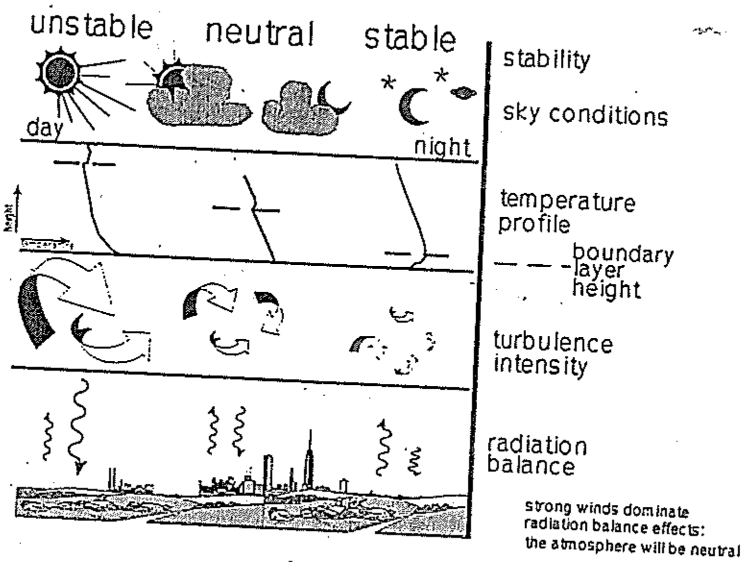

Figure 1 Qualitative presentation of atmospheric turbulence intensity, temperature profile, and the radiation during unstable, neutral and stable atmospheres.

Other parameters may be of interest (e.g. the exchange coefficient K_z), but will not be addressed in this report. Moisture profiles could be important in predicting, e.g., the visibility of condensing plumes, but we have not considered them here.
For particle models the third moment in wind speed fluctuations (the skewness) is often of importance, but will not be addressed in this paper. Higher moments (such as skewness) is reported by Sorbjan (1991), considering field experiments and by Nieuwstadt (1990) for Large Eddy Simulations. A recent extended discussion on higher moments has made by Du (1996). For short range dispersion these items are of minor importance.

1.3 Motivation of the work

Governments have issued a lot of measures to reduce air pollution and to monitor air quality. In doing so, air quality standards are introduced, such as the maximum admissible hourly or daily mean concentrations during a year and the so-called high percentiles. These standards are evaluated by means of measurements or (e.g. for future emissions) by applying dispersion models. This can be done on several spatial scales: local, regional and continental scales. In the Netherlands all parties that intend to start (or significantly change) activities with an environmental impact are obliged to present an Environmental Impact Statement in which all environmental effects are described. In such reports the air pollution concentrations around stacks should also be given and compared to the standards. In this respect there is an obvious need for adequate mathematical models and calculational tools that allow reliable estimates of concentrations. The use of modelling techniques is a strong

tool to calculate the effects of different kinds of air pollutants. Local authorities also use models to set up most effective strategies for controlling air pollution problems on a local or regional scale. The effect of environmental measures should also be evaluated by mathematical dispersion models.
On the local scale (a few kilometers), individual sources have occasionally proven to cause large problems. The pathway of pollutants in the air on a local scale is presented in Figure 2. For this purpose, dispersion models for stack emissions are necessary, at present; they are being implemented on computers in which the transport and dispersion of air pollutants is described. This type of models describes physical processes in the atmosphere. Therefore, atmospheric science is of importance and is frequently applied to air pollution studies.

1.4 Important features of dispersion models

Dispersion theory started with G.I. Taylor's analysis (1921), who described the behaviour of particles in homogeneous turbulence. This analysis proved to be very worthwhile and was taken as the basis for many recommendations. Cramer (1976), Draxler (1976) and Pasquill (1976) proposed pragmatic formulations based on this concept and fitted to measurements. These formulations appeared to be more reliable than others especially for the value of the lateral dispersion parameter σ_y (Irwin, 1983). However, more empirical formulations, which express σ_y and σ_z as functions of distance for each of a number of "stability categories", proposed by Pasquill (1961), Briggs (1973) or Singer and Smith (1966) became more popular, partly because they do not require turbulence data as input.

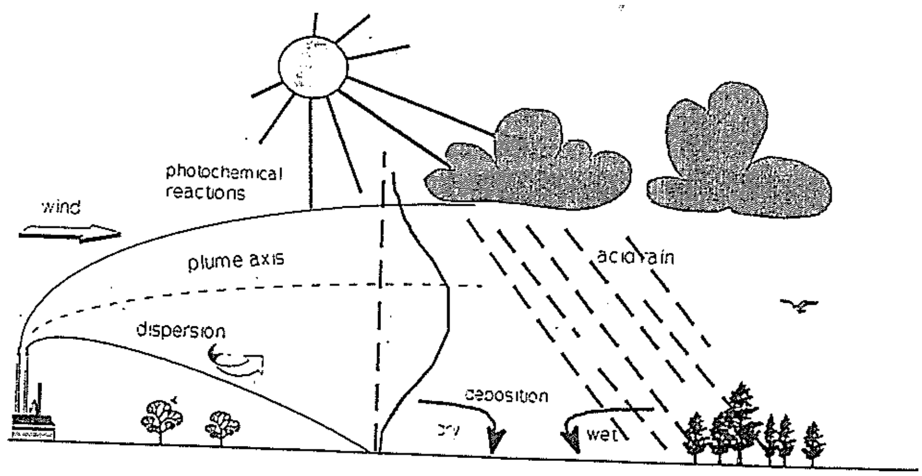

Figure 2 The pathway of pollutants in the air on a local scale.

mala and Pilinis (1991) in the Grand Canyon. Non-homogeneous turbulence above flat terrain is worked out by Baerentsen and Berkowicz (1984) and Brusasca et al. (1989).
A detailed overview is given by Zannetti (1990). The incorporation of buoyant sources was developed by Van Dop (1992), Beniston et al. (1990) and Hurley and Physik (1993) and in a simpler way by Anfossi et al. (1993).

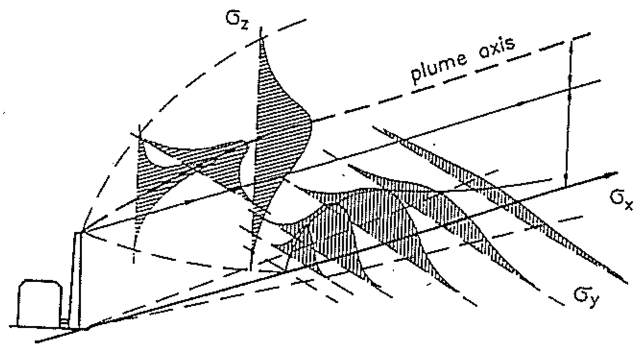

Figure 3 The gaussian plume concept.

A further technique to calculate dispersion is the Large Eddy Simulation (LES). The basic idea of LES is to solve the Navier Stokes equations for the energy containing eddies in a grid of cells. While the Monte Carlo models need turbulence profiles as input, the large eddy models generate those profiles themselves, with only the geostrophic wind field and surface conditions as input. By considering the motions of particles in this framework, the dispersion is calculated. Because a large number of cells must be followed with a small time step, calculations are expensive and can not be done to obtain concentration statistics over long periods (e.g. a year). Examples of such calculations were recently presented by Nieuwstadt (1992), Nieuwstadt and De Valk (1987), Nieuwstadt and Bouwmans (1994) and Henn and Sykes (1992).
All these different models reflect the reality that atmospheric processes are very complicated. Each model can only handle a restricted subset of processes, depending on the purpose of the model and the available input parameters. This determines the model's applicability and usefulness.

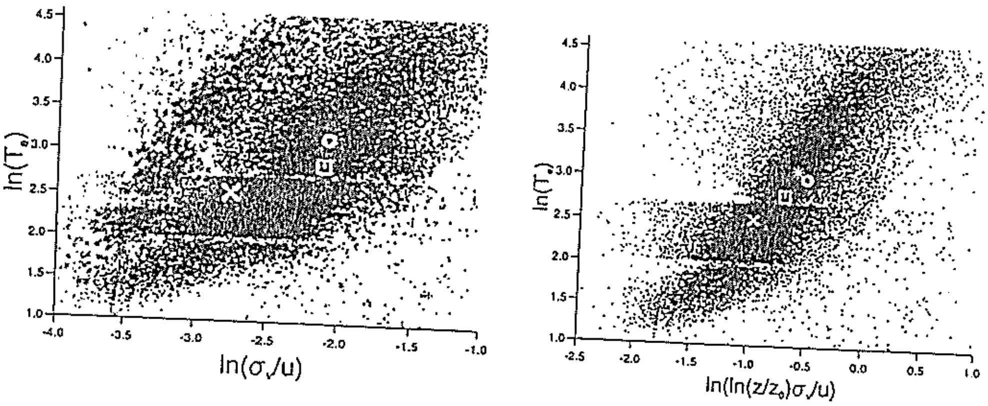

Figure 4 Combined plot of all data from 4 measuring sites with different roughness lengths. Measurements over several years, all stabilities. Left: $\ln(T_e)$ vs $\ln(\sigma_v/u)$; *: MPN, x: Kollum; o: Abbenes, □: Wageningen. Right: $\ln(T_e)$ vs $\ln\{\sigma_v/u)*\ln(z/z_0)\}$.

Although the time scale is thought to be dependent of height (see for example the work of Cenedese et al, as reported in Appendix C) we could not find a consistent formulation. Hence, we think it is best to use the calculated time scale values at the height of 10 m for the whole depth of the ABL, except for the surface layer. For this surface-layer (typically being the first 50 to 60 m of the atmopshere) an alternative method with a higher performance than (39) for the Prairie Grass data is found (Flesch et al. 1995):

$$T_l = \frac{z}{2\sigma_w}\left(\frac{1}{1+5z/L_*}\right), \quad for\ L_*>0,$$
$$T_l = \frac{z}{2\sigma_w}\left(1-6\frac{z}{L_*}\right)^{0.25}, \quad for\ L_*<0 \qquad (42)$$

In Figure 5 the differences in calculated concentrations with the advanced gaussian dispersion model STACKS in which Gryning σ_w and the height independent function of Erbrink (39) for T_l at one hand and the calculated concentrations when Holtslag and Moengs formulation for σ_w together with (42) for T_l at the other hand has been applied. These formulations (42) are useful for the surface layer and give about the same results as (39) at the top of the surface layer (say: 50 m).

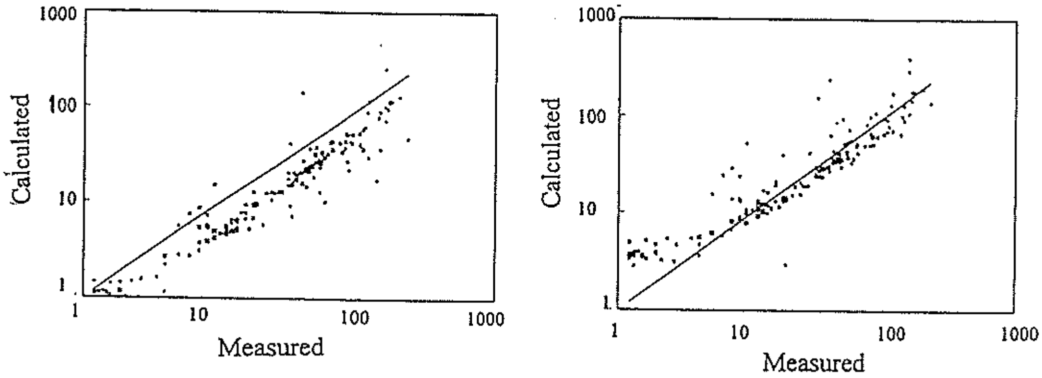

Figure 5 Calculated crosswind integrated concentrations of the Prairie grass experiments, compared with predictions of the gaussian model STACKS. Left: applying Grynings functions for σ_w and Erbrinks function (39) for T_l; right: applying the formulation of Holtslag and Moeng for σ_w together with (42) for T_l.