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# Pressure Perturbations Around Shelterbelts: Measurements and Model Results

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# PRESSURE PERTURBATIONS AROUND SHELTERBELTS: MEASUREMENTS AND MODEL RESULTS

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## 1. INTRODUCTION

Inhomogeneous vegetation can be considered as a collection of porous obstacles that creates a perturbation-pressure field in the presence of wind in the atmospheric surface layer. Gradients of this pressure field may be large over limited areas, and the resulting contribution to the balance of forces in these regions can likewise be quite large. An understanding of the pressure fluctuations and their role in determining the flow field through and around vegetation is key to describing the flow field, which, in turn, is critical to understanding the energy and water balances and of individual components of and hence the aggregate behavior of agricultural ecosystems.

Because of the close link between the pressure perturbation and the wind field, changes in wind direction can markedly change the pressure fluctuations in the lee of vegetation. In addition to their central role in the balance of forces, these pressure fluctuations may be important factors for trace gas evolution from the surface.

Static pressure measurements, however, are rarely a component of micrometeorological field programs. We have measured surface static pressure fields in the vicinity of a mature agricultural shelterbelt under different wind conditions. We have compared these measurements with results of a numerical model that simulates the flow field and its interaction with vegetation. A few results are given in the following sections.

## 2. MEASUREMENTS

We measured wind, temperature, and static surface pressure fields in the vicinity of a mature ash-conifer agricultural shelterbelt of height H =12 m and width 10.3 m at the University of Nebraska research farm approximately 50 km north of Lincoln, Nebraska, USA. Measurements were taken on the southerly of two east-west belts separated by 132 m (11 H). Details of the pressure measurements are given by Schmidt et al (1995). A typical horizontal profile of pressure coefficient for flow perpendicular to the shelter is given in Fig. 1, together with the 95% confidence limits on the measurements. The pressure coefficient is the pressure drop from the undisturbed value divided by $0.5\rho u^2$, where $\rho$ = density and u is the upwind reference wind speed at 10 m. The spacing of the sensors was determined in advance of the field measurements by use of a numerical model (see section 3). By this means, we predicted that a very sharp pressure maximum would exist upwind of the shelter and that a plateau of pressure would exist in the lee. Fig. 1 confirms existence of this abrupt change in pressure with upwind distance. Fig. 1 also demonstrates the large pressure gradients that exist in the vicinity of the shelter and a relatively flat pressure dependency in the near lee, followed by a pressure rise beyond 5 H. The very small rise in pressure within 1 H downwind of the shelter was a persistent feature and seems to be related to the widely observed jet through the vegetation near the surface (figure not shown).

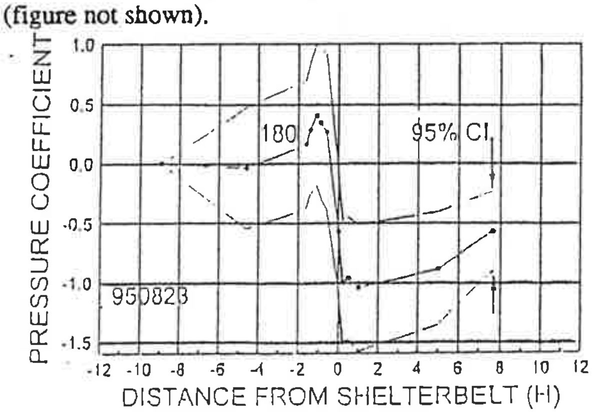


Fig. 1. Surface pressure near a shelterbelt.

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## 2. MODEL RESULTS

The numerical model we used simulates flow through a thick shelter as turbulent flow through a porous medium in the atmospheric boundary layer (Wang and Takle, 1995a). The velocity-dependent drag in the shelter creates a force in the Navier-Stokes equation that establishes a pressure field in and around the shelter (Wang and Takle, 1995b). Fig. 2 gives a simulation of the static pressure field at the ground for a tall shelterbelt. Note that the pressure field is very flat from the shelter to about 11 H in the lee and recovers to the upwind undisturbed value beyond 12 H. The shape of the calculated pressure profiles generally agrees with the measured fields plotted in Fig. 1 except that the pressure plateau in the lee is longer in the calculated results. The northerly shelter mentioned in section 2 likely contributed to the pressure rise at 8 H in Fig. 1.

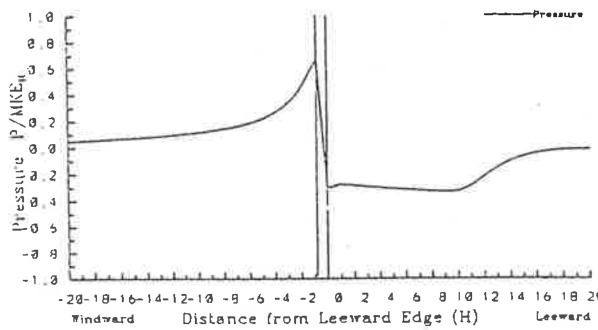


Fig. 2. Model simulated surface pressure.

The calculated dependence of pressure perturbation on wind angle for a shelter of 10.3/12 H = 0.86 H are shown in Fig. 3. Note the large decrease in pressure perturbation in the lee when the wind rotates from 30° to 70°. This suggests that for a large region in the lee, the pressure will fluctuate significantly with wind direction, particularly for flow oblique to the shelter. This will create a pumping action at the surface and could influence the surface fluxes of trace gases in ways not accounted for by turbulent processes.

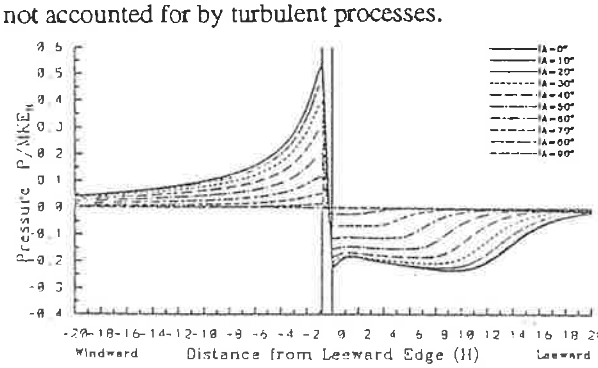


Fig. 3. Normalized pressure dependence on wind angle.

## 4. DISCUSSION

These preliminary results suggest that the horizontal static pressure field in the lee of an agricultural shelterbelt has a very asymmetric pattern across the shelter, being characterized by a monotonic rise ahead of the shelter, an abrupt drop across the shelter, a long plateau region in the lee, followed by a pressure-recovery region beyond 11 H for flow perpendicular to the shelter. The numerical model gives the general shape of the pressure field and suggests that the pressure perturbation will be markedly reduced for flow oblique to the shelter. Fluctuating wind direction will create a pumping action at a given location in the lee that may be important for evaluating surface fluxes of trace gases.

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