# LAGRANGIAN PARTICLE MODELLING FOR REGULATORY PURPOSES – A SURVEY OF RECENT DEVELOPMENTS IN GERMANY

*U. Janicke, L. Janicke*
Janicke Consulting, Dunum, Germany

## INTRODUCTION

Dispersion modelling using a Lagrangian particle model is routinely applied in a broad range of permit and assessment domains in Germany. The model type allows studying time-dependent dispersion situations in flat and complex terrain. The following physical processes are accounted for: atmospheric advection and turbulent mixing, dry and wet deposition, sedimentation, chemical conversion, and cloud radiation. Time scales typically range from some minutes to one year and spatial scales from some metres to some 100 kilometres with a time resolution down to about 10 seconds.

Since 1990, the commercial model LASAT (*Janicke, L.*, 1983) has been applied in various fields of air quality assessments. It has been operating since 1993 as part of a monitoring system for nuclear power plants in the federal state Niedersachsen (*Janicke, L.*, 1994). In course of the amendment of the German Regulation on Air Quality Control (*TA Luft*, 2002) in 2002, a Lagrangian particle model has been prescribed as regulatory model. The Federal Environmental Agency (UBA) established a free reference implementation on the basis of LASAT. The result, AUSTAL2000, has been used since 2002 as standard dispersion model for air quality assessments (*Janicke, L.*, 2002; *Janicke, L. and U. Janicke*, 2003). It was presented at this conference in 2002 (*Graff, A.*, 2002). It is available free of charge in the Internet, including source code (GNU licensed), reference book, reports, and examples.

AUSTAL2000 and LASAT are set up and verified in compliance with the German guideline "atmospheric dispersion models; particle model" (*VDI 3945 Part 3*, 2001). VDI guidelines (published in German and English) are established on behalf of UBA by the Commission on Air Quality Control (KRdL) within the Association of German Engineers (VDI).

The following gives a brief overview of selected applications of these models in the context of regulatory and assessment processes:

- AUSTAL2000: Regulatory practice
- AUSTAL2000: EU twinning projects
- AUSTAL2000G: Odour assessment
- ESOFIN: Estimation of odour emissions from field inspections
- LASAIR: Decision support system for nuclear hazards
- ARTM: Atmospheric radio nuclide transport model
- LASPORT: Application to airport-related source systems

## AUSTAL2000: REGULATORY PRACTICE

AUSTAL2000 has been applied since 2002 as regulatory model in Germany. As such it is extensively used. In 2004 two major extensions were added: calculation of odour hour frequencies (see below) and extension of the provided diagnostic wind field model to account for the influence of buildings (*Janicke, U. and L. Janicke*, 2004).

UBA supports the program system with a website (http://www.austal2000.de) and an Email hotline (2002-2004 and 2006). Regular updates have been provided which mainly implemented corrections of programming errors, additional log information and checking of input data, and workarounds in the context of specific problems with the prescribed boundary layer model of guideline VDI 3783 Part 8 (2002) and the classification of sedimenting particulate matter.

Hotline requests consisted mainly either of very basic questions (e.g. how to open a DOS window) or of rather complex ones (e.g. where to place the anemometer in complex terrain), indicating that the standard cases of *TA Luft* could be handled with the provided tool by professionals without difficulties.

A tendency has been observed that an increasing number of people with only little experience in the field of dispersion modelling and air quality assessment have been making use of AUSTAL2000, presumably stimulated by the free availability of the tool. The expert community reacted and formulated in several federal states codes of practise both for assistance and quality assurance. These efforts are presently being bundled in form of a VDI guideline on quality control in dispersion calculations according to *TA Luft* (VDI 3783 Part 13, in preparation).

## AUSTAL2000: EU TWINNING PROJECTS

AUSTAL2000 has been introduced and applied in several EU twinning "Air Quality" projects. Application and acceptance in foreign countries was facilitated by the free source code, the extensive documentation (reports, handbook, examples, guidelines), and program adjustments (adoptable land use data base and language support, UTM coordinates). Major problems were located in the provision of suitable meteorological data and in the quality assurance. More details are presented by *Müller, W. and U. Janicke* (2007).

## AUSTAL2000G: ODOUR ASSESSMENT

In Germany, odour assessment is based on the concept of the so-called odour hour. An hour is regarded as odour hour if in at least 10% of the time an odour perception is observed. Limits are given for the number of odour hours that are acceptable within a year (*GIRL*, 2004).

Typical sources of odorants are low sources (stables) and diffusive sources (sewage plants), often located in the vicinity of buildings – scenarios for which a Lagrangian particle model offers a more realistic description as compared to for example Gaussian plume models.

On behalf of several federal states, AUSTAL2000 was extended in 2004 to the calculation of odour hour frequencies. A model concept (AUSTAL2000G) was developed to derive odour frequencies on the basis of the mean concentrations as calculated by AUSTAL2000. The concept was checked against a more sophisticated model that explicitly parameterizes concentration fluctuations and it was validated with several experimental data sets (*Janicke, L. and U. Janicke*, 2007).

## ESOFIN: ESTIMATION OF ODOUR EMISSIONS FROM FIELD INSPECTIONS

For odour dispersion calculations, emission strengths are often unknown, partly because they are not accessible by measurement. An estimate can be obtained by comparing odour frequencies observed in field inspections with results from corresponding dispersion calculations.

In the project ESOFIN, carried out in 2006/2007 on behalf of the federal state Nordrhein-Westfalen, a model concept was developed to make such an estimate with the help of AUSTAL2000. For this purpose, AUSTAL2000 was extended to calculate time averages over successive minutes on the basis of a meteorological time series (optionally also averages over successive minutes) in order to explicitly account for plume meandering. More details are presented by *Janicke, U. et al.* (2007b).

## LASAIR: DECISION SUPPORT SYSTEM FOR NUCLEAR HAZARDS

In the context of the defence against nuclear hazards and safety analyses, the decision support system LASAIR was developed in 2001 on behalf of the German Federal Office for Radiation Protection (*BfS*, 2007).

LASAIR contains an interactive graphical user interface and implements LASAT as dispersion module. It provides a quick prognosis of the possible dispersion of radioactive material and the radiation exposure before the potential ignition of a radiological dispersal device. The prognosis quality can be successively refined, e.g. by the provision of actual meteorological data or a larger amount of simulation particles to reduce the statistical uncertainty within a given calculation time frame.

Based on local, optionally online-measured meteorological data and a selection made from pre-defined source configurations, the near-ground concentration of activity, the deposition, and the inhalation dose are calculated. Graphical visualization of the results is supported by an overlay with selected topographic background maps (covering the area of Germany) of different scales. LASAIR runs on an ordinary laptop computer.

LASAIR is available to the responsible land and federal authorities. It received particular attention in course of the Soccer World Championships 2006 in Germany.

## ARTM: ATMOSPHERIC RADIO NUCLIDE TRANSPORT MODEL

The model ARTM is a modification of AUSTAL2000 in the context of a technical revision and actualisation of the German General Administrative Provision (*AVV*, 2005; related to § 47 of the Radiation Protection Ordinance) and of the Incident Calculation Bases (*SBG*, 2004; related to § 49 of the Radiation Protection Ordinance).

It is intended to replace the Gaussian plume model implemented in these guidelines by a Lagrangian particle model according to *TA Luft*. The program AUSTAL2000, designed for the atmospheric dispersion of non-radioactive airborne substances, has been adapted and further developed for the application to airborne radio nuclides (ARTM, Atmospheric Radionuclide Transport Model): Algorithms regarding radioactive decay, cloud radiation, and wet deposition processes were implemented as well as interfaces to existing calculation procedures of AVV and SBG. The model is presently subject to a test phase, further information will be provided by the research organisation GRS (http://www.grs.de).

## LASPORT: APPLICATION TO AIRPORT-RELATED SOURCE SYSTEMS

Based on earlier experiences with LASAT applied to airport-related emission sources, the software package LASPORT (LASAT for airports) was developed in 2002 on behalf of the German Airports Association (ADV). LASPORT is a standard tool for emission and dispersion calculations with airport-related sources like aircraft, auxiliary power units, ground support equipment, and motor traffic. It has been used at a variety of airports, among other for the current licensing procedures at Frankfurt Airport and Munich Airport.

LASPORT is one of the three European candidate models addressing local air quality at airports that were submitted in 2006 to the International Civil Aviation Organization (ICAO/CAEP). More details are presented by *Janicke, U. et al.* (2007a).

## REFERENCES

*AVV*, 2005: (General administrative provision relating to Section 47 Radiation Protection Ordinance; determination of radiation exposure due to the discharge of radioactive materials from nuclear plants or installations) Allgemeine Verwaltungsvorschrift zu § 47 Strahlenschutzverordnung; Ermittlung der Strahlenexposition durch die Ableitung radioaktiver Stoffe aus kerntechnischen Anlagen oder Einrichtungen. Draft.

*BfS*, 2007: Contact person for further information on LASAIR: Hartmut Walter, Bundesamt für Strahlenschutz (BfS), SW 2.2, 85764 Oberschleissheim, Germany. Email: hwalter@bfs.de. See also http://www.bfs.de.

*GIRL*, 2004: (Odour nuisance guideline, GIRL) Feststellung und Beurteilung von Geruchsimmissionen (Geruchsimmissions-Richtlinie, GIRL) in der Fassung vom 21. September 2004 mit Begründung und Auslegungshinweisen, Düsseldorf, Ministerium für Natur und Umwelt, Landwirtschaft und Verbraucherschutz NRW.

*Graff, A.*, 2002: The new German regulatory model – a Lagrangian particle dispersion model. 8th conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Sofia. See http://www.harmo.org.

*Janicke, L.*, 1983: Particle simulation of inhomogeneous turbulent diffusion. Weber, B. (Ed.), Air Pollution Modeling and its Application II, Plenum Press, New York, 527-535.

*Janicke, L.*, 1994: Embedding of the Lagrangian dispersion model LASAT into a monitoring system for nuclear power plants. Gryning, S.-E. and M.M. Milán (Eds.), Air Pollution Modeling and its Application X, , Plenum Press, New York, 405-411.

*Janicke, L.*, 2002: Lagrangian dispersion modelling. Particulate Matter in and from Agriculture, **235**, 37-41, ISBN 3-933140-58-7.

*Janicke, L. and U. Janicke*, 2003: (A modelling system for licensing industrial facilities) Entwicklung eines modellgestützten Beurteilungssystems für den anlagenbezogenen Immissionsschutz. UFOPLAN 200 43 256, on behalf of the German Federal Environmental Agency (UBA). See http://www.austal2000.de.

*Janicke, L. and U. Janicke*, 2007: (The development of the dispersion model AUSTAL2000G) Entwicklung des Ausbreitungsmodells AUSTAL2000G. Reports on Environmental Physics, **1** Ed. 2, Janicke Consulting, ISSN 1439-8222. See http://www.janicke.de.

*Janicke, U. and L. Janicke*, 2004: Enhancement of a diagnostic wind field model for licensing industrial facilities (TA Luft). UFOPLAN 203 43 256, on behalf of the German Federal Environmental Agency (UBA). See http://www.austal2000.de.

*Janicke, U., E. Fleuti, I. Fuller*, 2007a: LASPORT - a model system for airport-related source systems based on a Lagrangian particle model. 11th conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Cambridge. See http://www.harmo.org.

*Janicke, U., L. Janicke, U. Hartmann*, 2007b: Estimation of odour emissions from field inspections (ESOFIN) and a screening model for odour dispersion (SMOD). 11th conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Cambridge. See http://www.harmo.org.

*Müller, W. and U. Janicke*, 2007: Experiences with the German regulatory model AUSTAL2000 in Germany and in other countries in the framework of EU twinning

projects. 11th conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Cambridge. See http://www.harmo.org.

*SBG,* 2004: (Incident calculation bases relating to section 49 of the Radiation Protection Ordinance; amendment of chapter 4: calculation of radiation exposure; recommendation of the Commission on Radiological Protection) Störfallberechnungsgrundlagen zu § 49 Strahlenschutzverordnung; Neufassung des Kapitels 4: Berechnung der Strahlenexposition; Empfehlung der Strahlenschutzkommission (SSK); Berichte der Strahlenschutzkommission des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit, Heft **44**, Elsevier, Urban & Fischer.

*TA Luft,* 2002: (German Regulation on Air Quality Control) Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft - TA Luft). GMBl. 2002, **25-29**, 511-605. See http://www.bmu.de/files/taluft.pdf.

*VDI 3783 Part 8,* 2002: Environmental meteorology; turbulence parameters for dispersion models supported by measurement data. Beuth, Berlin. See http://www.vdi.de.

*VDI 3945 Part 3,* 2000: Environmental meteorology; atmospheric dispersion models; particle model. Beuth, Berlin. See http://www.vdi.de.