Particle collection properties of high vegetation elements

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A new scheme for dry deposition of atmospheric aerosols onto surfaces is developed by the authors (2012, hereafter KS2012). For rough surfaces it utilizes a similarity between deposition processes for momentum and matter. The scheme considers deposition via three main processes: inertial impaction, interception and Brownian diffusion, controlled by three basic particle properties: inertial relaxation time τ_p, physical size d_p, and Brownian diffusivity D. It was found that there is a parameter a, called "collection scale" that, together with aerodynamic roughness, fully describes surface properties with respect to the deposition processes. The values of this parameter for few surface types including low vegetation were found from published wind-tunnel data. Current study attempts to evaluate the collection scales for high vegetation from three wind-tunnel experiments with vegetation elements.

In the experiments by Beckett et al. (2000), Freer-Smith et al. (2004) and Reinap et al. (2009), branches or small trees were exposed to a flow of particles NaCl particles of size $d_p \sim 1\ \mu$m. The wind speeds U in these experiments were within 1-10 m/s, which is higher than normally observed in natural canopies, but provides some dynamic range to evaluate collection scales. The deposition rates were evaluated as mass fluxes per unit of projected leaf area whereas the concentrations were measured as number densities.

Simple calculations with KS2012 scheme show that main deposition mechanism in the experiments is interception, i.e. capture of particles due to their finite size. The deposition velocity to a rough surface surface due to interception v_{int} is proportional to square of particle size:

$$v_{int} = u_* \cdot 80 \left(d_p/a\right)^2 \mathrm{Re}_*^{1/2}, \qquad (1)$$

where $\mathrm{Re}_* = u_* a/\nu$ is a collector Reynolds number, ν is the kinematic viscosity of the air, $a = d_c u_*/U_{top}$ is the collection scale, that fully describes the deposition within the canopy layer for diffusion and interception, d_c is a collector size (leaf width or needle diameter) and U_{top} is the wind speed at the canopy top. In the context of KS2012, the scale a can be considered as a surface parameter without its actual connection with actual collector geometry.

To match the experimental data with KS2012 few assumptions have to be made. Firstly, the drag coefficient of canopy elements $C_d = 1$ is assumed, which means that they have poor aerodynamics and shadowing is neglected. Secondly, the ratio $U_{top}/u* = 3$ is assumed. Then a single-element collection efficiency for a canopy element:

$$\eta = \frac{9}{2} \cdot 80 \left(d_p/d_c\right)^2 \mathrm{Re}^{1/2}, \qquad (2)$$

where $\mathrm{Re}_* = u_* d_c/\nu$. The collector size d_c can be obtained from best fit for each of the plant species (Fig. 1).

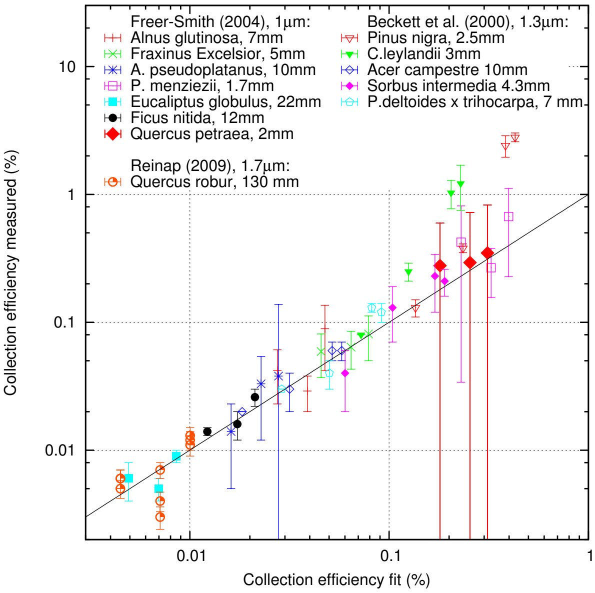

Figure 1: The fitted collection efficiencies for best-fit values of collector size d_c of each species

In general the relation $V_d \propto U^{3/2}$ (1:1 line in the plot) holds well for each species, except for the coniferous species (*Pinus nigra* and *Cupressus leylandii*) at high wind speeds when inertial impaction becomes significant. The collection scales obtained in different experiments appear incomparable for two oak species (*Q. robur* and *Q. petraea*), most probably due to significant effect of coarse tail in particle size distribution. The missing information on actual aerodynamic drag and uncertain coarse tails in particle-size distributions in the experiments prevented more accurate evaluation.

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Global Change Biol., *6*(8), 995–1003, doi:10.1046/j.1365-2486.2000.00376.x.

Freer-Smith, P., A. El-Khatib, and G. Taylor (2004) *Water, Air, & Soil Pollution*, *155*, 173–187, doi:10.1023/B:WATE.0000026521.99552.fd.

Kouznetsov, R., and M. Sofiev (2012) *J. Geophys. Res.*, *117*, D01,202, doi:10.1029/2011JD016366.

Reinap, A., B. Wiman, B. Svenningsson, and S. Gunnarsson (2009) *Trees – Structure and Function*, *23*, 1263–1274, doi:10.1007/s00468-009-0366-4.