Modelling the effect of landscape structure on the dispersal of biotic particles

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MODELLING THE EFFECT OF LANDSCAPE STRUCTURE ON THE DISPERSAL OF BIOTIC PARTICLES

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1. INTRODUCTION

The introduction of genetically modified crops and a growing tendency to limit the use of pesticides have led to increased interest in evaluating the dispersal mechanisms of biotic particles (pollen, spores). Real field situations are often far from the ideal, homogeneous case: they are characterised by landscape heterogeneities such as roughness changes, field discontinuities, gaps, roads, tree lines, forest plots, etc. It is therefore of primary importance to be able to assess the influence of these features on particle dispersal. Such investigation may also suggest possible ways of better controlling the dissemination, for example by increasing locally the deposition.

To address this problem we have developed a flow model able to simulate particle dispersal in the lower atmosphere. Lagrangian models are often used for this purpose because they tend to mimick particle motion and are relatively easy to use. However they are unable by essence to calculate the flow characteristics themselves and require velocity and turbulence fields to be prescribed a priori, which is not possible in most heterogeneous, real-world situations. This is the reason why we chose to model the dispersal in an Eulerian framework.

2. TRANSPORT MODEL

The flow model is based on the integration of Reynolds averaged conservation equations for mass, momentum and energy, with standard source-sink terms representing the action of the canopy. The set of equations is closed using an energy-dissipation turbulence model. A conservation equation for particle concentration was added, in which deposition is represented by a sink term accounting for impaction and sedimentation. A well-documented numerical scheme is used to solve the set of equations over a two- or three-dimensional domain (Foudhil, 2002).

3. VALIDATION

Accurate simulations of particle dispersal cannot be achieved without a correct simulation of the turbulent flow itself. We therefore found it important to validate the model in various heterogeneous configurations, using available experimental data collected in the field or in wind tunnels. The cases investigated were: smooth-to-rough roughness change (Bradley, 1968), temperature step with inversion in the wall flux (Charnay et al., 1979), flow in a uniform canopy (Brunet et al., 1994), flow in a heterogeneous canopy consisting of strips of vegetation and smoother surface (Raupach et al., 1987), spore dispersal in a homogeneous crop (Bainbridge and Stedman, 1979). In all cases validation was found satisfactory, except in a few heterogeneous cases just at the entry of the crop.

As an example, Fig. 1 shows in the latter case a comparison of measured and simulated spore concentration profiles at various distances from a line source in a 1 m tall barley crop. It can be seen that, apart from a slight overestimation of the concentration with no consequence on the deposition, the model reproduces well the vertical variation in concentration at all distances.

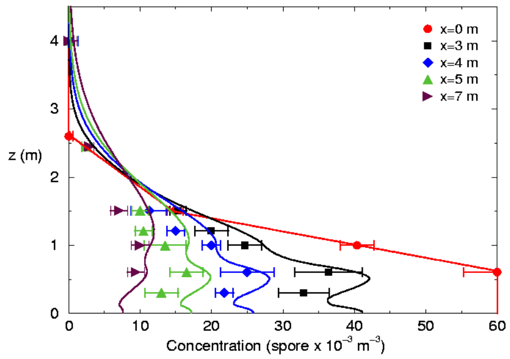

Figure 1. Comparison of measured and simulated spore concentration profiles over a 1 m barley crop, at various distances from a line source (Bainbridge and Stedman, 1979).

We are currently validating the model against data sets recently collected during two experiments, one on pollen dispersal over a maize field, the other on spore (*Uncinula Necator*) dispersal over a vineyard.

4. SIMULATIONS

4.1 *Sensitivity analysis*

A sensitivity analysis to several parameters or configurations can be performed. One example is displayed in Fig. 2, showing the influence of the particle terminal velocity. It can be seen that the

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heaviest particles rapidly impact on the ground (in this simulation example 50 % of the particles with $V_s = 40$ cm s^{-1} impact within the first 20 m) whereas the lightest ones are transported over much longer distances.

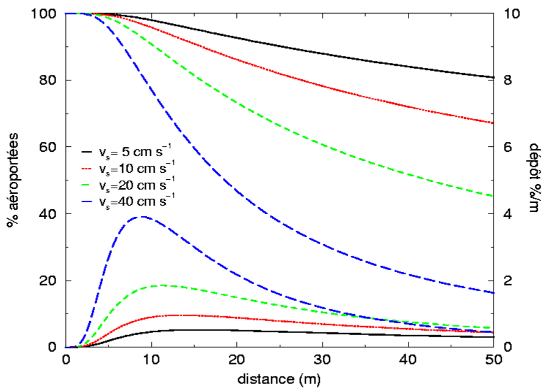

Figure 2. Influence of the sedimentation velocity on the deposition (bottom curves) and the remaining fraction of the initial horizontal flux (top curves). In this simulation the source height is 3 m, $u_* = 0.3$ m s^{-1} and $z_0 = 0.05$ m.

4.2 *Two-dimensional gaps and discontinuities*

In order to quantify the effect of discontinuities on particle dispersal several two-dimensional configurations have been studied. In the four cases presented here we consider a 20 m long crop providing an area source, followed by different surface types: (1) a continuous smooth surface, (2) a 50 m strip of smooth surface followed by a crop similar to the source, (3) a 25 m strip followed by a crop and (4) a continuous crop.

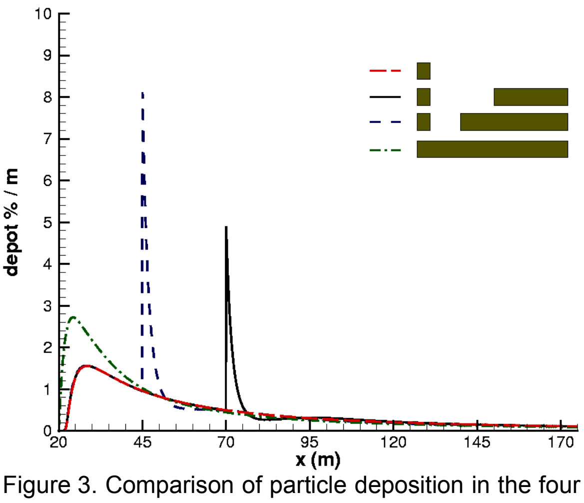

Figure 3. Comparison of particle deposition in the four cases considered (see text).

The results confirm that deposition is more efficient over rough surfaces (compare cases 1 and 4). They also show a peak in deposition at the upstream edge of a crop following a smoother surface.

4.3 *Pollen transfer across three-dimensional gaps*

An experiment was conducted in 1998 over a heterogeneous, three-dimensional field system with a 20 x 20 m square of blue maize in the middle of a larger square of a lower crop, itself embedded in a field of yellow maize (Klein, 2000). Observations on the proportion of blue grains in the yellow field were made at harvest. The whole system was simulated using our model, and a good qualitative agreement was obtained. In particular, the model reproduced quite well the strong deposition observed at the edge of the yellow field.

5. CONCLUSION

Good success was obtained with this model in the various simulated cases. The results obtained in some of the configurations tested indicate that special care must be given to the parameterisation of turbulence in the entry region of the crop. The present scheme must be improved with respect to this and the new set of experimental data collected using pollen and spores will be used for further validation. We are confident that the model can be an efficient tool for predicting the influence of landscape structure on atmospheric flow and particle dispersal.

6. REFERENCES

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