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Nuclear risk from atmospheric dispersion in Northern Europe

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Abstract

The aim of the 2005-06 NKS-B NordRisk project has been to present practical methods for probabilistic risk assessment from long-range atmospheric transport and deposition of radioactive material. In this project an atlas of long-range atmospheric dispersion and deposition patterns derived from archived numerical weather prediction (NWP) model data coupled to an atmospheric dispersion model has been produced, and a PC-based software tool has been developed, based on a simplified description of the long-term, long-range atmospheric dispersion and deposition. The atlas and the software tool may allow for a rapid, first assessment of the risks following a nuclear emergency, when detailed information on the long-range atmospheric dispersion and deposition is not available

Key words

Nuclear Emergency; Probabilistic Risk Assessment; Risk Atlas;

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Nuclear risk from atmospheric dispersion in Northern Europe

Final report of the NKS-B project NordRisk 2005-2006

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April 2007

Summary

The aim of the NordRisk project has been to provide a simple means for probabilistic assessment of risks from long-range atmospheric transport and deposition of radioactive material. This is accomplished in the form of two assessment tools,

1) an atlas over various long-range atmospheric dispersion and deposition scenarios derived from archived numerical weather prediction (NWP) model data coupled to an atmospheric dispersion model,

supplemented by

2) a PC-based software tool based on a simplified description of the long-term, long-range atmospheric dispersion and deposition.

The atlas contains case studies of hypothetical releases from nuclear installations in the Northern Hemisphere. From the systematics of the long-range dispersion and deposition patterns, a risk assessment tool based on historical data is obtained. Combined with assumptions on the release of radionuclides the atlas can be used in probabilistic risk assessment for future, hypothetical accidents.

The PC-based software tool is based on a simplified model for the ensemble-mean dispersion and deposition of radionuclides. While avoiding the complexity of long-range transport calculations based on actual NWP model data, the simplified model accounts for the gross structure of the long-term deposition patterns observed in the more involved dispersion model calculations (Lauritzen et al, 2006). The software allows the user to alter parameter values describing the release and meteorology and can therefore be used for assessment of the risks from e.g. other release sites or under prevailing meteorological conditions.

The potential end-users are foremost the Nordic emergency management authorities. The two assessment tools developed through the project are primarily intended for emergency preparedness planning purposes, but even for ongoing accidents the tools may be used for rapid assessment of the scale of the radioactive contamination and possibly affected locations. Hence, the atlas and the software tool are intended to be used as a supplement to decision support systems (DSS) currently applied in Nordic nuclear emergency preparedness. The assessment tools provide insight into the nature of long-range atmospheric dispersion and may be used for educational purposes.

While the two assessment tools can be used already in their present forms, they may need further refinement in order to be fully implemented into Nordic DSS: both the atlas and the software tool could preferably be made directly accessible from current DSS, such as the ARGOS system. This will require preparation of the underlying data in a format suitable for the DSS. Also, the parameters employed in the long-range dispersion model of the software tool will have a direct impact on the risk assessment, and further investigations and recommendations are needed on the proper choice of parameter values to describe (user-defined) accident scenarios and meteorological conditions. Such investigations, however, is not a part of the present project but will be taken up in an upcoming study.

Project overview

The NordRisk project was carried out in 2005-06 as part of the NKS-B projects on emergency preparedness. Nordic emergency management authorities and research institutions participated in the project, cf. Table 1.

Table 1. NordRisk project participants

Bent Lauritzen	Risø National Laboratory Denmark
Torben Mikkelsen	Risø National Laboratory Denmark
Poul Astrup	Risø National Laboratory Denmark
Alexander Baklanov	Danish Meteorological Institute (DMI)
Jens Havskov Sørensen	Danish Meteorological Institute (DMI)
Øyvind Selnæs	Norwegian Radiation Protection Authority (NRPA)
Robert Finck	Swedish Radiation Protection Authority (SSI)
Alexander Mahura	Kola Science Center of Russian Academy of Sciences (KSC)

A project web site, (http://www.risoe.dk/nuk/emergency/NordRisk.htm) has been maintained throughout the project period, and main results of the NordRisk project including the risk atlas and the PC-based software tool as well as other information relating to the project may be found on this site. In addition, both the atlas and the software tool will become available through NKS (http://www.nks.org).

Results of research originated within the project have been published in scientific journals and in conferences proceedings.

Risk Atlas

The NordRisk atlas describes risks from long-range atmospheric dispersion and deposition of radionuclides based on historical data. The atlas contains a number of case studies of hypothetical releases from selected nuclear risk sites in the Northern Hemisphere. The results of long-term, long-range atmospheric transport and deposition calculations are presented as a series of maps showing time-integrated air concentration and total deposition fields.

The meteorological base for the calculations is two years of analysed NWP data from the European Centre for Medium-range Weather Forecast (http://www.ecmwf.int) covering the Northern Hemisphere (ERA-40). Dispersion calculations are performed with the Danish long-range puff model DERMA (Sørensen et al., 2007); each puff is followed for up to three weeks from the time of release and the downwind radionuclide air concentration and dry and wet deposition fields have been determined.

In the risk atlas, the maps are based on one-year continuous releases. The atlas, however, applies both to accidental (short-term) releases of radionuclides and to continuous emission of radionuclides or other contaminants from a given risk site. In both cases, the atlas maps the “ensemble mean” concentration fields. For accidental releases, combined with a release risk assessment or an indication of the magnitude of the actual release the maps provide a first assessment of the mean-value of the radioactive contamination. For continuous emissions of radionuclides or other contaminants from a risk site, the atlas directly provides the expected geographical scale of contamination.

Both for the short-term and the long-term release conditions, large fluctuations due to the stochastic nature of atmospheric transport and deposition are to be expected compared to the ensemble mean-values. Therefore, in addition to the mean concentration fields the atlas provides information on the variability both in the case of a continuous release and based on (accidental) one-day releases. In combination with the ensemble-mean value, the assessed variability constitutes a probabilistic risk assessment of atmospheric transport of radionuclides under similar meteorological conditions as used for the atlas.

Different release sites and radionuclides are considered in the atlas. A general trend for the long-term averaged deposition or air concentration fields is the tendency towards pattern of a near-isotropic ensemble-mean deposition (see Fig. 1). Fluctuations around the mean value are in most cases well described by a gamma model distribution (Fig. 2).

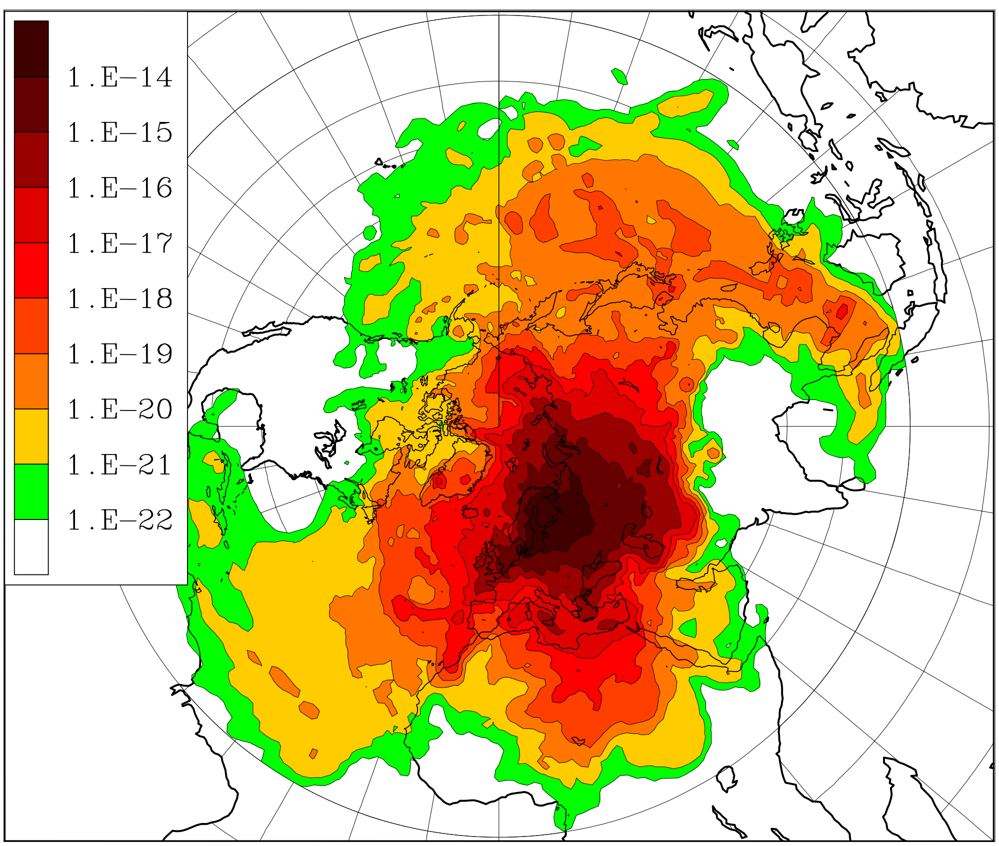

Figure 1. Deposition of ^{137}Cs from a one-year continuous release from Leningrad NPP.

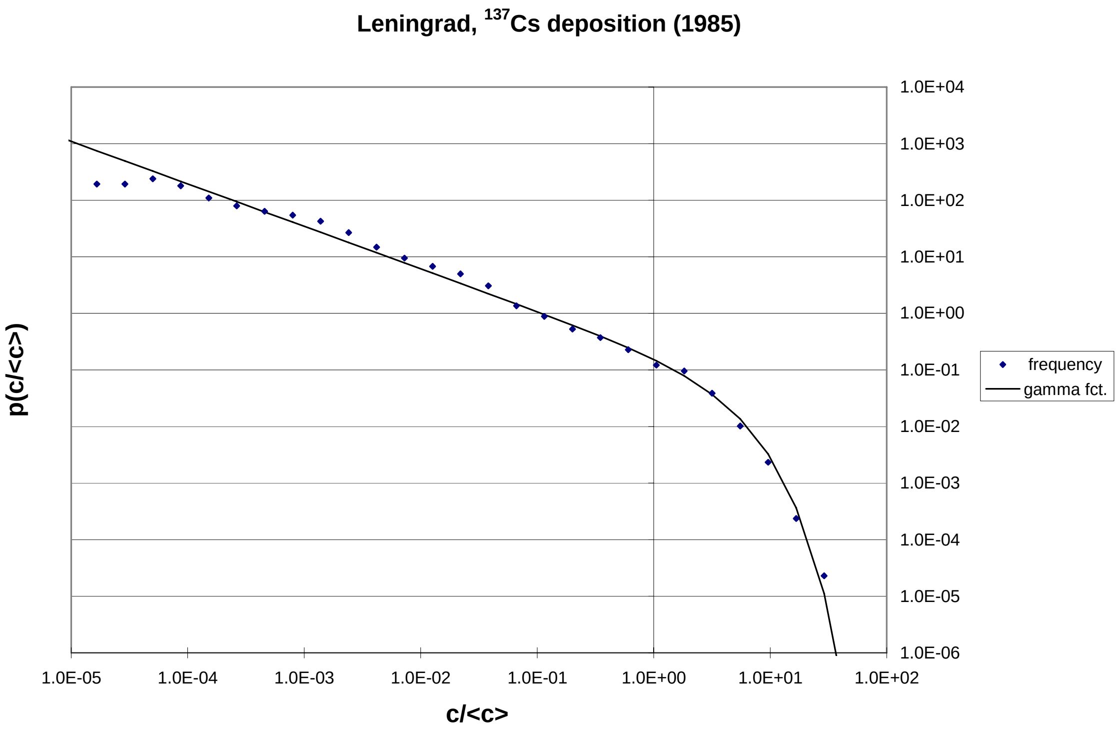

Figure 2. Probability density function of the deposition density scaled to local mean value. Solid line is gamma model distribution with shape parameter $1/\phi = 0.25$.

PC-based Software Tool

A simple model for the long-range atmospheric dispersion and deposition has been formulated as a pure advection-diffusion model with constant diffusivity and deposition parameters (Lauritzen and Mikkelsen, 1999). This model can be solved analytically and its resulting fields coded for graphical presentation. While the model does not account for the complexity associated with real-time dispersion model calculations, the simplified model does provide a fairly good approximation to the gross deposition patterns associated with the ensemble-mean dispersion and deposition (Lauritzen et al, 2006).

The model contains a small number of parameters, which depend both on the meteorological conditions as well as on the physical-chemical properties of the dispersed material. The parameter values must be set externally, either from model assumptions, e.g. from regression against numerical dispersion model calculations such as those used for the NordRisk atlas, or from expert judgments.

Within the NordRisk project, a PC-based software has been developed for presentation of the deposition fields from the simplified dispersion model. The values of the input parameters may be altered by the user to describe other release conditions or meteorological conditions. The presentation of the results is in the form of maps based on the web-based Google Earth global graphical display system (http://earth.google.com/), an example provided in Fig. 3. Maps developed for the NordRisk atlas may also be accessed through the Google Earth software.

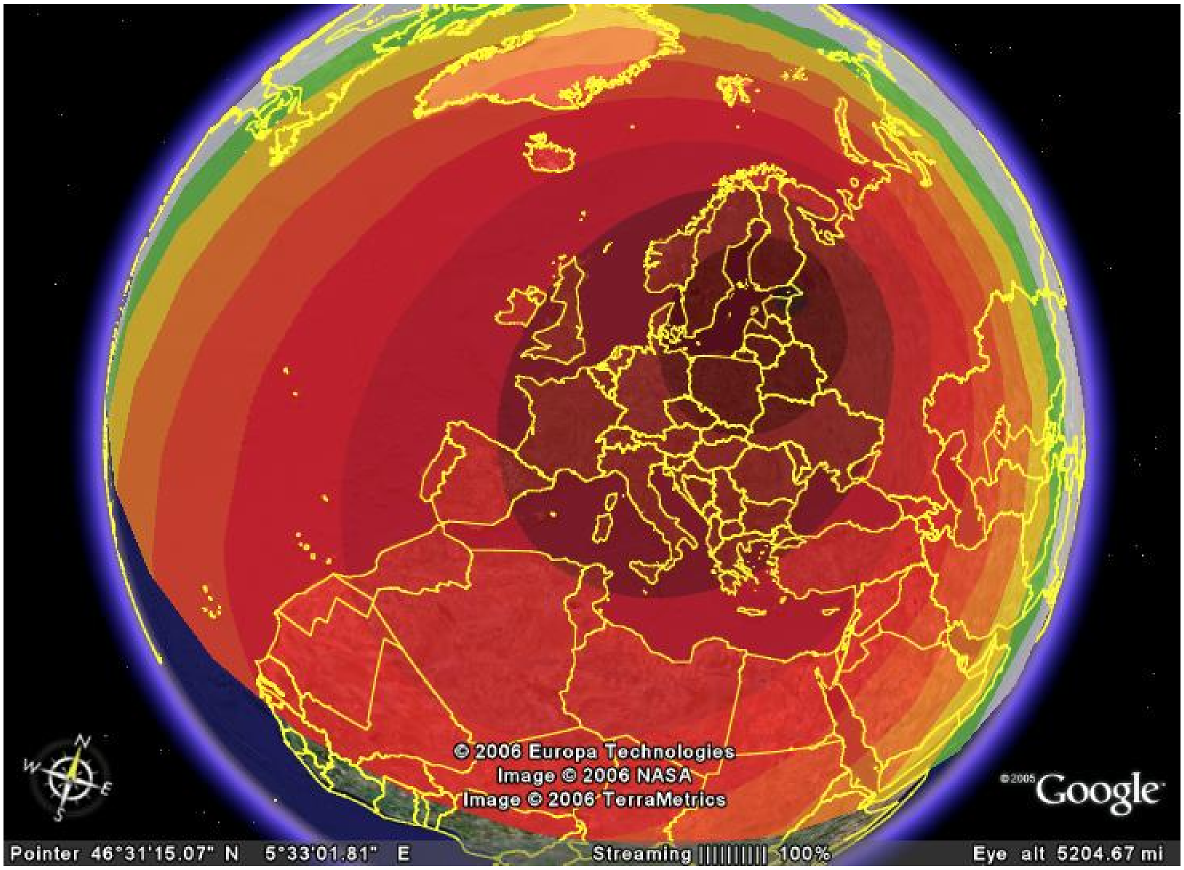

Figure 3. Simplified dispersion model calculation of the ensemble-mean deposition of ^{137}Cs released from Leningrad NPP. Google Earth image.

Concluding remarks

The main focus of the NKS NordRisk project has been to develop practical methods for rapid risk assessment from long-range atmospheric transport and deposition. Comprehensive numerical calculations of long-term, long-range atmospheric dispersion deposition have been carried out, and general trends of the ensemble mean and the variability have been derived from statistical analysis of the resulting deposition and air concentration fields. When coupled with assumed release profiles of radioactive material from North European sites we have provided a probabilistic risk assessment tool based on historical NWP model data.

During the study, we have inter-compared smoothed NWP model-based deposition and air concentration fields with predictions made with a simplified advection-diffusion model. In most cases, we find good agreement between the smoothed NWP-based predictions and the ensemble-mean fields obtained with the simplified model. The dispersion and deposition parameters depend on the physical-chemical properties of the released material, but only to a lesser degree on the location of the release site. Consequently, we propose to use the simplified model as a first attempt to estimate the risks, also from sites for which detailed, long-term numerical atmospheric dispersion model calculations have not already been carried out. In a forthcoming study we will investigate and recommend specific parameter values that apply to different release and dispersion scenarios.

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