On the Simulation of Pollutant Dispersion under Low Wind Speed Conditions

A contribution to subproject SATURN

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Summary

A Lagrangian dispersion model (GRAL) has been developed to account for the specific dispersion conditions under low wind speed conditions known as meandering. In combination with a suitable wind field model, the model can also handle dispersion of pollutants in complex terrain. Since it is not restricted to certain kinds of sources, the model can be used very versatile. The meteorological pre-processor of the model allows for using routine meteorological data and hence, the model can be applied for environmental assessment studies.

One main advantage compared to other existing models, which treat calm wind conditions, is, that the degree of meandering in the model is a continuous function of wind speed. In other words, simulations in highly complex terrain, where there may exist regions with high wind speeds (e.g. channelling effects), and regions with low wind speeds (e.g. basins), can all be performed simultaneously with the model.

Introduction

The dispersion of pollutants under low wind speed conditions is still a challenge for theoreticians and modellers. Under such conditions meandering of the flow can often be observed. A sound explanation of it could not be given so far. This makes it difficult for modellers to account for the resultant enhanced plume spreads in dispersion models.

Activities

In this study a new approach is presented, which can be used in a Lagrangian dispersion model. The new method to model dispersion under low wind speed conditions is based on observed Eulerian autocorrelation functions by means of a sonic anemometer. Eulerian autocorrelation functions $R_{Ev}(t)$ and $R_{Ew}(t)$ averaged over all stabilities (*n*=3613) for windspeeds less than 1 m s^{-1} are displayed in Fig. 1. While $R_{Ew}(t)$ exhibits an exponential form, $R_{Ev}(t)$ shows a negative lobe with a maximum at around 600 seconds. Since the standard deviation (shaded area) was found almost the same if only stable cases were taken, the negative tail seems to be unaffected by stability.

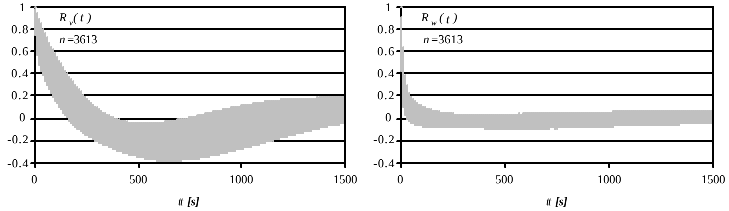

Figure 1. Eulerian autocorrelation functions averaged over all stability classes with $\overline{u}$ < 1 m s^{-1} for the *v*- and *w*-component of the wind vector. The standard deviation is indicated as shaded area.

The negative values found in the autocorrelation functions might be an effect of low frequency wind meandering. A possible explanation could be that the persistence of large eddies with a vertical axis in low wind situations is enhanced due to reduced microscale turbulent friction (Etling, 1990). Thus, they may cause a negative tail in the Eulerian autocorrelation functions. Such eddies would have a characteristic time scale of some hundreds of seconds and characteristic length scales of a few hundred metres. Clearly, the assumption of an exponential behaviour of the horizontal autocorrelation function in dispersion modelling is not a good approach for low wind situations, if meandering flows are treated as turbulence and not as advection when dividing the dispersion period into smaller time-intervals (e.g. Brusasca et al. 1992).

Here, use was made of the Lagrangian dispersion model of Wang and Stock (1992), which allows for a negative lobe in the Lagrangian autocorrelation function. The model is described in detail in Oettl et al. (2001). The model has being further developed using slightly different parameterisations for several boundary layer parameters. Now it can also be applied to dispersion problems for regulatory purposes, which are characterised by reduced information about meteorological input parameters (Monin-Obukhov length, friction velocity). These are obtained using a simple meteorological pre-processor (Golder 1972, Venkatram 1996).

Results

The model in its revised version was applied to various data sets, comprising point and line sources, varying meteorological conditions (stable to unstable, low to high wind speeds), and different complexity of terrain. The data sets and the results obtained with the model are listed below.

<u>Field experiment of the Idaho National Engineering Laboratory, U.S.</u>:

Terrain: Flat.

Meteorology: Stable, low wind speed.

Source: Point source 1.5 m above ground level.

Data points: 30 peak concentrations.
Results: Fractional bias = 0.10; Normalised mean square error = 0.20; Correlation coefficient = 0.79.

Field experiment of the Finish Meteorological Institute, Finland:
Terrain: Flat.
Meteorology: Stable to Unstable, low to high wind speeds.
Source: Elevated line source 1.5 m above ground level.
Data points: 577.
Results: Fractional bias = -0.13; Normalised mean square error = 0.19; Correlation coefficient = 0.85.

Field experiment of the Institute for Analytical Chemistry, Technical University Vienna, Austria:
Terrain: Flat.
Meteorology: Stable to Unstable, low to high wind speeds.
Source: Line source accompanied by a 6 m high noise barrier.
Data points: Concentration statistics (percentiles, annual mean) at four locations.
Results: Annual mean – 0.76, 1.36, 1.03, 1.42 (ratio pred. / obs.).

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List of publications in 2001 and aims for next year (i.e. 2002)

Öttl, D., R. A. Almbauer, and P. J. Sturm, 2001: A new method to estimate diffusion in stable, low wind conditions, *J. Appl. Meteorol.*, **40**, 259 - 268.

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Öttl, D., R. A. Almbauer, P. J. Sturm, 2001: On the simulation of pollutant dispersion in low wind speed conditions. *10th International Scientific Symposium on Transport and Air Pollution 17-19 Sep. 2001, Boulder, U.S.*

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Öttl, D., R. A. Almbauer, P. J. Sturm, 2001: On the determination of the 99.8 percentile of NO_2 concentrations required by the directive 99/30/EC: A case study. *Proceedings of the 7th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes 28-31 July, Belgirate (Italy)*, Eds. C. Cuvelier et al., Environment Institute, Joint Research Centre, European Comission, pp 429-433.

The aims for the year 2002 comprise the further development of the Lagrangian dispersion model GRAL, mainly the incorporation of a new parameterisation scheme according to Degrazia et al. (2000). It is planned to do some further experimental and theoretical research in the field of low wind speed dispersion conditions (i.e. meandering and intermittency).