RISKS FROM LONG-RANGE ATMOSPHERIC DISPERSION

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INTRODUCTION

Assessment of the consequences of major nuclear accidents or other widespread contamination requires prediction of long-range atmospheric dispersion and deposition. Probabilistic risk assessment (PSA studies) from long-range atmospheric dispersion of contaminants can be obtained by performing a large number of dispersion model calculations using an ensemble of numerical weather prediction (NWP) model data. Within the Nordic Nuclear Safety Research (NKS) study NordRisk, such calculations have been performed using two years of analyzed NWP model data from the European Centre for Medium-range Weather Forecast, as input to the Danish long-range puff dispersion model DERMA. For two years worth of data, ensemble-mean concentrations and fluctuations were extracted of the deposition and surface air concentration fields stemming from hypothetical releases from a number of nuclear installations within Europe. These accident scenarios have been compiled into a risk atlas. After smoothing of the numerical simulations, we find that a deterministic, simplified advection-diffusion model can account for the gross structure of the ensemble-mean deposition and air concentration fields. We also find that a simple stochastic gamma model accurately describes the variability about the mean predictions.

RISK ATLAS

The risk atlas describes the ensemble mean contamination stemming from long-range atmospheric dispersion and deposition of radionuclides and is based on historical weather 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 calculated.

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.

Especially for the short-term release conditions, large fluctuations of the concentration fields are to be expected due to the stochastic nature of atmospheric transport and deposition. In addition to the mean concentration fields information on the variability based on (accidental) short-term releases may be obtained from the model calculations. 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 near-isotropic ensemble-mean deposition fields (Fig. 1). Therefore, to a first approximation, the concentrations only depend on the distance from the release site. The relative fluctuations around this mean value are in most cases well described by a gamma model (Fig. 2).

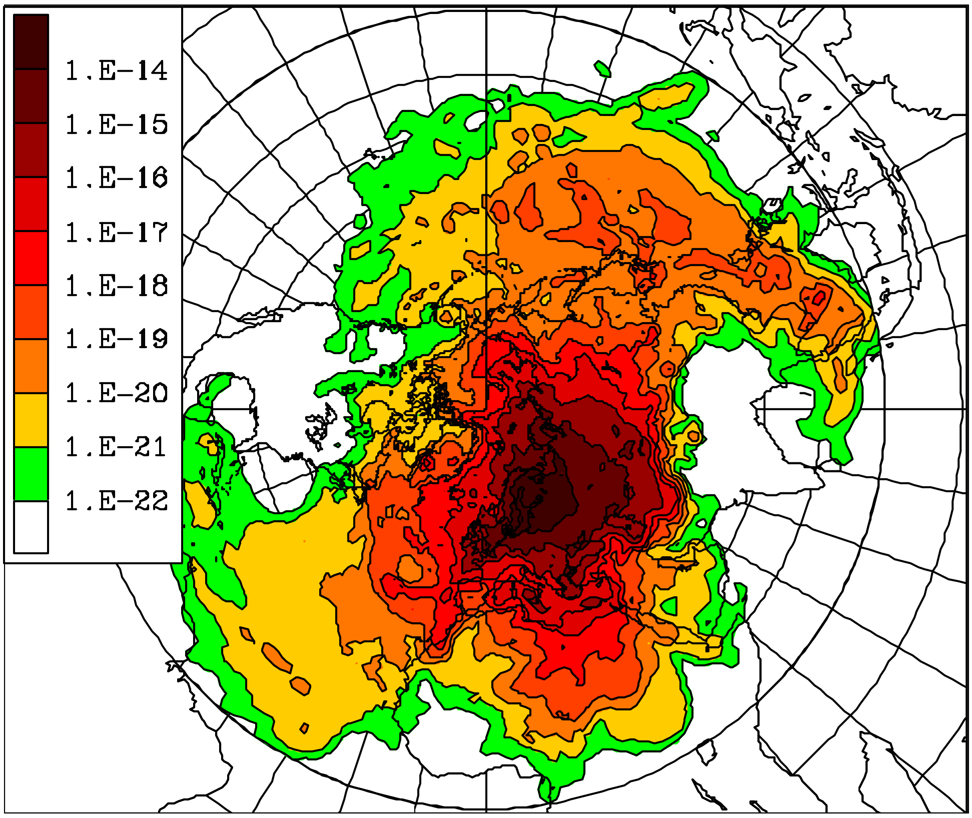

Fig. 1; Deposition of ^{137}Cs from a one-year continuous release from Leningrad NPP.

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 results easily 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, or from expert judgments.

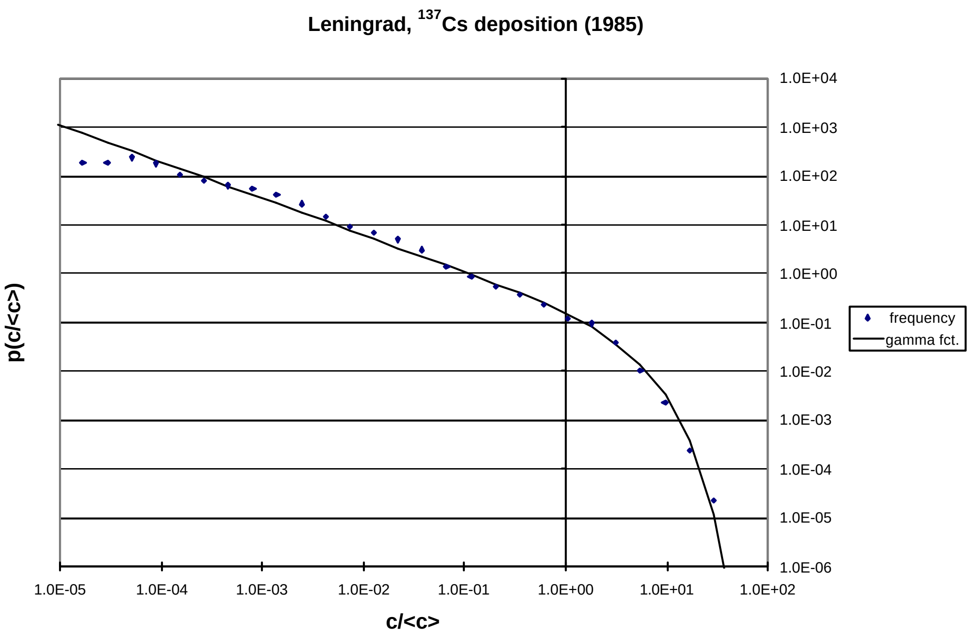

Fig. 2; Probability density function of the relative deposition density. The solid line is a gamma model distribution with shape parameter $1/f = 0.25$.

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 sites, 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 is provided in Fig. 3.

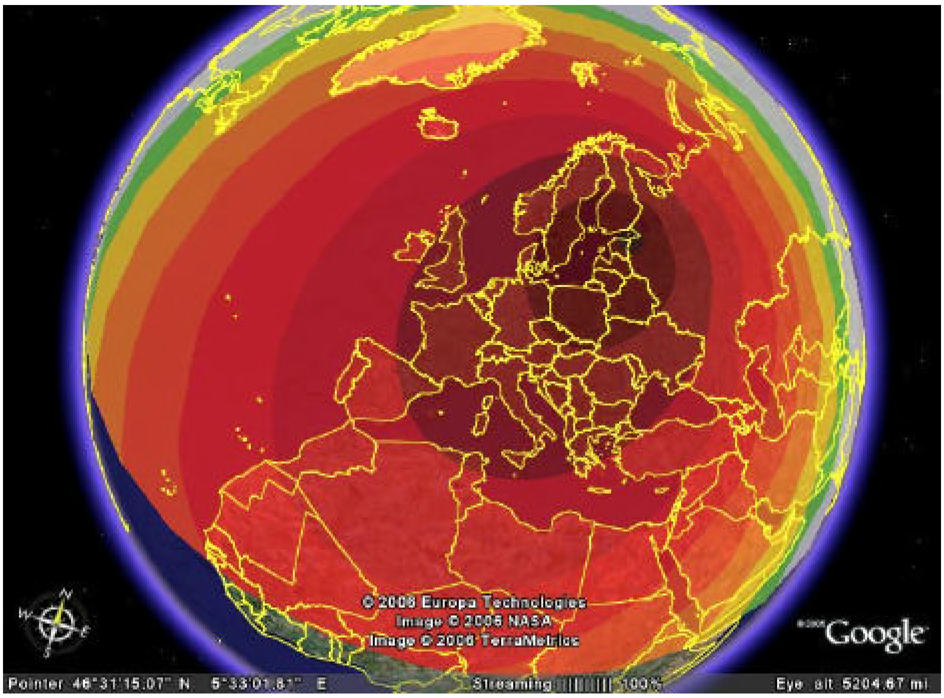

Figure 3. Simplified dispersion model calculation of the ensemble-mean deposition of ^{137}Cs *released from Leningrad NPP. Google Earth image.*

CONCLUSION

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**.(www.NKS_Risoe....)** The dispersion and deposition parameters depend on the physical-chemical properties of the released material, and 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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