H13-90
ATMOSPHERIC DISPERSION MODELLING – PROGNOSTIC WIND FIELD LIBRARIES

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Abstract: Diagnostic wind field models are widely used to calculate wind fields applied in Lagrangian dispersion models. The applicability of such models is limited in steep and complex terrain. Prognostic wind field models are able to deal with such orography. The method "prognostic wind field library" allows the application of prognostic wind fields in standard dispersion models. The concept is illustrated schematically and by examples. The benefits compared to the standard approach are demonstrated.

Key words: *prognostic wind field library, dispersion modelling, meso-scale meteorology, AUSTAL2000, complex terrain.*

INTRODUCTION

Diagnostic models are a fast and efficient tool for calculating wind fields. Those wind fields are widely used in dispersion modelling, for example in governmental licensing procedures in Germany. But, due to their physical foundation, those models are limited in certain ways. For example, characteristics of air flows in complex and steep terrain, like eddies in the wake of hills, cannot be simulated.

Hence, for example the Technical Instructions on Air Quality, which defines the rules for dispersion modelling in Germany, limits the appliance of such models with a steepness criteria: Only in terrain with differences in elevation less than 1:5 the models can be applied safely.

Already in low mountain ranges all across Europe, this criterion is violated. Without an adequate technique, the legal security of licensing procedures with dispersion modelling in such terrain is restricted.

How to process in steep terrain? A possible approach, which allows operation in steep terrain and can incorporate thermically induced wind systems like cold air flows, is the concept of a prognostic wind field library. The method is rather simple: the diagnostic wind fields are replaced by wind fields calculated with a prognostic wind field model. The actual modelling of the dispersion remains unchanged.

The approach of the prognostic wind field library will be explained conceptionally as well as illustrated with an example from the practical experience.

BASICS

The lagrangian based model which forecasts, for example the dispersion of pollutants, is structured in three steps (Fig. 1). First, the surveyor selects the topography of the investigation area and meteorological data appropriate to the topic. In the "classic" approach, a diagnostic wind field model calculates wind fields for different oncoming flow directions and wind speeds. Those classified wind fields are stored in a so called library. The lagrangian dispersion model (e.g. AUSTAL2000) accesses that library for each simulated situation and chooses the appropriate wind fields (depending on wind direction and turbulence of the atmosphere). This procedure is very economic concerning calculation time, since the recomputation of wind fields, which would be necessary for every hour of the year otherwise, is omitted.

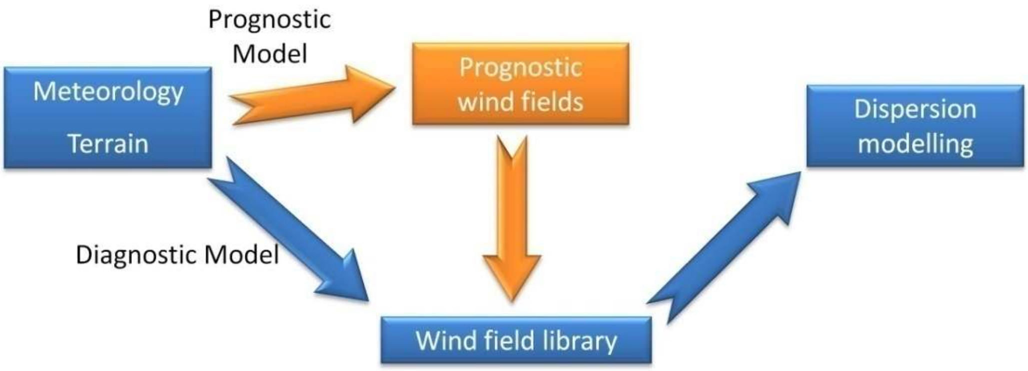

Figure 8. Scheme of the different steps in lagrangian dispersion modelling. Blue path is the "classic" approach with wind fields generated by a diagnostic model, orange with use of a prognostic wind field model.

This procedure has proved itself reliable for years in practice. But, as explained in the introduction, the use is limited in steep terrain due to the characteristics of the commonly used diagnostic wind field model. Nevertheless, regions which do not fulfil the criteria of a diagnostic model are not rare. In recent years, different solutions to this problem have been developed. The convenient method of a prognostic wind field library will be explained here.

Models, which can be applied in steep terrain, are prognostic wind field models. These mesoscale models like FITNAH or METRAS solve the complete three-dimensional equations of motion to calculate atmospheric flows. Dynamically as well as thermally induced wind systems (e.g. cold air flows) can be provided without constraints concerning the orography and its steepness. The method of a prognostic wind field library is based on the easy and obvious approach to imply prognostically calculated wind fields in spite of diagnostic ones for dispersion modelling. Those wind fields are calculated considering

terrain and meteorology and stored in the library (Fig. 1, orange path). The dispersion model can access these wind fields for the simulation, the classic approach is retained.
In detail, the service of a prognostic model and the conversion of its results to wind fields valid for a specific dispersion model demand high standards for computing power as well as a high grade of the user's experience. Manual controlling and treatment of the results is essential. Hence, the complexity of dispersion modelling based on prognostic models is considerably higher compared to the standard method.

Application example

In low mountain ranges, steep terrain is widely spread. Emissions in deeply carved river valleys, which influences cannot be expected to be limited to the valley volume, cannot be handled by the standard diagnostic approach. The following example demonstrates the capability of prognostic wind field models and the method of a prognostic wind field library.

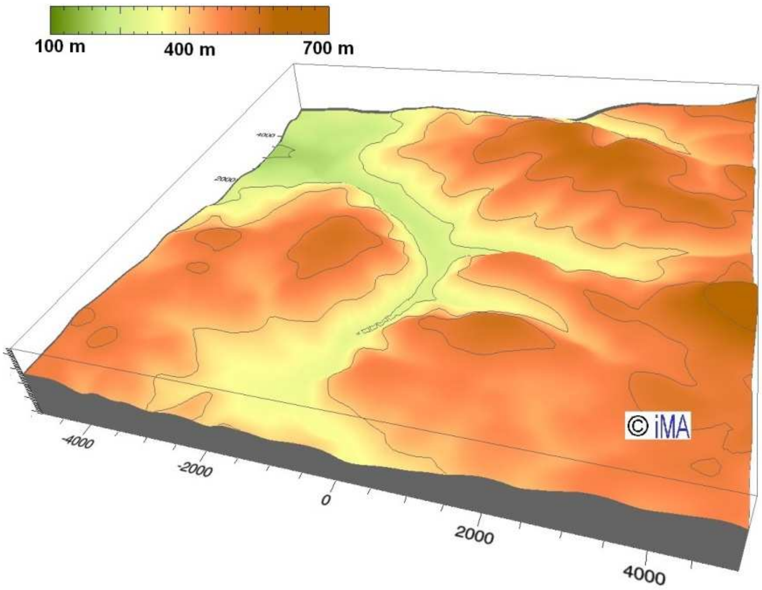

Figure 2. Orography of the area under investigation

The area under investigation contains a narrow valley and its tributary valleys (Fig. 2). In the northern part of the area the main valley is oriented southeast to northwest, the southern half form south to north.

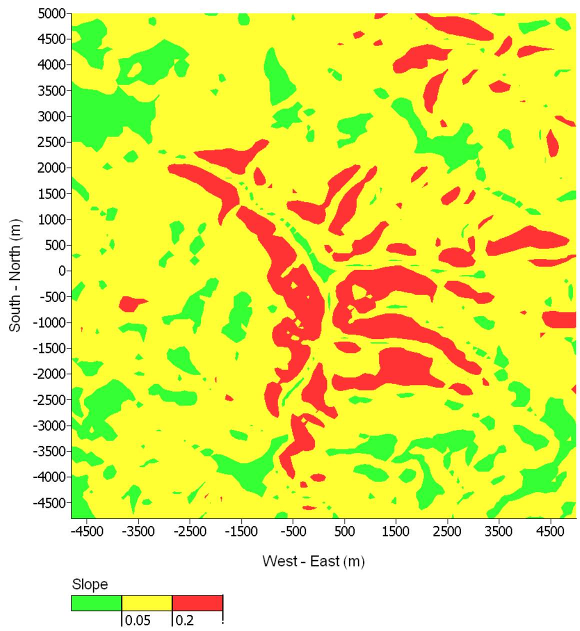

Figure 3. Slope in the area of investigation (calculated for a horizontal distance of 100 m). Red colours indicate areas which excess a slope of 1:5, which is the slope limit for diagnostic wind field models in the German Technical Instructions on Air Quality.

At the adjoining ridges of the valleys, high values of the slope occur (Fig. 3), which forbids the use of a diagnostic wind field model.

Meteorological data, which is adequate for dispersion modelling, is sampled at a very limited number of sites. The wind field model performs the task to spread those singular point data to the whole area of investigation and allows the dispersion model to determine the distribution of pollution. Meteorological data used in the context of a prognostic wind field library has to represent the characteristics of large-scale conditions, independent of local orographic effects.

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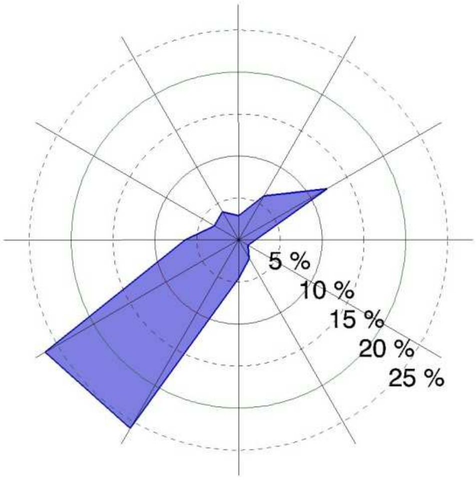

Figure 4. Frequency distribution of wind directions applied in the described example.

In the area of investigation, temporary local meteorological measurements were available, which could be used to validate the results of the wind field model. Measurements show the channelling effect of orography (Fig. 5). In the northern part of the valley, the frequency distribution of the measurements is clearly different from the southern part.

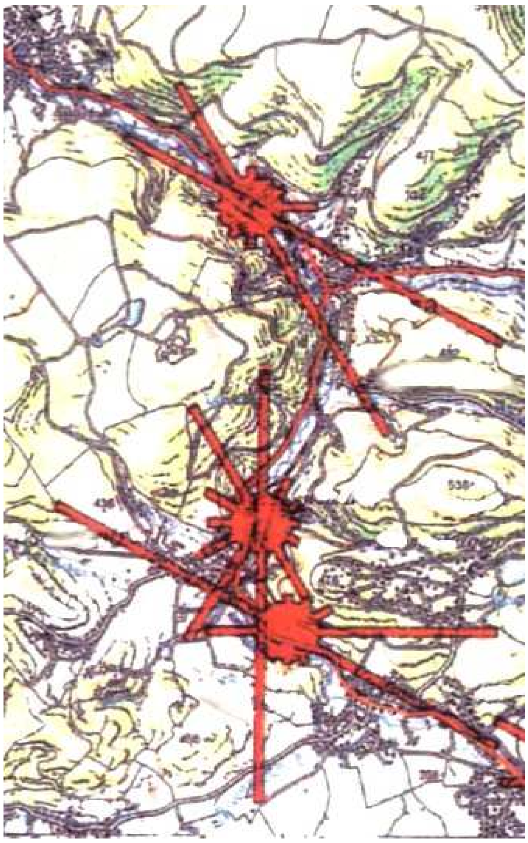

Figure 5. Frequency distribution of wind directions, measured at different sites along the valley.

The calculated frequency distributions of wind directions, based on the wind fields of the prognostic model (used model: METRAS-PC), display comparable characteristics to the measurements. The influence of the valley shape on the flow can be reproduced; a distinct turn between the distributions in north and south is obvious (Fig. 6, right). On the contrary, the frequency distribution of wind directions as a result of diagnostic wind fields (used model: TALdia) reveals significant differences compared to the measurements (Fig. 6, left). Especially in the northern part of the area, the diagnostic model does not reproduce the orographic effects as realistically as the prognostic one.

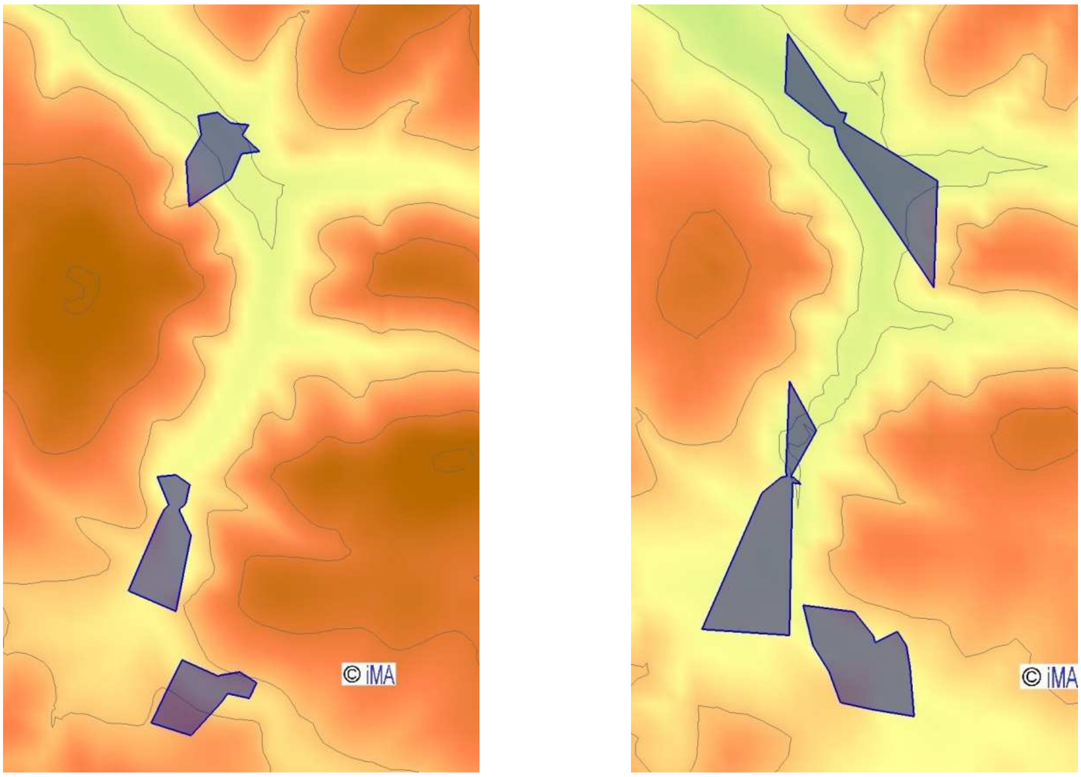

Figure 6. Calculated frequency distribution of wind directions of one year, left: based on diagnostic, right: based on prognostic wind fields.

Accordingly, the results of dispersion modelling implying diagnostic and prognostic wind fields are different. For a low source of odours (height 10 m above ground) emitted in the northern part of the area, diagnostically based dispersion modelling shows pollution parallel as well as perpendicular to the valley orientation (Fig. 7).

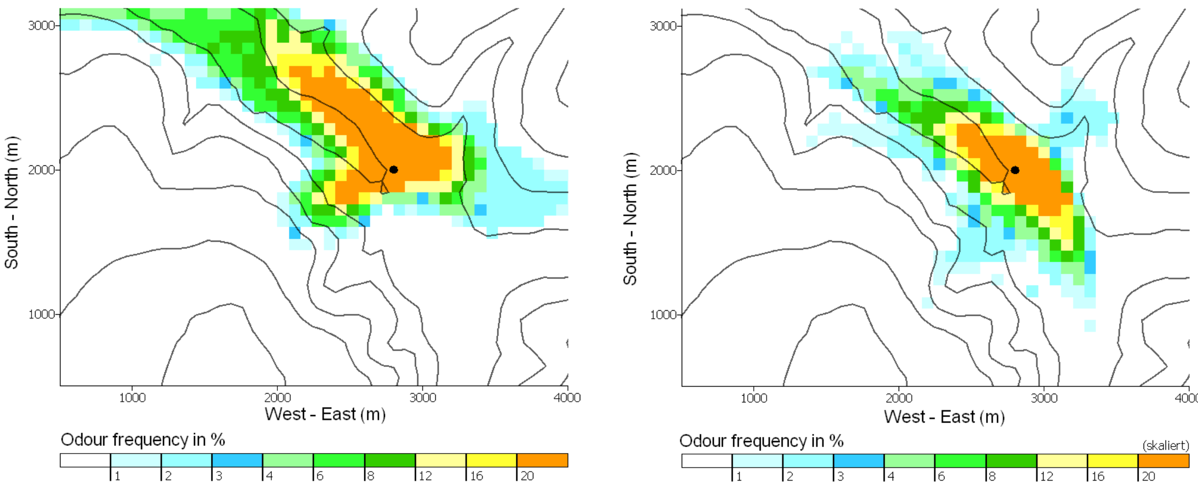

Figure 7. Calculated pollution of an odour source with a height of 10 m (left: based on prognostic, right: diagnostic wind fields).

The distribution of odour based on prognostic wind fields is slimmer and more parallel to the valley. Hence, the calculated exposure affects different places in the valley compared to the diagnostic simulation.

CONCLUSIONS

The method of a prognostic wind field library allows an appropriate dispersion modelling beyond the scope of the standard approach. The discussed example from practical work shows the differences between diagnostic and prognostic computed wind fields and the resulting frequency distribution of wind directions, induced by a steep area of investigation. The prognostic model shows adequate results even in heterogeneous and complex terrain, impressively shown by the comparison with available nature wind measurements. The incorporated wind fields determine the results of dispersion modelling. Only with the appliance of sophisticated methods like the prognostic wind field library, can prognoses of environmental impacts in steep and complex terrain be provided in a reliable and comprehensible way.