6.20 DISPERSION MODELLING IN ALPINE VALLEYS NECESSITY AND IMPLEMENTATION OF NON-HYDROSTATIC PROGNOSTIC FLOW SIMULATION WITH FITNAH FOR A PLANT IN GRENOBLE

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INTRODUCTION

Dispersion modelling nowadays has to be performed on base of hourly measurements of meteorological conditions (see e.g. the updated TA Luft in Germany). Since the stated limit values of air pollutions are defined with respect to one year, it is required to calculate the dispersion for 8.760 consecutive situations.

The calculation of air pollution dispersion in complex terrain must be preceded by the simulation of realistic 3D flow- and turbulence fields, which contain every influence and interaction of and between terrain structures (e.g. channelling, drainage flows etc.). A special model type exists, which is prominent to provide such flow and turbulence fields: the non-hydrostatic, prognostic mesoscale models. Unfortunately, the time dependent calculation of flow and turbulence is a very (computer-) time-consuming task. Therefore, the usual dispersion models are content with the application of diagnostic flow modules. Using this approach, thermally induced wind systems cannot be calculated, and the dynamic flow in steep terrain or edging valleys is not simulated accurately.

Fig. 1 gives an impression of the differences which occur by application of different model approaches. On the left, 10 m wind vectors taken from results of a drainage flow simulation with the prognostic model FITNAH are shown. On the right, the windfield of a diagnostic model can be seen, which has been calculated by using the 10 m wind measured at the site during a drainage flow situation. There are significant different features, most prominent the calculated uphill winds on all western slopes in the diagnostic results, which are not observed during drainage flow situations.

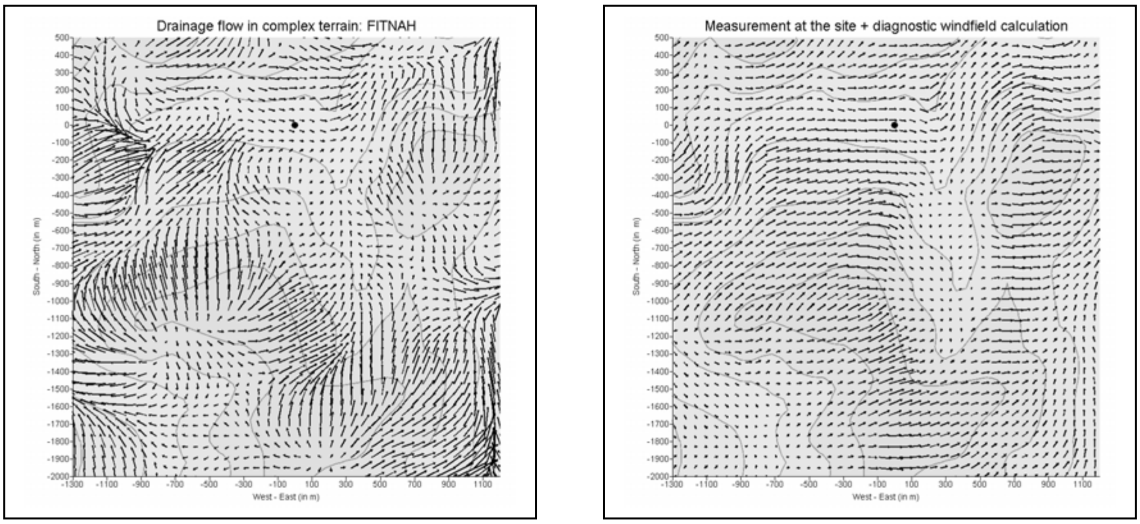

Figure 1. Drainage flow simulation with prognostic model FITNAH (left) and similar situation calculated with a diagnostic approach (right), using the identical wind measured at the marked site (black dot)

The more structured the terrain and the higher the frequency of thermally influenced weather situations is, the more erroneous will the dispersion modelling will become by using only the diagnostic approach. Since the simulation of a full years cycle of hourly situations is not feasible with a prognostic model at present, an approach to combine both will be suggested in this contribution:

APPROACH

The idea is to combine two separately performed dispersion calculations: For dynamically dominated weather situations, the dispersion modelling is carried out by use of a diagnostic wind field. For the case of the occurrence of thermally induced wind systems, the diurnal cycle of wind is being considered by simulation results of FITNAH as meteorological input for the dispersion model. Besides the more technical question of practically coupling the different types of models, the central point is how to merge the two fields of air pollution concentrations into one result for a years mean value.

NUMERICAL MODELS

The numerical models used in this study are the Lagrangian dispersion model **LASAT** (**LA**grange **S**imulation von **A**erosol **T**ransport, see e.g. *Janicke, L. (1983)*), and the prognostic, non-hydrostatic mesoscale model **FITNAH** (**F**low over **I**rregular **T**errain with **N**atural and **A**nthropogenic **H**eat-Sources, e.g. *Groß, G, (1993)* or *Nielinger, J. and W.-J. Kost, (2001)*).

LASAT meets the requirements of the VDI Guideline 3945 Blatt 3 and is the basis for the Lagrangian dispersion model AUSTAL2000, the most distributed implementation of the German legislation TA Luft. FITNAH has been developed in the 1980's and since then permanently enhanced to calculate 3D meteorological fields in complex terrain, especially thermally induced flow systems. The model has been successfully used in a lot of studies even in steep terrain (e.g. *Groß, G., 1990*).

CASE STUDY: GRENOBLE, FRANCE

For an industrial plant in Grenoble, France, a dispersion simulation for a whole year had to be performed. Grenoble is situated in the heart of a Y-shaped valley and in the nearby vicinity, mountains rise up to 2.000 m (Fig.2). Meteorological measurements show a high frequency of low wind speeds and a large contingent of thermally induced weather situations (Fig. 3).

Figure 2. Air photograph of the Y-shaped valley of Grenoble. Line of sight is northwest (left) Model domain of FITNAH (right) Grenoble is indicated with a circle.

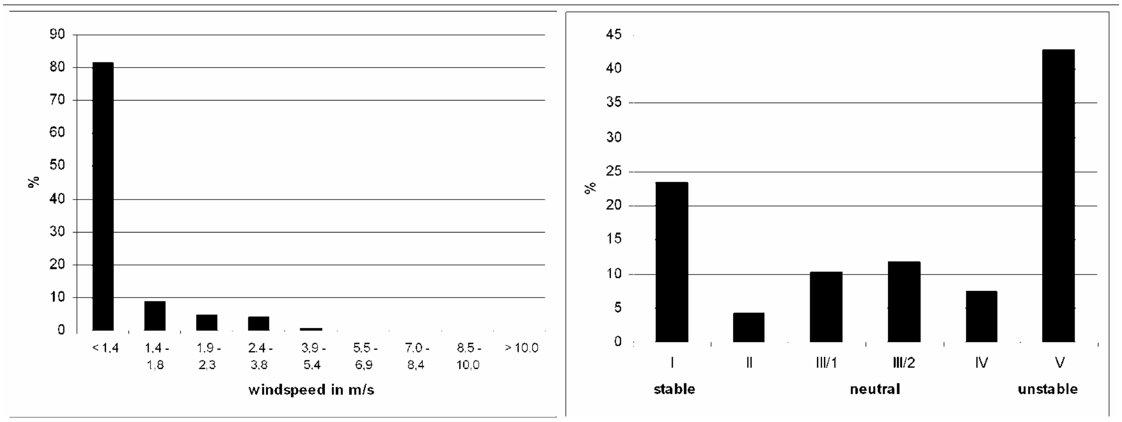

Figure 3. Frequency of wind speed (left) and air-stability (right) measured at Grenoble.

NUMERICAL SIMULATIONS

In this case, a diurnal cycle of thermally induced wind systems has been calculated by use of the model FITNAH. Fortunately, a study from French Meteorologists has been available where measurements of such an episode at different sites in an area of 70 km x 80 km around Grenoble are documented (*Couach, O. et al., 2000*). Fig.4 shows two examples of the good agreement of model results with measurements. Wind direction and wind speed at Pons de Claix, approx. 11 km southwest of the plant, as well as the vertical profiles, measured at Vif, situated 17 km southwest, are calculated in the right order of magnitude and in satisfying accordance with the course of time.

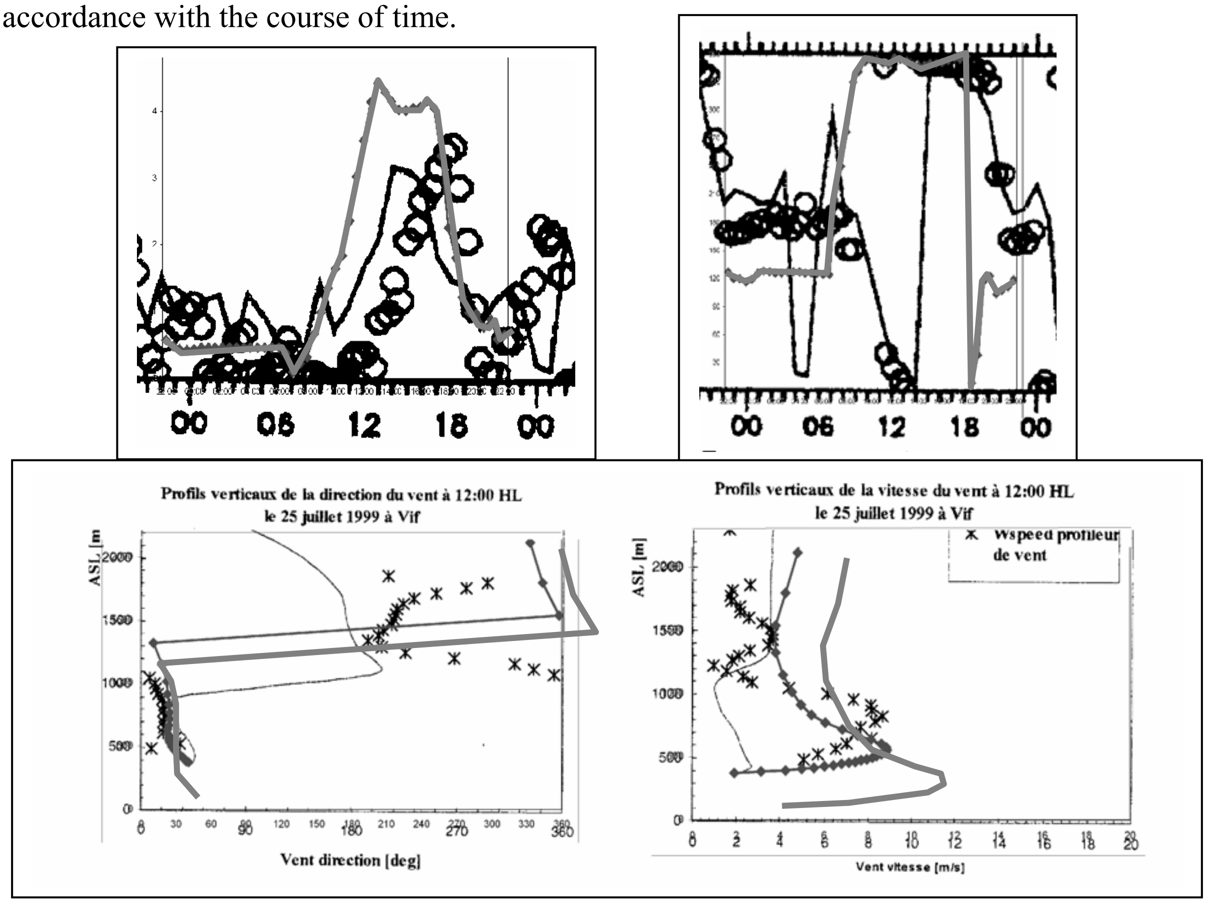

Figure 4. Measurements (cycles and crosses) and FITNAH results (bold grey line) for top) time series of wind speed and wind direction at Pons de Claix and bottom) vertical Profiles of Wind speed and wind direction at Vif.

The 3D-flow- and turbulence fields have been given in hourly packages directly to the dispersion model LASAT, bypassing the implemented diagnostic flow module. In Fig. 5, the near surface concentration field at night and during day time are shown. With nightly drainage flows, emitted substances are transported with cold and stable air first up (cold air from the Chartreuse), later with a greater scale flow system down the Isère valley. Turning to Northwest over the city centre of Grenoble, the air pollutants are incorporated into a strong southerly flow from the Drac valley. At daytime, when the higher Alpine region is heated by the sun and develops intensive thermal updrafts, air from the surrounding lower areas is being incorporated in regional flow systems. So at the eastern part of Grenoble, the wind is directed to the Massif des Ecrins, southeast of the city.

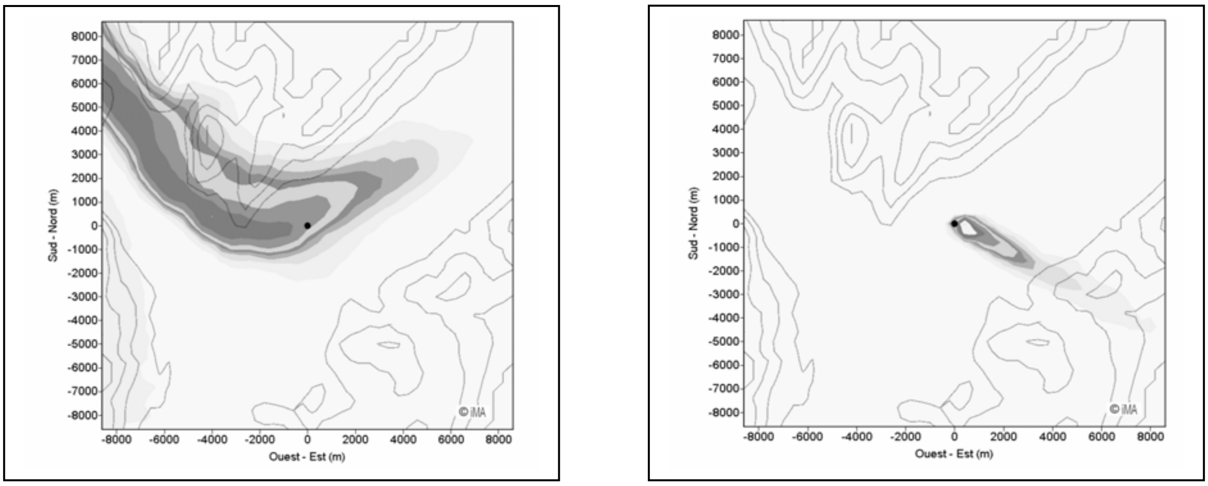

Figure 5. Near-surface concentration of emitted substance at night (03:00, left) and during daytime (14:00, right)

Having performed this simulations, a full diurnal time-dependent cycle of air pollution dispersion and the related ambient air quality is available. This data had to be combined with those results which are contributed by dynamically dominated flow situations, which can be easily calculated with the diagnostic module of LASAT.

COMBINATION OF DIAGNOSTIC AND PROGNOSTIC SIMULATIONS

Here, a very simple and pragmatic approach had been developed, based on the diurnal span of temperature, to make a difference between thermally and dynamically dominated weather regimes. Fig. 6 (next page) shows the Frequency of diurnal spans of temperature, based on measurements at Grenoble during one year.

There is a significant gap at 10 K, which is used to divide dynamically dominated and thermally weather regimes. When the difference between daily maximum temperatures and minimum values during the night is lower than 10 K, it is very likely to be a cloud covered situation which is rather defined by dynamic processes. When the diurnal temperature span is 11 K – 17 K or even more, that day is in most cases influenced by solar heating, which in turn is a sign of a thermally dominated situation.

RESULTS

The combination of mean values of both, the dynamic simulation with LASAT and the coupled FITNAH-LASAT calculations, led to suitable results of impact concentrations. Thanks to related measurements, the results could be proved realistic for the 3 available sites (Tab 1).

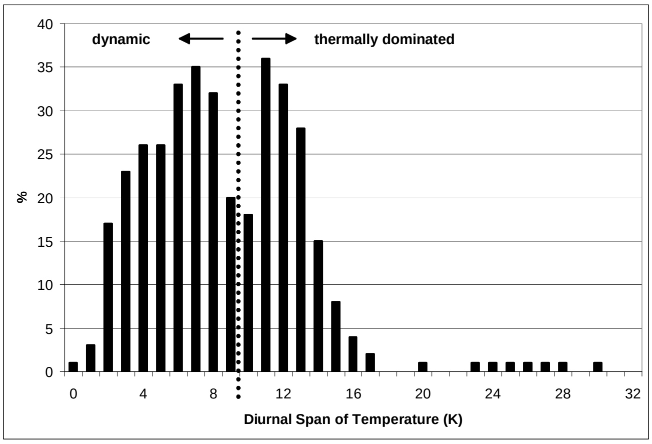

Figure 6. Frequency of diurnal temperature span at Grenoble..

Table 1. Measurement of emitted substance and model results (Example)

	gaseous component		particle component	
	Mesures	Simulation	Mesures	Simulation
Point 1	9,1	1,9	12,6	2,6
Point 2	18,6	22,9	25,7	31,6
Point 3	72,4	31,1	100	43

Point 1 was significantly underestimated by the simulations, which is due to the presence of a second major source in the nearby vicinity. The measurements at Point 3 have to be considered carefully, since there was a great (and still unexplained) scattering of the measured values. At Point 2, the model results agree quite well (and with an appreciated slight overestimation) with the measurements. Subsequent to these results, a new measurement campaign is planned with sites chosen carefully with the help of the model results.

Thus, as a first overall conclusion, the incorporation of high sophisticated flow simulations into dispersion modeling in complex terrain is not only necessary, but currently successfully practicable and recommended.

ACKNOWLEDGEMENTES
We are grateful to the association *La Metro, Grenoble Alpes Métropole*, who assigned and kindly supported this study.

REFERENCES

Couach, O., I. Balin, R. Jimenez, S. Perego, F. Kirchner, P. Ristori, V. Simeonov, P. Quaglia, V. Vestri, A. Clappier, B. Calpini and H. v.d. Bergh, 2000: Etude d’un episode photochimique à l’aide d’un modèle méso-échelle et de measures intensives sur la region de Grenoble. Soumis à la revue *Pollution Atmosphérique* en tant qu’article.

Groß, G., 1990: On the wind field in the Loisach Valley - Numerical simulation and comparison with the LOWEX III data. Meteorol. Atmos. Phys. 42, 231-247.

Groß, G., 1993: Numerical Simulations of Canopy Flow. Springer Verlag, Heidelberg, Springer Series in Physical Environment 12, 167 pp.

Janicke, L., 1983: Particle simulation of inhomogeneous turbulent diffusion. Air pollution modeling and its application II (Ed. Weber). Plenum Press, N.Y., 527-535.

Nielinger, J., and W.-J. Kost, 2001: Simulation of realistic location-related wind distributions with the mesoscale model FITNAH. Meteorol. Zeitschr., 10, No. 4, S. 235-238.