Biogeosciences Discussions, 2, S630–S632, 2005
www.biogeosciences.net/bgd/2/S630/
European Geosciences Union

Biogeosciences Discussions

Interactive comment on "A simple model to estimate exchange rates of nitrogen dioxide between the atmosphere and forests" *by* J. Duyzer et al.

Anonymous Referee #4

Received and published: 13 October 2005

This contribution is dealing with a simple two-layer model that is used to describe the exchange of the reactive trace species NO, NO_2, and ozone between the atmosphere and forests-soil system. The authors used flux-resistance approach to predict this exchange. Because of a notably violation of the governing balance equations of these trace species, explained in my major comments, I do not recommend to publish the contribution of Duyzer et al. in BG.

Major comments

Under the conditions of horizontal homogeneity and stationary state we can argue that the vertical part of the flux divergence equals the source/sink terms due to chemical reactions. Thus, we have a variation of the vertical eddy fluxes of the reactive trace species under study with height. If chemical reactions are important, this variation with height cannot be ignored, as already stated by various authors (see, e.g., the reference list of this manuscript). Consequently, any use of a flux-resistance approach for the turbulent region of the atmospheric layer above the tree tops, for which the characteristic time scales of transport and chemical reactions are of the same order of magnitude (usually expressed by the Damkohler number), is not in agreement with the variation of the eddy fluxes with height due to chemical reactions because the flux-resistance relationship requires that the flux must be height-invariant.

The same is true for the trunk space, even though the situation is more complex. The use of flux-resistance approach for the canopy, often proposed in the literature and applied in the two-layer model of Duyzer et al., cannot be justified even in the case of the fluxes of long-lived trace species, water vapor, and/or sensible heat because all these fluxes strongly vary with height inside the canopy of tall vegetation like a forest and may even change their directions (e.g., Denmead and Bradley, 1985; Raupach et al., 1996). This is the main reason why higher-order closure methods (e.g., Meyers and Paw U, 1986, 1987; Pyles et al., 2000) and large-eddy simulation techniques (e.g., Shaw and Schumann, 1992) have been developed for realistically simulating the exchange between the atmosphere and tall vegetation. Since chemical reaction taking place inside such canopies can, in addition, appreciably modify this flux behavior, we have to recognize that no theoretical or empirical basis for the use of flux-resistance approaches inside the canopy of tall vegetation exists. Therefore, the simple two-layer model of Duyzer et al. is really too simple and it can only produce unsuitable results. In comparison, for instance, with the model of Gao et al. (1993), this simple two-layer model can only be assessed as a serious setback.

References

Denmead, O.T., Bradley, E.F., 1985: Flux-gradient relationships in a forest canopy. In: Hutchison, B.A., Hicks, B.B. (eds.), The Forest-Atmosphere Interaction. D. Reidel, Dordrecht/Boston/ Lancaster, 421-442.

Gao, W. Wesely, M.L., Doskey, P.V., 1993: Numerical modelling of the turbulent-diffusion and chemistry of NO_x, O_3, isoprene, and other reactive trace gases in and above a forest canopy. J. Geophys. Res. 98(D10): 18339-18353.

Meyers, T., Paw U, K.T., 1986: Testing of a higher-order closure model for modeling airflow within and above plant canopies. Boundary-Layer Meteorol. 37, 297-311.

Meyers, T.P., Paw U, K.T., 1987: Modelling the plant canopy micrometeorology with higher-order closure principles. Agric. Forest Meteorol. 41, 143-163.

Pyles, R.D., Weare, B.C., Paw U, K.T., 2000: The UCD advanced canopy-atmosphere-soil algorithm: Comparisons with observations from different climate and vegetation regimes. Quart. J. R. Met. Soc. 126, 2951-2980

Raupach, M.R., Finnigan, J.J., Brunet, Y., 1996: Coherent eddies and turbulence in vegetation canopies: The mixing-layer analogy. Boundary-Layer Meteorol. 78, 351-382.

Shaw, R.H., Schumann, U., 1992: Large-eddy simulation of turbulent flow above and within a forest. Boundary-Layer Meteorol. 61: 47-64.

Interactive comment on Biogeosciences Discussions, 2, 1033, 2005.