations.

The results of the scheme agree well to the available experimental data on particle deposition onto solid and water surfaces at least up to 20 m/s wind speeds. The scheme agrees well with the data of wind tunnel studies of deposition onto low-vegetated and gravel surfaces. The scheme also agrees with wind-tunnel experiments on the deposition to vegetation elements, but no quantitative conclusion can be made due to the experimental uncertainties. The data of outdoor experiments have too much scattering to judge on the performance of the parameterization.

The resulting scheme for chemical transport models is shown in Fig. 1. The deposition fluxes are evaluated at height z_1. Each model grid cell is assumed to have "smooth" and "rough" tiles with corresponding velocity scales. The resulting flux is a weighted sum of fluxes onto tiles. The fluxes for "smooth" tiles are evaluated directly from height z_1. For "rough" tiles the deposition pathway is split into above-canopy- and in-canopy layer. The latter is assumed to start at z_0. $V_d(z_0)$ is calculated as a sum of deposition velocities due to different mechanisms and then the above-canopy layer is accounted with standard Monin-Obukhov profiles for eddy diffusivity and exponential scheme that treats diffusion and regular velocity (settling) consistently, and unlike earlier resistance-based schemes, allows for the concentration evaluation at particular height z_{obz}.

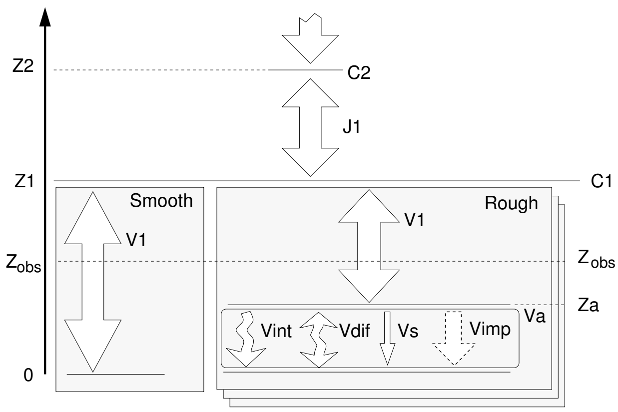

Figure 1: The outline of KS2012 dry deposition scheme

The scheme in a reduced form is implemented into SILAM chemical transport model (`http://silam.fmi.fi`). The full implementation requires a knowledge of collection scales for various land-use types. Few of them were found from available data of experiments with calibrated aerosols. Unfortunately, such experiments are very few in literature so more experiments for various surfaces are needed (see our poster).

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