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Abstract

The objective of the NordRisk II project has been to derive practical means for assessing the risks from long-range atmospheric dispersion of radioactive materials. An atlas over different atmospheric dispersion and deposition scenarios has been developed using historical numerical weather prediction (NWP) model data. The NWP model data covers three years spanning the climate variability associated with the North Atlantic Oscillation, and the atlas considers radioactive releases from 16 release sites in and near the Nordic countries. A statistical analysis of the long-range dispersion and deposition patterns is undertaken to quantify the mean dispersion and deposition as well as the variability. Preliminary analyses show that the large-scale atmospheric dispersion and deposition is near-isotropic, irrespective of the release site and detailed climatology, and allows for a simple parameterization of the global dispersion and deposition patterns. The atlas and the underlying data are made available in a format compatible with the ARGOS decision support system, and have been implemented in ARGOS.

Key words

risk assessment; long-range transport; radionuclide; pollutants; deposition

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NKS NordRisk II: Nuclear risk from atmospheric dispersion in Northern Europe – Summary Report

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3 May 2011

Summary

The objective of the NordRisk II (2009-10) project has been to find practical means for assessing the risks due to long-range atmospheric dispersion of radioactive materials. As in the preceding project, NordRisk (2005-6), an atlas over different atmospheric dispersion and deposition scenarios based on numerical weather prediction model data has been developed, aimed at providing a simplified risk assessment tool using historical data. The NordRisk II atlas has been extended to cover more release sites in and near the Nordic countries. The numerical weather prediction model data covers three full years, spanning the climate variability associated with the North Atlantic Oscillation. The atmospheric dispersion model calculations have been extended to a period of 30 days following each release to ensure almost complete deposition of the dispersed radionuclides.

A thorough statistical analysis of the long-range dispersion and deposition patterns is being undertaken aimed at quantifying the mean dispersion and deposition as well as the variability associated with long-range atmospheric transport and deposition. The results of these investigations will be published in the scientific literature. Preliminary analyses show that the large-scale atmospheric dispersion and deposition is near-isotropic, irrespective of the release site and detailed climatology, and allows for a simple parameterization of the global dispersion and deposition patterns. In turn, these generic patterns provide a simplified probabilistic risk assessment (PRA) tool, in which the (default) parameters needed to describe the probability density functions can be derived from the statistical analysis of the atmospheric dispersion model data.

The potential end-users of the NordRisk projects are foremost the Nordic emergency management authorities, and the Nordic authorities have participated in the project. The atlas and the underlying data are made available in a format compatible with the ARGOS decision support system, and have been implemented in ARGOS. The NordRisk II atlas is primarily intended for emergency preparedness planning purposes, but even for ongoing accidents in which the release is still uncertain, the atlas may be used for a rapid assessment of the possible scale of contamination, as a supplement to decision support systems currently applied in Nordic nuclear emergency preparedness.

Project overview

The aim of the two NordRisk projects has been to find practical means for assessing risks due to long-range atmospheric dispersion of radioactive materials. In the first NordRisk project (2005-6) two such assessment tools were developed:

1. an atlas over different atmospheric dispersion and deposition scenarios based on historical numerical weather prediction (NWP) model data
2. a software tool based on a simplified model for the long-term average air-concentration and deposition of radionuclides.

In the NordRisk II project (2009-10), the atlas has been extended to cover more release scenarios and larger climate variability, with an increased focus on risk sites in Northern Europe. In addition, the atlas includes a more detailed accounting for the time development of the atmospheric dispersion and deposition. A thorough statistical data analysis is undertaken, aimed at providing insight in to the very large-scale atmospheric dispersion and providing input (default parameters) for the simplified software tool developed in NordRisk. And finally, the data are made available for implementation in the ARGOS decision support system to facilitate end-use of the project results.

Table 1. NordRisk projects participants

NordRisk and NordRisk II	Risø National Laboratory Denmark
	Danish Meteorological Institute (DMI)
	Norwegian Radiation Protection Authority (NRPA)
	Swedish Radiation Protection Authority (SSI)
NordRisk II	Danish Emergency Management Agency

Dispersion model calculations and risk atlas

In the NordRisk II project, long-range atmospheric dispersion model calculations have been carried out with the purpose of developing an atlas of atmospheric dispersion and deposition scenarios. The calculations are based on the Danish atmospheric stochastic puff dispersion model DERMA using archived NWP model data (Sørensen et al., 2007, ERA-40).

The NWP data cover three full years (1983, 1985 and 1996) spanning much of the climate variability associated with the North Atlantic Oscillation, which is the dominant climate variation mode for Northern Europe (Fig. 1). The dispersion model calculations comprise hypothetical releases of Cs-137, I-131 aerosols, and elementary I-131 from a total of 16 nuclear risk sites on the Northern Hemisphere (Table 2). Atmospheric transport and deposition of the released materials are calculated for a period of 30 days, ensuring almost complete deposition, and annual averages (ensemble-mean values) of dry and wet deposition and time-integrated air concentration are derived.

Table 2. Release sites used for the NordRisk II Atlas

Risk site	Lon (°E)	Lat (°N)	Risk site	Lon (°E)	Lat (°N)
Balakovo	47.37	51.92	Kola	32.75	67.75
Belojarsk	61.32	56.85	Kosloduj	23.63	43.75
Bilibino	166.45	68.05	Leningrad	29.00	59.90
Borssele	3.72	51.43	Novaya Zemlya	54.50	72.50
Chernobyl	30.25	51.30	Savannah River	-81.70	33.30
Davis Besse	-83.09	41.60	Sellafield	-3.50	54.42
Dukovany	16.13	49.08	Sinpo	128.22	40.00
Kanupp	66.79	24.87	Tricastin	4.73	44.33

The results of these long-term, long-range atmospheric transport and deposition calculations are presented in a risk atlas as a series of maps showing the time-integrated air concentration and total deposition fields (Fig. 2). A general trend for the long-term averaged deposition or air concentration fields is the tendency towards patterns of near-isotropic distributions.

The atlas applies both to accidental short-term releases and to continuous emission of contaminants from a given risk site. For short-term releases, the atlas provides the expected range of atmospheric transport before deposition. The actual deposition pattern following a short-duration release to the atmosphere, however, will be much more anisotropic than the ensemble mean pattern. For continuous emissions of radionuclides or other contaminants from a risk site, on the other hand, the atlas directly provides the expected geographical scale of contamination and the atlas can be viewed as case studies of such continuous releases.

The long puff advection time (30 days) yields the static picture of contamination long time after a release. In the atlas, this is supplemented by figures showing the time-development of the dispersion length scales (Fig. 3) and of the total deposition.

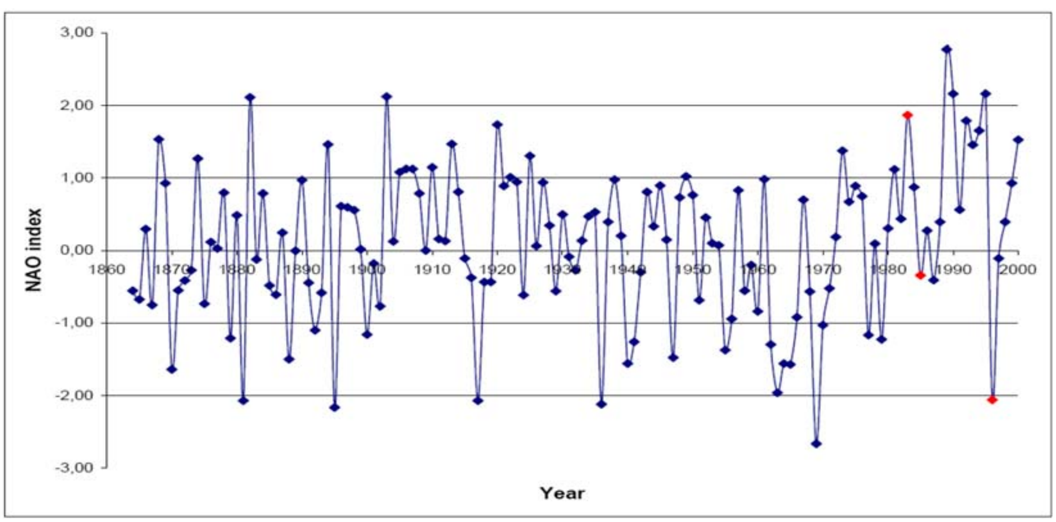

Figure 1. North Atlantic Oscillation index. The years 1983, 1985 and 1996 (marked in red) were selected for the atlas.

Plate 31 Nuclear power plant: **Leningrad**; Nuclide: **Caesium-137 aerosol**

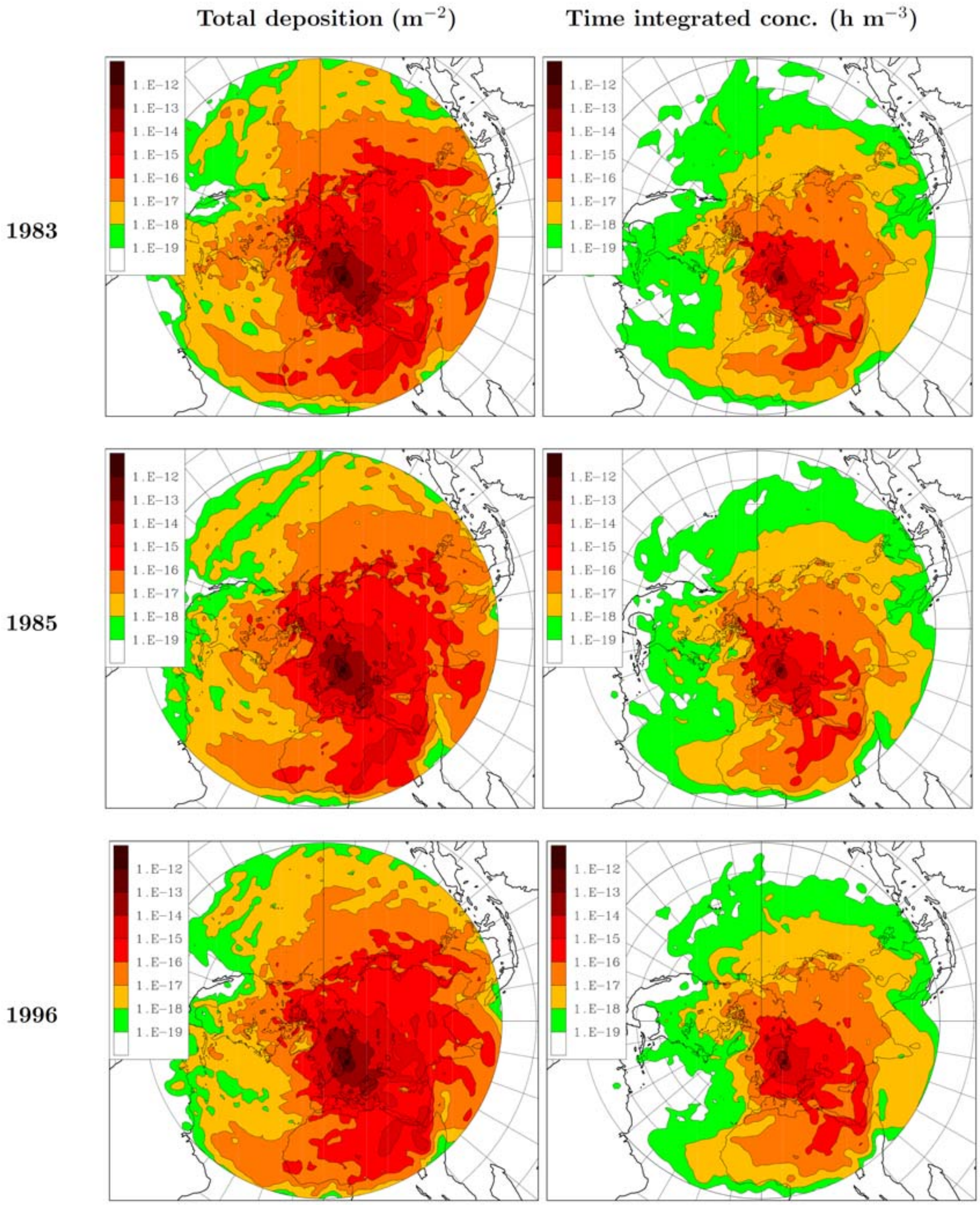

Figure 2. NordRisk II atlas. Ensemble mean total deposition and time-integrated air concentration following a hypothetical unit release of Cs-137 from Leningrad NPP.

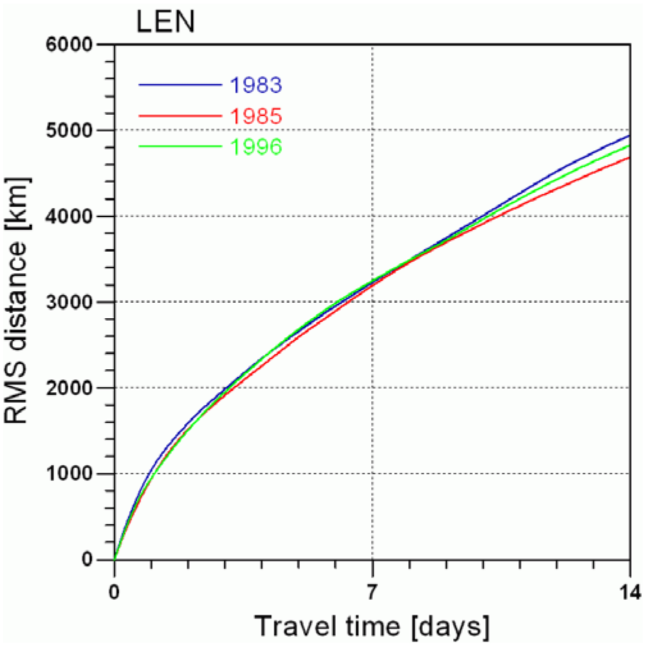

Figure 3. Root-mean-square distance from the Leningrad release site to puff centres as function of travel time. Annual averages for 1983, 1985 and 1996.

Statistical data analysis

A very large number of atmospheric dispersion model calculations are performed within the NordRisk II project, allowing for a detailed statistical assessment of the large-scale deposition patterns. To a first approximation, ensemble-mean long-range atmospheric dispersion and deposition can be modeled as a pure advection-diffusion process with constant diffusivity and deposition parameters (Lauritzen and Mikkelsen, 1999). The model does not account for the complexity associated with real-time dispersion model calculations, but yields a fairly good description of the large-scale deposition patterns (Lauritzen et al., 2006), and provides the basis for a non-linear regression of the deposition data (Fig. 4).

From the regression analysis, the mean dispersion and deposition as well as the variability associated with long-range atmospheric transport and deposition can be quantified. Preliminary analyses show that the mean large-scale atmospheric dispersion and deposition is near-isotropic, irrespective of the release site and detailed climatology.

This allows for a simple parameterization of the large-scale atmospheric dispersion and deposition. When coupled with assumed release profiles of radioactive material from North European sites it provides a simplified probabilistic risk-assessment tool based on historical NWP model data. With default parameters for the long-range atmospheric transport of radionuclides the simplified model will allow for a rapid assessment of risks from sites and for accident release scenarios for which detailed, long-term numerical atmospheric dispersion model calculations have not already been carried out.

The results of the statistical data analysis will be published in the scientific literature.

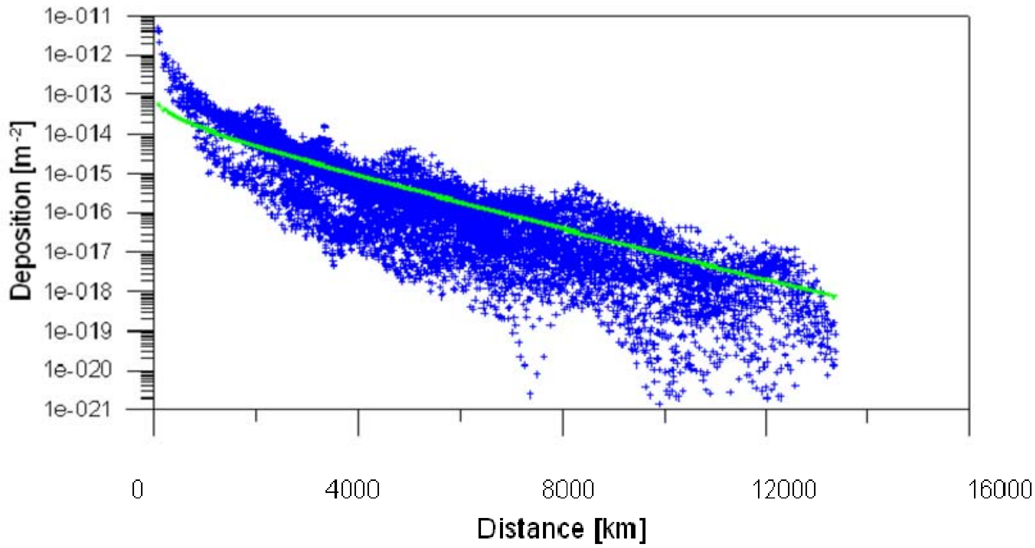

Figure 4. Annual mean deposition of ^{137}Cs as function of the distance from the release site (Leningrad NPP, 1983 data). The average (inserted curve) results from a non-linear regression to the deposition data.

Discussion

The atlas derived in the NordRisk II project is more complete than the previous atlas of the NordRisk (2005-6) project; not only does it cover more release sites, but it also spans the North Atlantic Oscillation (including a negative NAO index year) and it is based on extended atmospheric transport calculations to ensure that most (> 95%) of the released material has deposited. The atlas has been implemented in the ARGOS decision support system allowing easy access for the Nordic emergency management authorities.

A main finding is that travel times and depositions patterns are insensitive to the model year (NAO index). Furthermore, the deposition patterns are rather similar for the different release sites, with some deviations for the low-latitude release sites. In almost all cases close to isotropic deposition patterns are obtained, with only little variation in the dispersion length scale. This finding corroborates the assumption that ensemble mean large-scale dynamics of atmospheric transport can be modeled as a simple advection-diffusion process (Lauritzen et al., 2006). The statistical analysis which is currently undertaken attempts to derive the global parameters describing this process.

The atlas is foremost intended to be used for planning purposes, e.g. in ranking threat scenarios related to releases from nuclear installations. But even for ongoing accidents in which the scale and duration of a possible release is unknown, such as, at the time of writing, the ongoing Fukushima accident, the atlas may be used for crude risk assessment. At present, more than one month after the initiating event of the Fukushima accident, new releases from the power plant cannot be ruled out, thus calling for probabilistic assessments.

Acknowledgements

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