6.3 Modelling of the atmospheric dispersion in case of accidents

After radioactive materials have been released into the atmosphere due to an accident in a nuclear facility or a transportation accident, a prediction as soon and as precise as possible on the atmospheric dispersion of the released radionuclides is indispensable for the planning of disaster response measures. Also in connection with so-called "accident management" measures in nuclear power plants during events and accidents, dispersion forecasts are helpful to identify the moments, for example, where a deliberately initiated release from the plant (e.g. pressure relief of the containment) leads to the lowest possible radiation exposure of the environment.

In the 90s already, GRS developed two model chains to diagnose and predict the dispersion and deposition of airborne radioactive substances for a distance of up to 30 km. This so-called mesoscale model system was successfully used for the recalculation of meteorological measurement campaigns and of dispersion experiments. Both GRS model chains could be initiated with the numerical weather forecast data of the until 1999 operational *Deutschlandmodell (DM)* of the *Deutscher Wetterdienst* (DWD). That way it was possible to realistically determine the dispersion and deposition of radioactive materials for the forecast period of the weather forecast model which captured several days. After commissioning a new, improved forecast model at DWD, both model chains were updated, optimised and validated within the scope of a research project promoted by the Federal Ministry of Economics.
6.3 Modelling of the atmospheric dispersion in case of accidents

![Diagram showing the components of the mesoscale model system.](image)

**MESOSCALE MODEL SYSTEM**

Fig. 67
Possible links between individual components of the model system
GRS's mesoscale model system

Components of the model system. GRS's mesoscale model system consists of a diagnostic and a prognostic model chain. As meteorological input data for the model system, either measured data – of the meteorological instrumentation of a nuclear power plant, for example – or the result fields of numerical weather forecast models can be used. The model system comprises different flow models to describe the wind field as well as several subsequent alternative dispersion models with which, along the transport path, the dilution of noxious pollutants due to turbulent motions in the atmosphere and the deposition of the materials can be simulated (see Fig. 67 »MESOSCALE MODEL SYSTEM»).

Diagnostic model chain. When calculating the flow field with a simple diagnostic model, three-dimensional wind fields are diagnosed based on the wind data which are already known (i.e. measured or given) for some positions within the calculation area. If initialisation takes place with wind data from a weather forecast model, also wind field forecasts are possible with diagnostic models. The diagnostic GRS model chain works with the mass-consistent flow model MCF (Mass Consistent Flow). The calculated wind fields fulfil the continuity equation (conservation of mass). However, this model type does not render turbulence fields; these are provided by the turbulence model of VDI guideline 3783, Part 8.

Prognostic flow model. As an alternative to the diagnostic model chain, the flow field can also be calculated with a physically more complex prognostic model which, besides the conservation of mass, also takes the conservation of momentum and of energy into account. Furthermore, the two model types differ in respect of considering the lower limitation of the calculation area which can be represented by ground, expanses of water, natural cover and development, for example, and which is very heterogeneous depending on the land use. So, the thermal influence of heterogeneous surfaces on the flow and turbulence at ground-level which is included in prognostic flow models as lower boundary condition is not considered in diagnostic models. Thus, thermally induced flow patterns can only be simulated in a realistic manner with prognostic models. In addition to the medium wind field, this model type also yields turbulence values (e.g. diffusion coefficients) and allows the calculation of the future development (forecast) of the wind and turbulence fields. To calculate the flow field, GRS's prognostic model chain uses the non-hydrostatic model FOOT3DK (Flow Over Orographically Structured Terrain, 3-dimensional version of the University of Cologne).

Models to predict dispersion. For the dispersion calculations subsequent to the flow field calculations also, different dispersion models are available such as the simple Gaussian puff model RIMPUFF, the Euler model TRADI, or the particle model LASAT® in the GRS version. GRS prefers to use the two model chains FOOT3DK>LASAT and MCF>LASAT for dispersion calculations. Despite the model-induced weaknesses of diagnostic flow models compared to the physically more complex prognostic models, the use of diagnostic model chains is often preferred for fast dispersion forecasts, for example in decision support systems, since due to the long calculation time and demand in resources, the use of prognostic models still does not seem practicable.
6.3 Modelling of the atmospheric dispersion in case of accidents

![Diagram of model chains](image)

**OPTIMISATION OF MODEL SYSTEM**

Fig. 68
Coupling of the two model chains to improve the accuracy of diagnostically calculated wind fields
**Adaptation and optimisation of the model system**

*New boundary conditions due to improved weather forecast models.* With the commissioning of newer, improved weather forecast models at DWD, the boundary conditions for the overriding initialisation of the two model chains have changed significantly: The new DWD model (Lokal-Modell, LM) has other model physics and a more refined, spatial and temporal resolution than the DM which has been used for the initialisation of the two model chains so far. GRS has adapted the interface modules with which the two model chains are linked to the Lokal-Modell (see Fig. 68 »Optimisation of the Model System«).

*Optimisation of thermal influence calculations.* Within the scope of the adaptation and optimisation activities, it was also verified if the results achieved with the prognostic model chain in respect of the thermal influence of heterogeneous surfaces on the flow and turbulence at ground level can be used to improve the accuracy of the wind fields calculated with the diagnostic model. As a standard, the diagnostic model chain only includes turbulence information which is derived only from the LM initialisation on the 7-km-grid. The thermal influence of heterogeneous surfaces with a more refined spatial resolution (e.g. 1-km-grid) can not be taken into account with the MCF simulations used here. In the prognostic model chain, however, surface structures of such a fine resolution are captured with the high-resolution soil-vegetation module integrated in FOOT3DK. By using the boundary layer parameters thus gained on the 1-km grid to initialise the MCF, repercussions on the wind field at ground level can also be taken into account with MCF. One example for such repercussions is the local, thermally-induced flows at ground level which emerge due to intensive solar radiation on a summer’s day. The effectiveness of this procedure could be demonstrated with the example of corresponding diurnal data gained during the meteorological measurement campaign LITFASS2003 (Lindenberg Homogeneous Terrain - Fluxes between Atmosphere and Surface: A long-term study).

*Validating the calculations.* The validation of the activities to adapt and optimise the two model chains was effected on the basis of the data available for LITFASS2003 and the calculated fields of LM. The investigation area of this campaign, which is located approx. 60 km south-east of Berlin and is about 40x40 km², is characterised by outstanding data availability for an investigation period in the summer. The area shows weak orographical structures and pronounced heterogeneity in respect of land use with changes of forest areas, agriculturally used farming and grazing areas as well as individual lakes and rural settlements (see Fig. 69 »Land Use LITFASS2003«). LITFASS2003 comprises both weather conditions in the early summer with weak winds and pronounced weather conditions with strong west winds with low day temperatures; thus it provides a wide range of different situations in respect of intensity and variation range of thermally-induced turbulent flows.
Summary

Successful updating of the mesoscale model system. The mesoscale model system used by GRS for the diagnosis and forecast of the dispersion and deposition of airborne radioactive substances in structured terrain was successfully updated and adapted to the current structure of the numerical weather forecast models of DWD. With the investigations, the forecast capability of both model chains and the high level of accuracy of the calculated distributions of the airborne concentration and of the deposition after radionuclide release were not only maintained but also improved. Due to the procedure which was developed for the diagnostic model chain to consider the thermal influence of the surface inhomogeneity, future uses of diagnose-based model systems in integrated decision support systems of the entire environmental field (e.g. in RODOS/RESY) can be expected.
Fig. 69 Land use in the LITFASS2003 area
The pronounced heterogeneity of the surface of the 30x30 km² investigation area is clearly visible.