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Nordic Network of Meteorological Services Engaged in Nuclear Emergency Preparedness NKS-MetNet

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Abstract

The current NKS-MetNet project was initiated to strengthen the Nordic collaboration within the field of real-time atmospheric transport modelling for nuclear emergency preparedness and to improve its contacts to the Nordic radiation protection authorities. A backup facility for the network has been established regarding exchange of operational real-time long-range dispersion model calculations. The facility consists of national password protected Web sites, at which some few basic results (maps) of atmospheric dispersion model calculations (forecasts) in emergency situations (or exercises) can be made available to the network. Technical problems at one institute will not influence the calculations or presentations from the other participants, which makes the system robust.
The project has fulfilled its main harmonization goal by bringing the Nordic emergency modelling towards more unified approaches of the presentations of results and introduced a voluntary unification of the model output formats. It was left optional to upload raw data in a format enabling import into one of the Decision Support System (DSS) ARGOS or RODOS. However, implementation of either of these formats is feasible only in case of availability and utilization of the systems by the end-users in the specific country. Within the Nordic countries to-date most but not all of the models are capable of producing the ARGOS-compatible results. Another format of the output data supported by almost all MetNet participants is ENSEMBLE – a standard developed within the scope of the EC ENSEMBLE project that currently continues on a voluntary basis, regulated by a joint MoU, and covers nearly all European emergency-engaged services.
It seems to be feasible to keep the Nordic network of MetNet Web sites also in a near future and continue its development regardless of presence of a third-party large-scale DSS, whether it is ARGOS, RODOS, ENSEMBLE or any other. Foreseen future close cooperation of the meteorological modelling groups with the DSS developers and national Radiation Protection Agencies may eventually help in determining a common platform supported by all Nordic and European models. Until this goal is achieved the Nordic network of Web sites would form a solid basis for operational cooperation and mutual backup of the emergency modelling

Key words

Air concentration, atmospheric, back-up, deposition, dispersion, emergency, forecast, meteorology, model, network, Nordic, nuclear, preparedness, radioactivity, real-time, transport, Denmark, Finland, Iceland, Norway, Sweden

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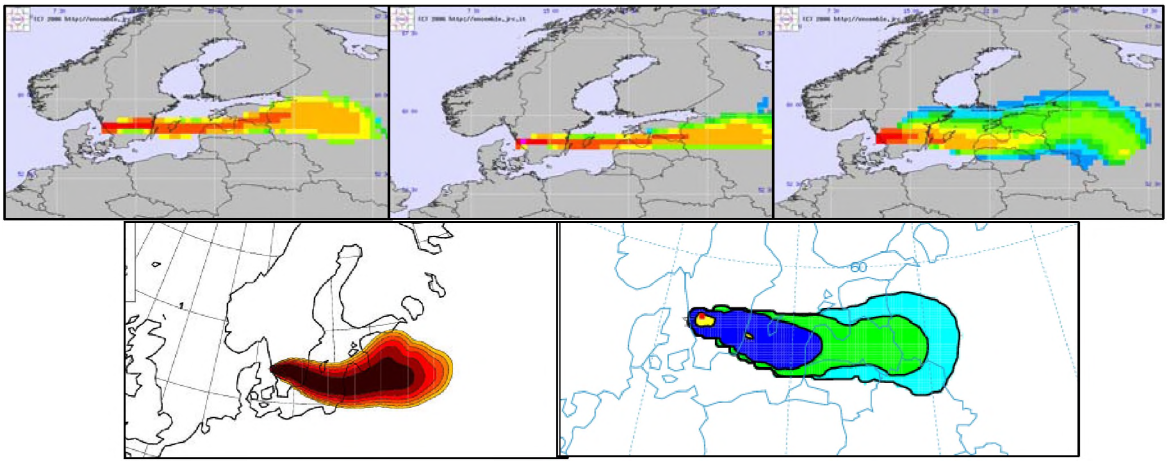

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EXECUTIVE SUMMARY

The current NKS-MetNet project, supported by NKS-B for the four year period 2003-2006, was initiated to strengthen the Nordic collaboration within the field of real-time atmospheric transport modelling for nuclear emergency preparedness, to create a real-time back-up facility for this emergency preparedness and to improve its contacts to the Nordic radiation protection authorities. All five Nordic Meteorological Services have taken part in this Nordic MetNet network.

By using modern information technology, a backup facility for the network has been established regarding exchange of operational real-time long-range dispersion model calculations. The facility consists of national password protected Web sites, at which some few basic results of atmospheric dispersion model calculations (forecasts) in emergency situations (or exercises) can be made available to the network. Technical problems at one institute will not influence the calculations or presentations from the other participants, which makes the system robust.

Two exercises per year have been performed during the project period. Experiences from these exercises indicate that despite well organised emergency systems at each individual meteorological institute unexpected things due to the human or technical factors can happen – and do sometimes happen – in emergency situations when time is critical. A well establish and operational network is in such situations of great value.

The NKS-MetNet project has fulfilled its main harmonization goal by bringing the Nordic emergency modelling towards more unified approaches of the presentations of results and introduced a voluntary unification of the model output formats. It was left optional to upload raw data in a format enabling import into on a decision support system, e.g. ARGOS or RODOS. A problem of both ARGOS and RODOS formats is their uniqueness. Both systems are based on their own set of agreements, which, though largely resembling each other, do not coincide and do not correspond to any commonly accepted format. Therefore, implementation of either of these formats is feasible only in case of availability and utilization of the systems by the end-users in the specific country. Within the Nordic countries to-date most but not all of the models are capable of producing the ARGOS-compatible results. Some users use ARGOS or RODOS, depending on the specific country, while others rely on various simpler systems, graphics produced by the dispersion models, trajectory analysis, etc.

A format of the output data supported by almost all MetNet participants is ENSEMBLE – a standard developed within the scope of the EC ENSEMBLE project that currently continues on a voluntary basis, regulated by a joint MoU, and covers nearly all European emergency-engaged services. The main strength of this format is that it is arguably the most widespread among the European emergency modellers. However, it is not used by all MetNet participants and not by the Nordic radiation protection end-users.

At the current stage, it seems to be feasible to keep the Nordic network of MetNet Web sites also in a near future and continue its development regardless of presence of a third-party large-scale Decision Support System (DSS), whether it is ARGOS, RODOS, ENSEMBLE or any other. The level of complexity of such systems is much higher than that of the MetNet sites and their availability and friendliness for various users is and will be far beyond that of the simple service developed by MetNet.

Foreseen future close cooperation of the meteorological modelling groups with the DSS developers and national Radiation Protection Agencies, as well as further efforts of harmonization in individual countries and across Europe may eventually help in determining a common platform supported by all Nordic and European models. Until this goal is achieved

the Nordic network of Web sites would form a solid basis for operational cooperation and mutual backup of the emergency modelling.

KEY WORDS

Air concentration, atmospheric, back-up, deposition, dispersion, emergency, forecast, meteorology, model, network, Nordic, nuclear, preparedness, radioactivity, real-time, transport, Denmark, Finland, Iceland, Norway, Sweden.

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1 BACKGROUND

The Nordic meteorological services are since many years engaged in nuclear emergency preparedness. In real emergency situations, like e.g. the Chernobyl accident, the emergency organisations at the individual meteorological services (often dependent on few key persons) can be exposed to very demanding tasks, which have to be solved in a shortage of time. New emergency situations can also differ substantially from old experience. Substantial uncertainties can occur and things in the emergency preparedness can even go wrong. In such situations the immediate availability of contacts within an established network and of a back-up system, including some basic emergency preparedness calculations for the present situation, can be of large importance for the emergency preparedness in each individual country. The development of a real-time preparedness including atmospheric transport models, systems for producing probability or ensemble forecasts, software for presentations of results and real-time back-up facilities is also both very time consuming and costly. It was therefore regarded as beneficial to start the establishment of an operational Nordic network among the meteorological services, as a fast back-up service and for a close co-operation concerning atmospheric transport emergency preparedness. The NKS-MetNet network was created and supported by NKS-B for the four year period 2003-2006.

2 OBJECTIVES

The overall aim of the present NKS-MetNet project is to establish a network of Nordic meteorological services engaged in national nuclear emergency preparedness and response through operational real-time calculation of long-range atmospheric dispersion of radioactive material from accidental releases. The main objectives of the network are to establish:

- A Nordic web-based back-up facility for long-range atmospheric dispersion calculations including exchange of real-time and forecast model results. The back-up system shall be fast, robust and simple.
- A forum for exchange of scientific information concerning atmospheric emergency preparedness modelling.
- Two Nordic real-time exercises per year.
- Link developments within the EC ENSEMBLE project to needs from Nordic radiation protection authorities.

3 A NORDIC NETWORK FOR EMERGENCY PREPAREDNESS

Since each of the Nordic countries has its own national emergency preparedness system including atmospheric transport modelling, the network shall only be a support to the national systems regarding atmospheric transport model calculations, and by no means an alternative. The network shall – in principle - be possible to be utilised regardless of time in order to support the national preparedness in case of e.g. technical problems, absence of model expert or as a way to get an estimate of the uncertainty in the transport model forecast. However, at present the availability of the network outside normal office hours depends on voluntary contributions by the members of the network.

3.1 Back-up system for real-time emergency modelling

A back-up system to be used in emergency situations, which details cannot be foreseen in advance, shall be robust, simple and easy to understand and use.

By using modern information technology, a backup facility for the network has been established regarding exchange of operational real-time long-range dispersion model calculations. The facility consists of national password protected Web sites, at which some few basic results of atmospheric dispersion model calculations (forecasts) in emergency situations (or exercises) can be made available to the network. The basic results to be presented can be e.g. 24h or 48h forecast maps for integrated concentration and accumulated deposition. The Web sites do not include any tools for further analyses or time sequence presentations. Access to the Web sites, which are managed by the Nordic meteorological services, is also granted to the national nuclear emergency preparedness authorities and to NKS.

The back-up system within the present network is based on the meteorological numerical forecasts, atmospheric transport models and Web servers at each individual meteorological institute. Technical problems at one institute will thus not influence the calculations or presentations from the other participants, which makes the system robust.

3.2 Harmonisation of graphical presentations and data format

One of the problems addressed during the MetNet project was harmonization of the model results, their formats and visualizations, as well as the technical means behind. Several aspects of the problem were identified.

1. Currently, the responsible authorities in the Nordic countries utilise different emergency preparedness modelling systems, some of them involving models developed at national levels. The models are developed in very different conditions, environments and infrastructures. This diversity is considered as one of the key assets of the network as the evidence mounts that single model cannot pretend to be "good" in all cases. There is a wide consensus, at least in Europe, that there is no such thing as "the best model".
2. By the nature of emergency situations including stressful conditions and a need for prompt decisions based on the optimum information available, the model results must be easily available and comprehensive for the users in order to reduce possibilities for mis-interpretations. One of the significant factors here is that the graphical presentations of plumes from different systems considered as a mutual backup should be:
    a. sufficiently close to each other from users stand point to make the transition from one model to another seamless, instant and effortless;
    b. include certain "marks" or "labels" or be otherwise different, which would still allow instant distinguishing between the results of different models.

The above conditions evidently contradict each other. Therefore the group decided to approach the problem step-by-step in the following order.

1. Harmonization of the information content and the basic forms of its presentation at the individual-model Web sites regarding: variables showed, time slices, structures of the sites, navigation chains, etc. At this level the presentations themselves and visualization details are kept entirely up to the modelling groups.

2. Harmonization of the presentation templates in order to unify to a maximum extent the appearance of the material to the user. Due to a very wide variety of potential emergency situations, it is impossible to determine all characteristics of the formats and this level would have to rely either on a set of rules or on real-time communicated details of presentations.
3. Creation of a full mutual backup of models at a data level, so that the users and modellers in one country could utilise the numerical results of the simulations from another country. This would imply creation of several converters and bridges between the models or agreeing on a common format used by all modelling groups.

The level 1 of the harmonization has been achieved by the project. All Web sites have similar structure, based on a unified template and present the same set of model results. The default content includes one map of time-integrated concentrations and one map of total (wet+dry) deposition of the substance (nuclide) in question. This default can be fine-tuned for each specific case depending on the situation and a request from coordinator of the network.

The levels 2 and 3 were subjects for intensive discussions and analyses, and the level-2 unification has been partly implemented in the last-year exercises. It was also decided that a complete harmonization up to the level 3 has to be considered within the broader scope of European emergency systems. It was left optional to upload raw data in a format enabling import into on a decision support system, e.g. ARGOS or RODOS.

Possibilities for automation of the initiation of model runs (without having to involve a duty meteorologist), generation of results and upload on the web-pages have been discussed extensively. Obviously there is a contradiction between the need for fast automated procedures for operational use and a degree of flexibility allowing the systems to adapt to a new unforeseen incident without undue delay.

For the user of the model results in a real emergency situation it is very important with an easy access and easy understanding of the presented model results. We have identified three (four) different possibilities.

3.2.1 Individual graphical presentations

As stated in the previous section, each modelling system of the network has been developed within a unique environment and uses its own way of visualization of the output results. Availability of various free or nearly-free visualization platforms for the modelling groups has contributed to the diversity. At present, there is no single graphical format or platform that can be used by all MetNet models. Analysis of the problem showed that in most cases the amount of efforts for the unification of the graphical platform is equivalent or exceeding the investments in harmonization of the model outputs themselves. Therefore, it was decided to limit the presentation unification efforts to agreeing on similar types of graphs (maps with coloured shading/isolines), similar projection types (geographical or rotated lon-lat projection) and approximate number of colours and range of the parameters presented (though specific palettes, levels etc are left to individual models and cases).

The harmonization at the level 3 would require a selection of a common data format, which, as follows from long-term experience of all such exercises, is a very difficult and ambiguous task. A survey around MetNet showed that there were only two formats used by more than two models (and no format used by all models) in the network: ARGOS and ENSEMBLE.

3.2.2 ARGOS data format and graphics

The ARGOS system is a commercial Decision Support System (DSS) capable of requesting long-range simulations automatically carried out at remotely located collaborating national meteorological services via internet. Upon completion of model runs, ARGOS receives the simulation results, displaying them by means of sophisticated graphics and performing certain numerical analyses, e.g. dose calculations, based on the model results. These features represent a clear strength of the system and, providing that all data providers and users in the Nordic countries have access to ARGOS, the problem of harmonization would be largely (but not completely, however, – see below) solved.

The main obstacle on full utilization of the ARGOS system is its commercial nature and the presence of the other European-scale DSS RODOS, which possesses somewhat similar features and has been supported by the EC in a push towards harmonization of such system across Europe.

The second problem of both ARGOS and RODOS formats is their uniqueness. Both systems are based on their own set of agreements, which, though largely resembling each other, do not coincide and do not correspond to any commonly accepted format. Therefore, implementation of either of these formats is feasible only in case of availability and utilization of the systems by the users in the specific country. This condition is not fulfilled to-date.

Within MetNet, most but not all of the models are capable of producing the ARGOS-compatible results. Some users use ARGOS or RODOS, depending on the specific country, while others rely on various simpler systems, graphics produced by the dispersion models, trajectory analysis, etc.

3.2.3 ENSEMBLE data format and graphics

The second format of the output data supported by almost all MetNet participants is ENSEMBLE – a standard developed within the scope of the EC ENSEMBLE project that currently continues on a voluntary basis, regulated by a joint MoU, and covers nearly all European emergency-engaged services.

The main strength of this format is that it is arguably the most widespread among the European emergency modellers and thus could serve as almost effort-free platform for the unification.

The list of weaknesses, however, includes several crucial problems:

1. The visualization platform for this format is created by a commercial company and is entirely concentrated within a single Web site operated by the Joint Research Centre (JRC) in Ispra, Italy. The visualization software itself is not available, and the use of it requires administrator access to the ENSEMBLE web site;
2. The current state of the JRC Ispra site does not allow for operational use and is not feasible for such type of applications due to its manual management of the cases by the site administrator, complicated interface and numerous options for analysis, which very well serve research and expert modellers purposes but might be confusing for non-expert users;
3. The format itself is again unique and too limiting to accommodate all the variety of potential future situations. It is also incompatible with ARGOS and RODOS systems.

With the above limitations, this format and the functionality of the central ENSEMBLE Web site is considered by the MetNet group as a nearly perfect platform for model intercomparison and for creation of simple multi-model ensemble forecasts, but not as a platform for model unification. One of the MetNet exercises in 2006 was using the ENSEMBLE platform (with permission from the site administrator) and the results are presented in section 4.7.

3.2.4 RODOS data format and graphics

RODOS is a product of a same-name project started within the EC 4FP and continued to-date aiming at development and implementation of European-wide unified DSS. As for the ARGOS system, RODOS includes detailed dose assessment modules that utilise the results of atmospheric dispersion module. The system has its own graphical interface and standards for input and output files.

To-date the RODOS system is available free of charge but there is a provision that it will eventually become self-financing via certain limited licence fees, which will be used for further development of the system.

Since RODOS incorporates own local- and regional-scale dispersion models, it does not have that well-developed interfaces with external modelling systems and recent attempt to create such interface between RODOS and ENSEMBLE was so far unsuccessful. Within MetNet countries, only Finland has RODOS as the main DSS but the system is so far not interfaced with Finnish atmospheric transport model SILAM (the work is in progress).

With the above strengths and limitations of the system, it was decided not to consider the RODOS system as a platform for unification within MetNet.

3.2.5 Provisions for model harmonization within the follow-up network project(s)

The current NKS MetNet project has fulfilled its main harmonization goal by bringing the Nordic emergency dispersion modellers closer to each other and ensuring semi-operational mutual backup of model results. The first level of harmonization has been achieved with a reasonable extension towards more unified approaches of the results presentations (level 2) and even unification of the model output formats (level 3).

A natural further step of system harmonization would be two-fold: (i) continue the level-2 harmonization of the presentation formats in the individual web sites (without a mandatory requirement of a complete unification of the presentation software and standards); (ii) continue analysis and development work towards a common numerical format of the model output files.

At the current stage, it seems to be feasible to keep the network of Web sites and continue its development regardless of presence of a third-party large-scale DSS, whether it is ARGOS, RODOS, ENSEMBLE or any other. The level of complexity of such systems is much higher than that of the MetNet sites and their availability and friendliness for various users is and will be far beyond that of the simple service developed by MetNet.

The existing partial harmonization of the Nordic models on the basis of ARGOS DSS should not be under-estimated and should be continued. This system provides large in-depth possibilities for data exchange allowing, for example, a quantitative analysis of information obtained from a model in another country. This option for experienced users is a very useful addition to the basic MetNet Web-based system.

Foreseen future close cooperation of the modelling groups with the DSS developers and further efforts of harmonization in individual countries and across Europe may eventually help in determining a common platform supported by all Nordic and European models. Until this goal is achieved, the above-outlined two-way harmonization would form a solid basis for operational network and mutual backup of the Nordic emergency models.

3.3 MetNet address list

An address list (see Appendix 1), including addresses and passwords (not visible in the report) for the MetNet web-pages and all relevant telephone numbers, is continuously up-dated. The address list is available from the different home-pages and also circulated twice a year within MetNet.

3.4 MetNet scientific exchange

The network has acted as a forum through annual meetings at which the participants have presented and discussed recent progress and development regarding the models and systems used, as well as problems faced, related research activities and operational procedures implemented.

The MetNet cooperated closely with the EC 5FP project FUMAPEX: “Integrated Systems for Forecasting Urban Meteorology, Air Pollution and Population Exposure” (http://fumapex.dmi.dk), where 8 Nordic partners were involved. Extensions and further developments regarding the models and systems for urban emergency preparedness simulations and forecasting were actively discussed in such forum. As one example, a new experimental urbanised version of DMI-HIRLAM (U) with horizontal resolution 1.4x1.4 km was tested with the ARGOS system for the Copenhagen area and the Øresund region (Baklanov et al., 2006). This version can be used by other Nordic meteorological services with HIRLAM systems for the urban nuclear and other emergency preparedness (e.g. accidents, terror, etc.). This work in cooperation with the MetNet was presented on the NKS ‘Urban remediation’ workshop, Risø, September, 2003.

Other possible extension of the applicability of the operational real-time long-range dispersion models for probabilistic long-term (or ensemble) simulations for the nuclear risk assessments was also presented and discussed. Such methodology of the probabilistic risk assessments with long-term runs of the atmospheric transport models was developed in the NARP ‘Arctic Risk’ (AR-NARP, 2003; Baklanov et al., 2003, 2004) and further in the NKS NordRisk projects (Lauritzen et al., 2006) and a new project proposal ‘NordRisk: Nuclear risk from atmospheric dispersion in Northern Europe’ was initiated. This NordRisk project is supported by the NKS.

The MetNet Literature List, with publications closely related to the work within the group, is given in Appendix 2.

3.5 MetNet contacts outside the Nordic countries

During 2004, via contacts within ARGOS, a contact was established between NKS-MetNet and the Environmental Emergency Response Division, Meteorological Service of Canada represented by Mr Réal D'Amours, who expressed an interest to take part as observer within the NKS-MetNet group. This contact was beneficial also for the MetNet group in several ways. A co-operation should increase the modelling capability within MetNet, Canada and the Nordic countries share a geographical area of interest in the Arctic region, and also Canada, as well as three of the Nordic MetNet coutries, is using the ARGOS emergency system. After agreement from NKS Program Manager and NKS Sekretariat, Canada was welcomed as an observer. In 2006 Canada took part in the NKS-MetNet extra meeting in Ispra as well as in both the yearly exercises.

4 EXERCISES

MetNet has performed two emergency modelling exercises per year during the 4-year project period. About half of these exercises have been co-ordinated with major national or international exercises with participation by national radiation protection authorities within the Nordic countries (SSI in Sweden and STUK in Finland).

The numerical weather forecast and atmospheric emergency transport models applied at each participating institute are indicated in section 4.1 below. In this chapter also the main performed exercises within NKS-MetNet are presented and briefly evaluated. The exercises 4.2-4.7 refer to NPP (Nuclear Power Plant) emergency situations. These exercises were all preceded by pre-alert messages, which were sent out some few days ahead of each exercise. The intention with the pre-alert messages was to certify that all (or most all) countries had skilled persons available to take part. No information concerning the planned simulated accident was distributed before the alert message, which started the MetNet-exercise.

Within MetNet we have also tried to test our capability for real-time emergency modelling when large-scale non-nuclear threats to the European air quality have occurred in reality. Such examples are the volcano Grimsvötn eruption in Iceland, November 2004, and the big oil fire at Buncefield, outside London UK, December 2005. Both occasions were associated with very big emissions being of large interest for the Nordic and European society. These two real-time exercises, denoted 4.8 and 4.9 below, were especially demanding, with no pre-alert information at all, and with needs for performing changes of the dispersion models and the emergency systems in real-time. In such situations the support from a well established and in real-time functioning network is extremely valuable for an individual country or individual institute.

During all MetNet exercises Christer Persson, SMHI, initiated the alarms and – when co-ordinated with official Nordic radiation emergency exercises - acted as the contact point between MetNet and the responsible radiation protection authority. All alarms were sent out as email with double headlines “This is an exercise”.

All time-integrated concentrations should – in principle – be presented as (kBq*h/m^3) and depositions as (kBq/m^2) but in some cases presented below the legends are incomplete.

4.1 Models used by the participating meteorological institutes

DMI (Denmark):
Atmospheric transport model: DERMA, hybrid stochastic particle/puff model
Meteorological forecast model: Operational DMI-HIRLAM-S horizontal resolution 5×5 km, DMI-HIRLAM-T horizontal resolution 15×15 km, experimental urban version DMI-HIRLAM-U horizontal resolution 1.4×1.4 km (test version). IFS (global model of ECMWF) available at DMI for the northern hemisphere at about 100×100 km horizontal resolution.

FMI (Finland):
Atmospheric transport model: SILAM, Lagrangian particle model.
Meteorological forecast model: Operational FMI-HIRLAM, horizontal resolution 0.2x0.2 degree rotated lat/lon (larger area) or 0.1×0.1 (smaller area), test runs for 0.05×0.05 degree. Optionally (e.g. for longer forecasts) the ECMWF global model forecasts with horizontal resolution of 0.4×0.4 degree can be used.

IMO (Iceland):
Atmospheric transport model: The US-NOAA HYSPLIT model.
Meteorological forecast model: The US-NOAA GFS model, horizontal resolution 1×1 degree lat/lon (about 111×55 km within the Nordic area).

met.no (Norway):
Atmospheric transport model: SNAP, Particle model.
Meteorological forecast model: Operational HIRLAM at met.no, horizontal resolution 0.2x0.2 degree rotated lat/lon (22×22 km, larger area) or 0.1×0.1 (11×11 km, smaller area), test runs for 0.05×0.05 degree (5×5 km).

SMHI (Sweden):
Atmospheric transport model: MATCH-Reactor, designed as a Particle model for first 12h after emission, subsequently as an Eulerian model.
Meteorological forecast model: Operational SMHI-HIRLAM, horizontal resolution 0.2×0.2 degree rotated lat/lon (larger area) or 0.1×0.1 degree (smaller area). Test runs for 0.025×0.025 degree (2.5×2.5 km) based on ALADIN/AROME forecasts. MATCH is also possible to operate on deterministic ECMWF global forecasts, 0.5×0.5 degree lat/lon resolution, for selected sub-areas when needed for emergency preparedness. The prognostic area is then adapted to requirements.

For the MetNet exercises, performed within the present project, only the more large-scale operational models (but not ECMWF) have been applied.

4.2 Fictitious NPP in central Sweden

In order to have a complex atmospheric dispersion situation to study, an exercise was created with a fictitious NPP in central Sweden. At the time of the emergency alarm, the available weather forecasts indicated a complex wind field for the area of the NPP.

4.2.1 Emission scenario

Alarm issued by MetNet: 2003-10-07 08:10 UTC
Release Point: Östersund, Sweden
Coordinates: Longitude 14 deg 30 min E, Latitude: 63 deg 12 min N
Time and date for Start of Release: 08:00 UTC, Date: 2003-10-07
Release rate: 0.24E+12 Bq/s
Duration of Release: 2h
Height of the Emission: 20 m
Nature of Release: Spreading
Isotope released: Cs-137
Time Horizon of Forecast: 2003-10-09 00:00 UTC

4.2.2 Weather situation

At the time of the assumed start of release and during the following two days the horizontal wind field was very complex in the area around the selected point of emission. That can be seen from Figure 1, indicating low wind speeds and variable wind direction in the area. In such weather situations emergency transport model calculations can sometimes be quite uncertain and having access to a network of different models can be especially important in order to estimate the uncertainties.

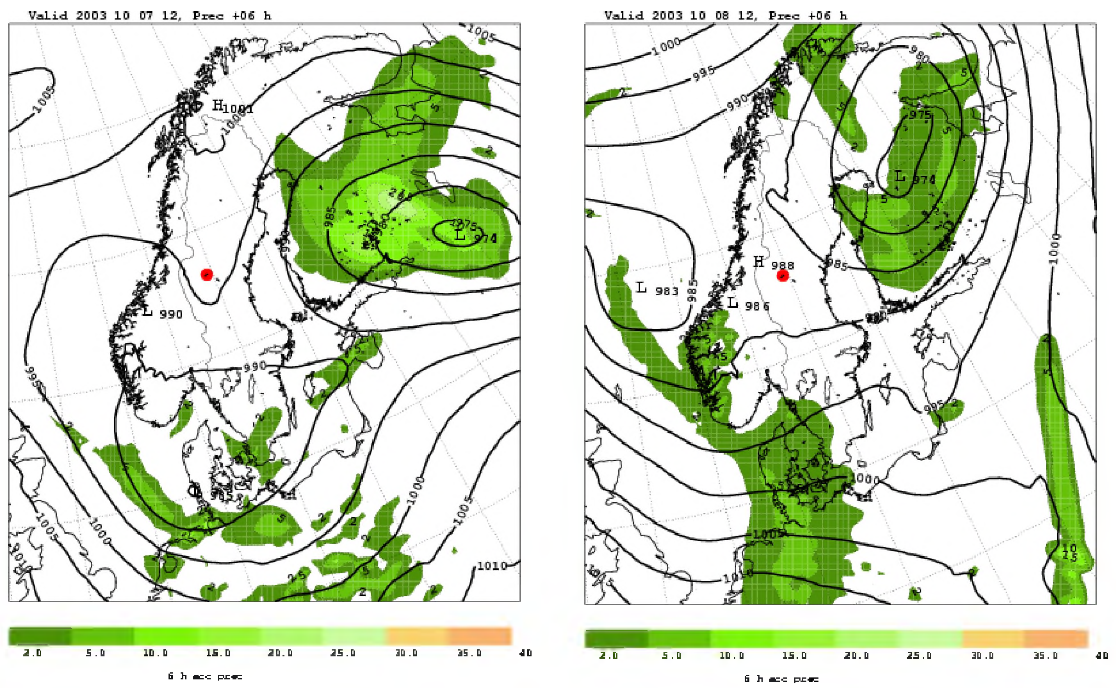


Figure 1. *Weather map, with a red dot denoting assumed point of emission, based on SMHI-HIRLAM showing pressure field at sea level and +6h forecast of accumulated precipitation. Left: Valid time 2003-10-07 12UTC; Right: Valid time 2003-10-08 12UTC.*

4.2.3 Model results

Despite the complex weather situation the dispersion model forecasts valid 2003-10-09 00:00 UTC agreed fairly well for the Danish, Finnish, Swedish and Norwegian calculations (no plots presented here). In the complex meteorological situation the assumed radioactive emissions were transported simultaneously both westward and eastward. According to the first model forecasts all three countries Norway, Sweden and Finland were influenced by radioactivity in air and deposition on ground within 40h from start of emission. The results from the Icelandic model indicated a much larger influence area compared to the other models, which was due to the much coarser horizontal grid used in that model.

4.3 Finnish NPP exercise Loviisa

The exercise was carried out jointly with a national nuclear emergency preparedness exercise in Finland, where NKS-MetNet contacts were obtained via STUK, Finland.

4.3.1 Emission scenario

Alarm issued by MetNet: 2003-11-25 08:45 UTC
Release Point: Loviisa NPP, Finland
Geographical Coordinates: Latitude 60° 28' N, longitude: 26° 14' E
Time and date for Start of Release: 08:30 UTC, Date: 2003-11-25
Release rate: 0.08×10^{12} Bq/s
Isotope released: Cs-137
Duration of Release: 6h
Height of the Emission: 20 m
Nature of Release: Leakage
Time Horizon of Forecast: 2003-11-27 00:00 UTC

4.3.2 Weather situation

Related with a low pressure system which passed north of Loviisa during the night between 24 and 25 November, the wind in the atmospheric boundary layer was initially from southwest over the release site with low to moderate wind speed (roughly the first six hours). Then the wind turned to south-east over Loviisa, while the wind remained from western directions a couple of hundred kilometres east of Loviisa. This development was due to a high-pressure ridge passing from south up over the release site, cf. Figure 2.

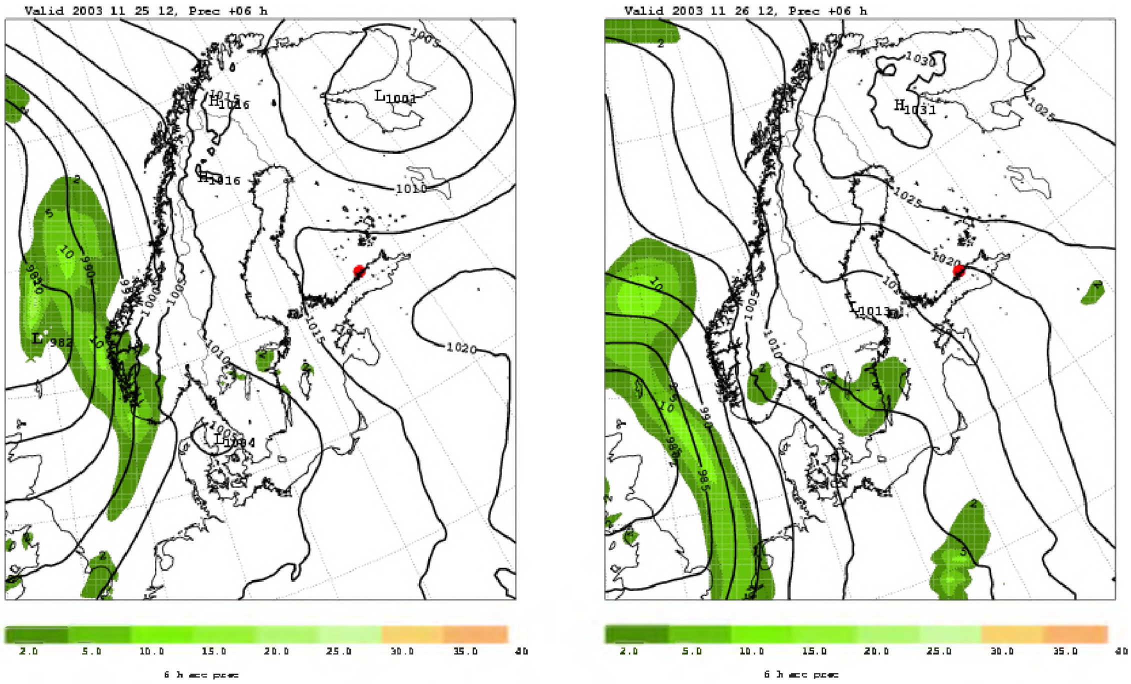
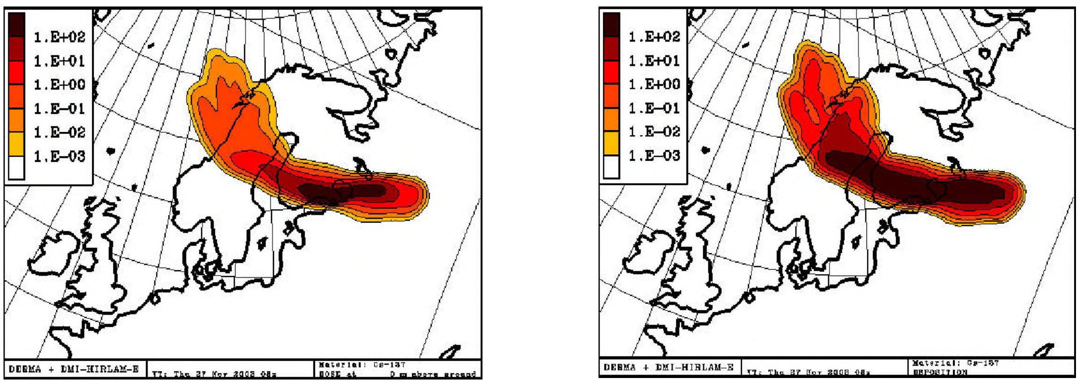


Figure 2. *Weather map, with a red dot denoting assumed point of emission, based on SMHI-HIRLAM showing pressure field at sea level and +6h forecast of accumulated precipitation. Left: Valid time 2003-11-25 12UTC; Right: Valid time 2003-11-26 12UTC.*

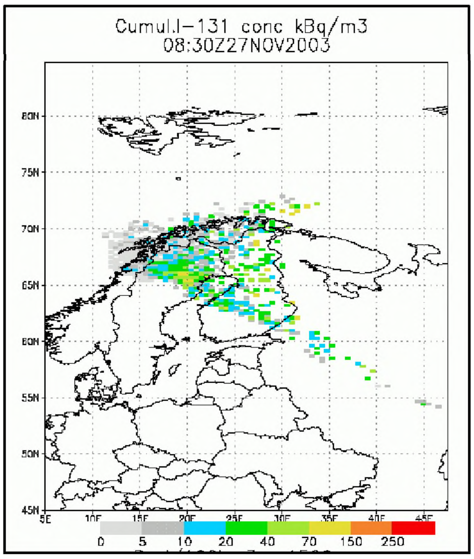
4.3.3 Model results

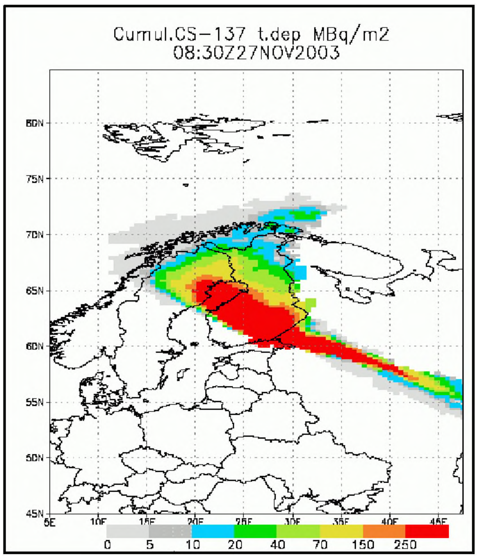
Below the results, which were presented in real-time during the exercise on the five different homepages, are shown. The results from DMI and FMI were available about 45 minutes after the alert alarm, the others somewhat later. It has to be noted that DMI and FMI presented results valid about 8 hours after the official exercise time window, thus including a somewhat further transport of the plume. It also has to be noted that SMHI used a smaller model area than the other institutes and did not describe the plume transport east of St Petersburg, Russia.

DMI (Denmark), Cs-137: Left) Time-integrated ground-level concentration; Right) Total accumulated deposition. Valid time 2003-11-27, 08 UTC.

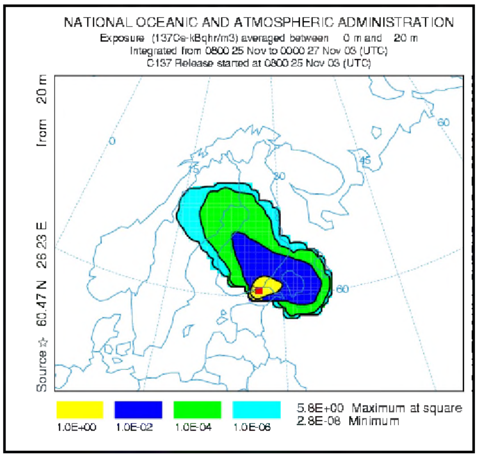


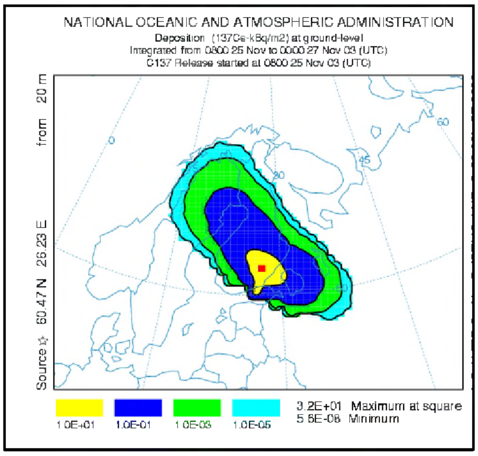
FMI (Finland), Cs-137: Left) Time-integrated ground-level concentration; Right) Total accumulated deposition. Valid time 2003-11-26, 08:30 UTC. By mistake FMI presented time-integrated concentration for I-131 instead of Cs-137.



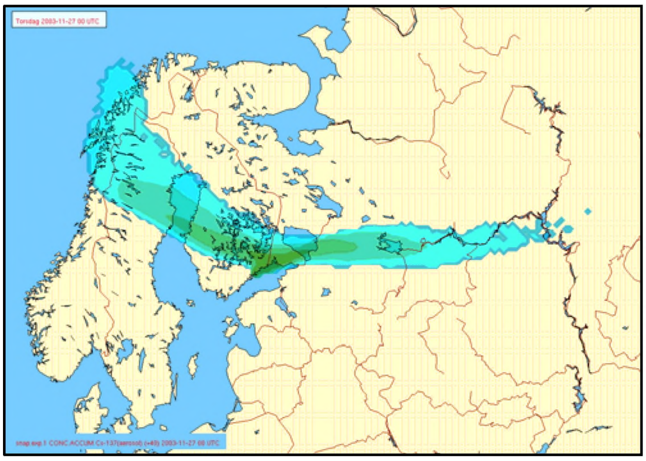


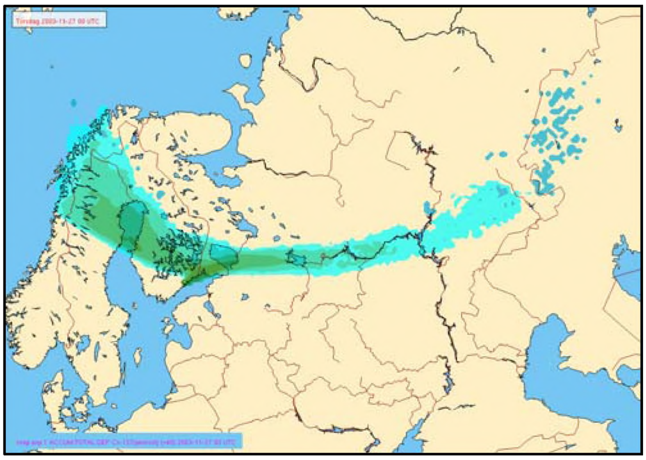
IMO (Iceland), Cs-137: Left) Time-integrated ground-level concentration; Right) Total accumulated deposition, valid time: 2003-11-27, 00 UTC.



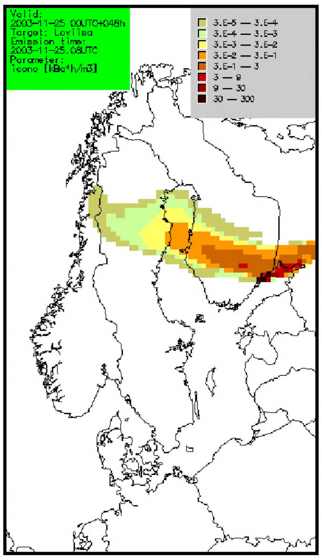


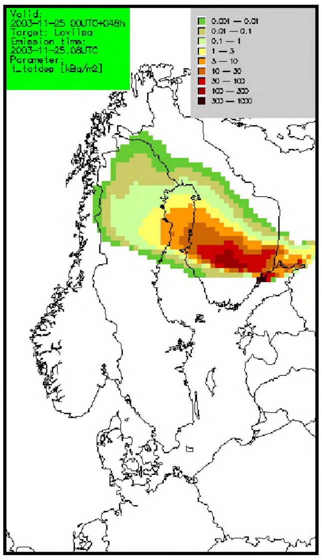
Met.no (Norway), Cs-137: Left) Time-integrated concentration: Right) Total accumulated deposition. Valid time 2003-11-27, 00 UTC. (Legend missing.)





SMHI (Sweden), Cs-137: Left) Time-integrated ground-level concentration; Right) Total accumulated deposition. Valid time 2003-11-27, 00 UTC.





The rather complex atmospheric transport situation implied that the radioactive plume initially was transported towards east. Then the western part of the plume was affected by the turning of the wind and thus started to move towards Sweden and, later experiencing a much increased wind from south-east, also reaching Norway. However, most of the transport across Norway happened after the official time window for the exercise (2003-11-27 00 UTC). Simultaneously the eastern-most part of the plume kept moving further east. Thereby the overall plume became stretched in the east-west direction. This was well described by all models, but with a poor geographical resolution in the IMO calculation (due to large grid-cells in the model). The model forecast calculations showed that three Nordic countries plus Russia would be influenced by the radioactive plume within about 40h. The probability for this conclusion is high, since all five models agree in this respect.

4.4 Swedish NPP exercise “Havsörn”

NKS-MetNet group was invited, via contacts with SSI, to run real-time dispersion model simulations in parallel with the yearly major Swedish nuclear emergency preparedness exercise ‘Havsörn’, September 2004. This exercise included all relevant Swedish organisations. The MetNet group was however ordered not to take contact with the active players in the exercise, since it was basically a national Swedish nuclear emergency preparedness exercise.

Well before the exercise started two of the MetNet partners (met.no and IMO) informed they would have problem meeting all exercise requirements, due to other obligations for the persons involved. Their model calculations were performed some days afterwards.

4.4.1 Emission scenario

The exercise was split up into three parts. First alarm issued by MetNet: 2004-09-08 12:03 UTC with the following content.

Part 1:
A major release is expected to take place within 12 hr. Please make a forecast.
Geographical Coordinates of the Release Point: Forsmark, Sweden

Longitude: 18 deg 10 min E, Latitude: 60 deg 24 min N
Time and date for Start of Release: 21:00 UTC, Date: 2004-09-08
Release rate: 1.0E+11 Bq/s
Isotope released: Cs-137
Duration of Release: 6 hr.
Height of Release: 100 m
Nature of Release: Spreading
Present model results valid for time: 2004-09-10 06:00 UTC
Part 2:
First alert message was followed by an updated message on September 9th 10:01 UTC giving the exact start and stop time for the release but with no other new information compared to the earlier message.
Part 3:
On September 10th 12:50 UTC a message was sent out where the MetNet participants were asked to perform same model simulations as the day before but based on latest available meteorological data (in order to study the effect of uncertainties in forecast weather data compared to using weather analyses).

4.4.2 Weather situation

A high pressure system dominated the weather over southern Scandinavia with N to NW winds over the NPP when the emissions were simulated to take part, cf. Figure 3.

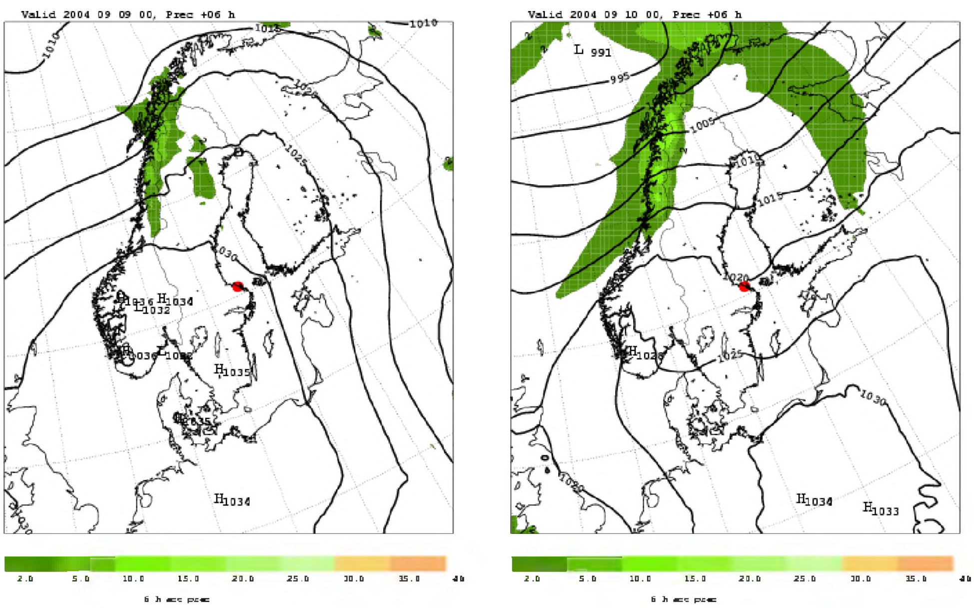


Figure 3. *Weather map, with a red dot denoting assumed point of emission, based on SMHI-HIRLAM showing pressure field at sea level and +6h forecast of accumulated precipitation. Left) Valid time 2004-09-09 00UTC; Right) Valid time 2004-09-10 00UTC.*

4.4.3 Model results

Only three countries took part in real-time (Norway and Iceland not present) and initial problems with model code delayed the Swedish results 4.5 hours. Thus, only results from two models were available during the first five hours. Such a situation can happen also in real emergency situations and shows the importance of an active network giving a back-up facility. The weather situation was relatively simple from dispersion modelling point of view, and when all five model results were available it was obvious that all models agreed quite well. In Figure 4 some examples of results are given.

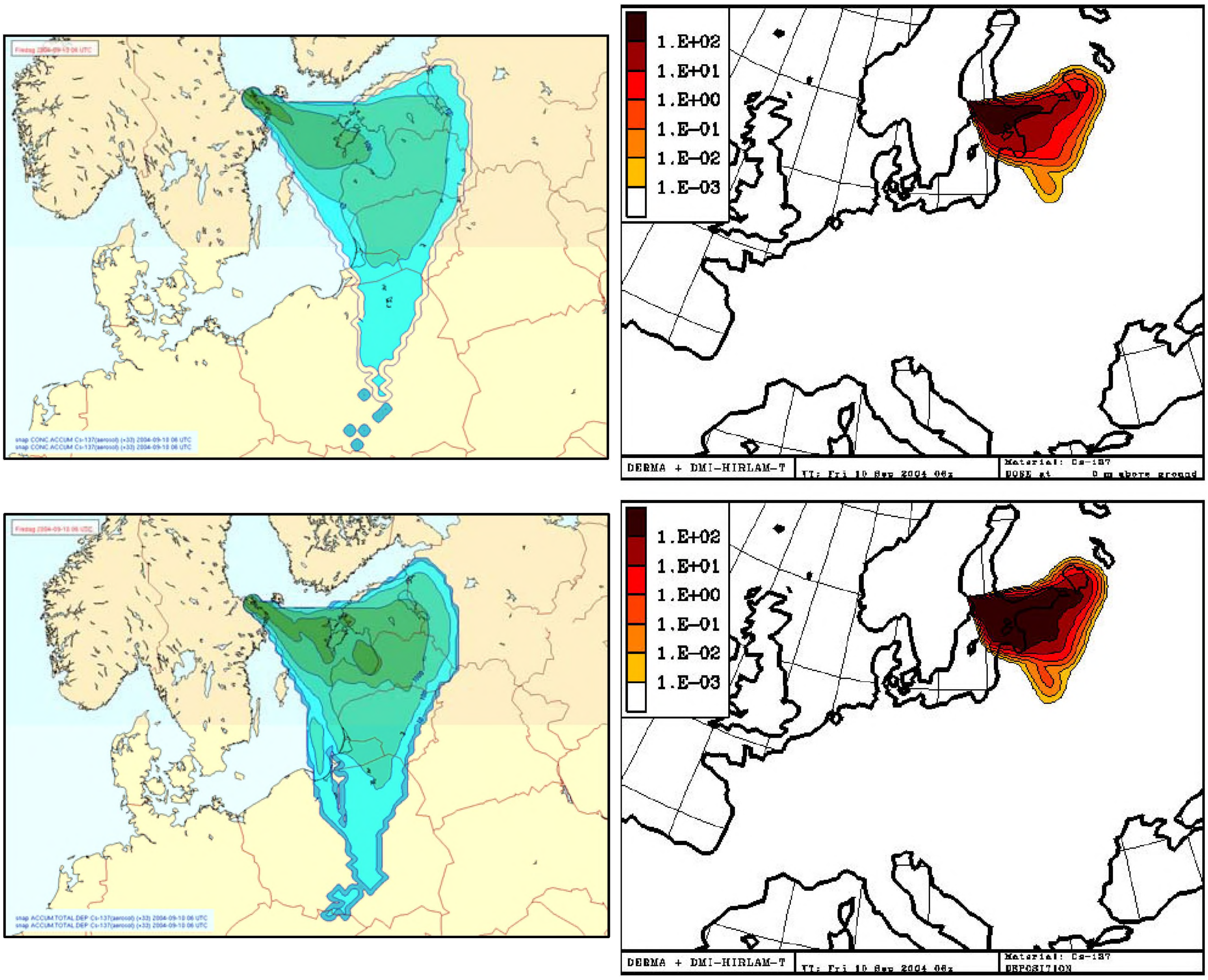


Figure 4. *Upper row: Time integrated concentrations (kBq h m^{-3}) and Lower row: Total (wet+dry) accumulated deposition (k Bq m^{-2}). All maps are valid 33 hours after start of release (2004-09-10 06:00 UTC). Left column: results from Met.no; Right column: results from DMI.*

4.5 The international NPP exercise "KOLA"

This exercise was performed in co-operation between Swedish, Norwegian, Finnish and Russian radiation protection authorities. Also international observers from countries outside the Nordic area took part. The MetNet exercise was co-ordinated with "KOLA" only through contacts with SSI. During this exercise SSI utilized information from the ordinary emergency preparedness system at SMHI, information from MetNet and for the first time for SSI also the ARGOS system. Representatives from MetNet took part in a real-time video conference with radiation protection experts included in the Kola exercise.

4.5.1 Emission scenario

Name: KOLA, Russia, alarm issued 2004-09-06, 07:43 UTC
Geographical Coordinates of the Release Point: Lon 32 deg 28 min E, Lat: 67 deg 28 min N
Date and time for Start of Release: 2005-09-06, 00:00 UTC

Release rate: 1.0E+11 Bq/s
Duration of Release: 6h
Height of Release: 100 m
Nature of Release: Spreading
Isotope released: Cs-137
Valid Time of forecast: 2004-09-08 00:00 UTC

A second alarm was sent out, when more information was available, with a somewhat later time of emission.

4.5.2 Weather situation

The weather around the point of emission was determined by a low pressure situated NW of the Kola NPP. Winds around SW dominated during the whole exercise.

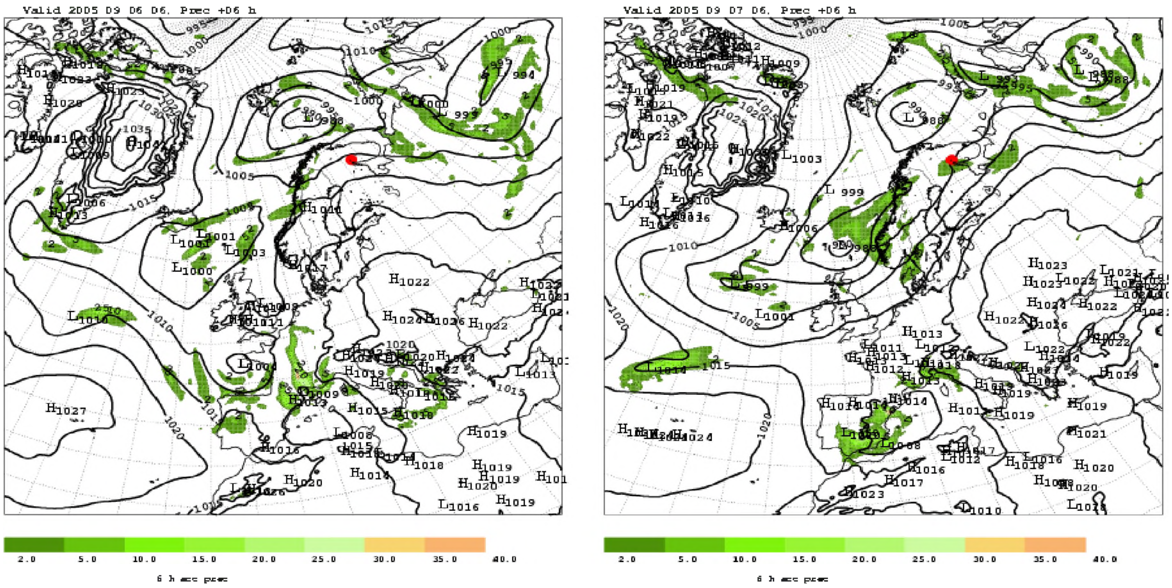


Figure 5. *Weather map, with a red dot denoting assumed point of emission, based on SMHI-HIRLAM showing pressure field at sea level and +6h forecast of accumulated precipitation. Left) Valid time 2005-09-06 06UTC; Right) Valid time 2005-09-07 06UTC.*

4.5.3 Model results

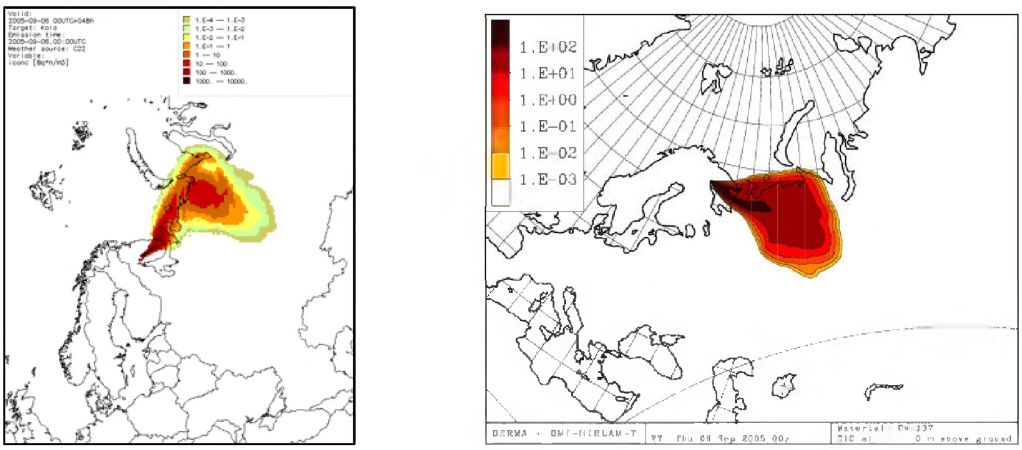


Figure 6. *Forecasts for integrated concentration, valid time 2005-09-08, 00:00 (+42h from start of emission). Left) SMHI, Sweden; Right) DMI, Denmark.*

4.6 Swedish NPP exercise ”Falken”

A MetNet exercise was at an early planning stage, through contacts with SSI, decided to be co-ordinated with the yearly major Swedish exercise “Falken”, including all relevant Swedish organisations. Information from “Falken” was also decided to be distributed as ECURIE level 3 messages and sent out to all EU-countries.

At a late stage it was decided within the EC-ENSEMBLE project, with participants from many European countries, to use these ECURIE level 3 messages for a separate ENSEMBLE exercise. Since four of the five participating Nordic countries in MetNet also are participants in ENSEMBLE, it was decided to utilize this opportunity to add some additional MetNet-related results into ENSEMBLE and use the ENSEMBLE software for presentations. An agreement on this was made between ENSEMBLE and NKS-MetNet. In section 4.7, below, this is illustrated.

Canada has during 2005-2006 been acting as an observer of the NKS-MetNet group but without any active participating in exercises during 2005. At an extra NKS-MetNet meeting in Ispra in May 2006, where also Canada was represented, it was decided that Canada should take part in the 2006 NKS-MetNet exercises, thus the exercises 4.6 and 4.7 in this report. Canada should only distribute model results through email in real time, and not establish any homepage for MetNet.

4.6.1 Emission scenario

Name: “Exercise connected to FALKEN 2006,
Case 1” issued 2006-10-04 07:07UTC
Location: Ringhals, Sweden
Coordinates of the Release Point: Longitude 12 deg 07 min E   Latitude: 57 deg 15 min N
Date and time for Start of Release: 2006-10-04, 07:00 UTC
Duration of Release: 5h
Height of Release: 140 m
Nature of Release: Leakage
Valid Time of forecast: 2006-10-05, 12:00 UTC
#
Nuclide 1: Cs-137
Release rate: 1.0E+16 Bq/h
#
Nuclide 2: Xe-133
Release rate: 4.0E+16 Bq/h
#

Case 2 issued 2006-10-04 12:17 UTC
Same as case 1 but with start of emission at 09.00 UTC, duration of release 6h and valid time of forecast 2006-10-06 06:00 UTC.

4.6.2 Weather situation

The wind conditions in the region around the NPP were very variable during the night before the assumed emission took place, due to the passage of a minor low pressure centre. Easterly winds were in the morning replaced by south-westerly and later by a stronger westerly wind.

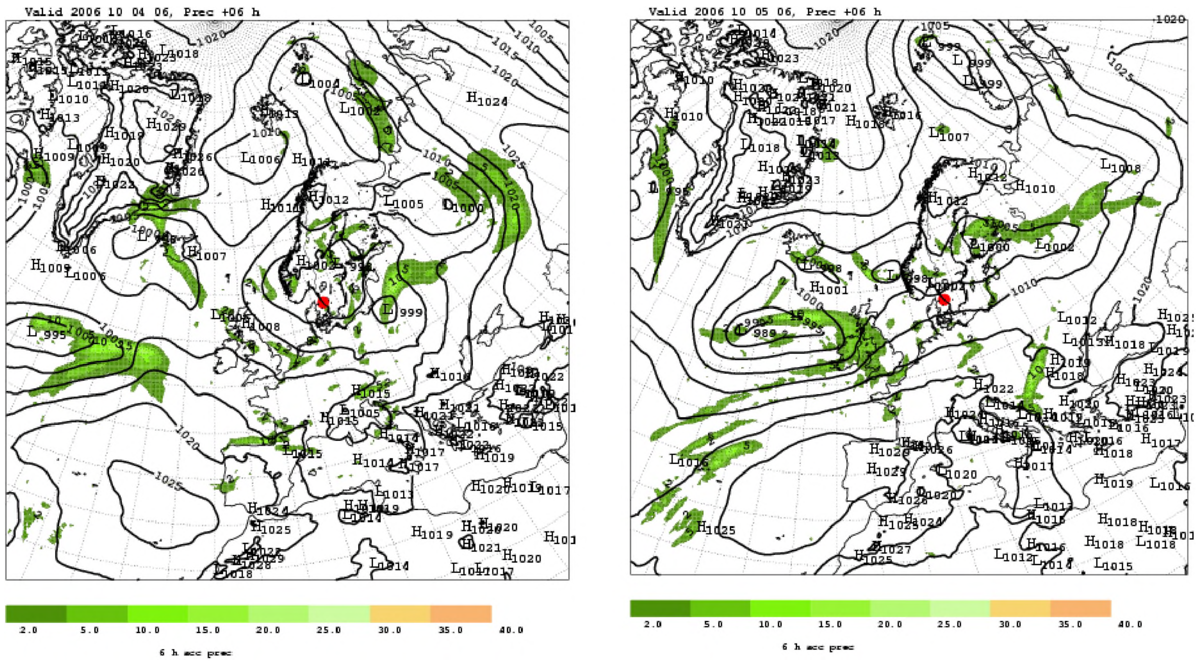


***Figure 7.** Weather map, with a red dot denoting assumed point of emission, based on SMHI-HIRLAM showing pressure field at sea level and +6h forecast of accumulated precipitation. Left) Valid time 2006-10-04 06UTC; Right) Valid time 2006-10-05 06UTC.*

4.6.3 Model results

Norway did not take part in the exercise due to that the modeller in duty was ill.

When the first assumed emission from the NPP started, the wind direction in the local area around the NPP had just turned from about east to west and the wind speed gradually increased. The weather situation later on developed to become relatively easy from dispersion modelling point of view and, according to Figure 8 below, all models gave quite similar results.

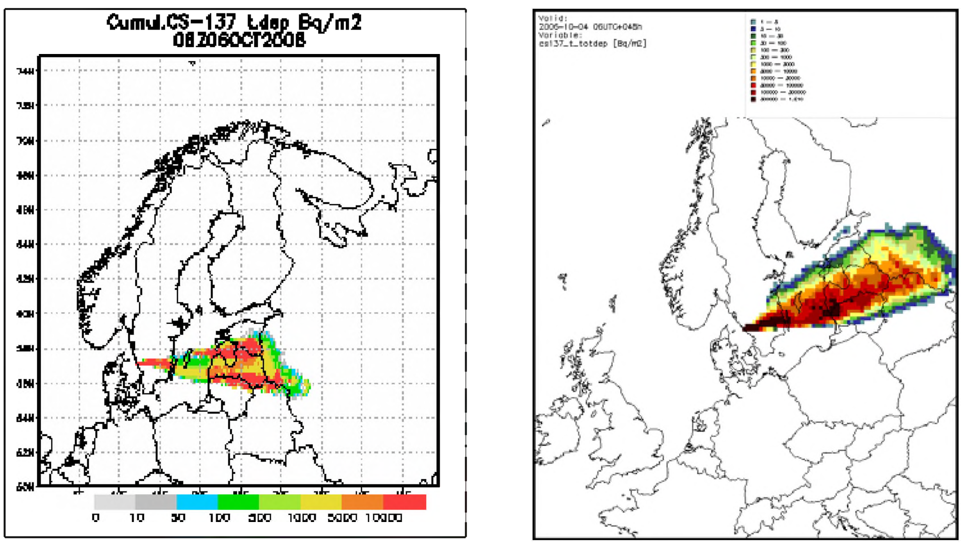


***Figure 8a.** Results from case 2. Accumulated dry+wet deposition of Cs-137 at 2006-10-06 06UTC, as presented in real-time on the MetNet homepages. Dispersion model forecasts from: Upper left) Finland; Upper right) Sweden.*

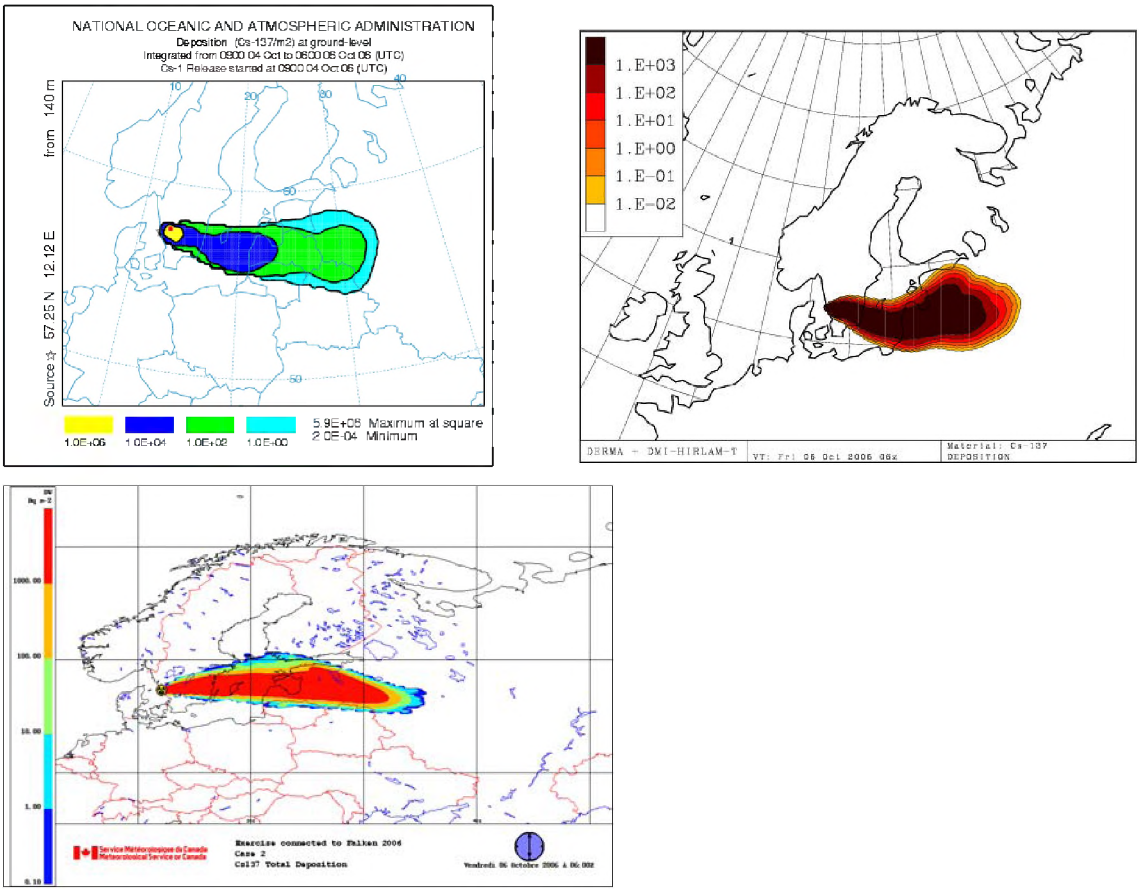


Figure 8b. *Results from case 2. Accumulated dry+wet deposition of Cs-137 at 2006-10-06 06UTC, as presented in real-time on the MetNet homepages. Dispersion model forecasts from: Upper left) Iceland; Upper right) Denmark; Lower left) Canada.*

4.7 MetNet NPP exercise based on ENSEMBLE software

4.7.1 Emission scenario

Case 1, issued 2006-10-04 07.22 UTC by the ENSEMBLE project leader
Location: Ringhals, Sweden
Coordinates of the Release Point: Longitude 12.11 degree E, Latitude: 57.25 degree N
Date and time for Start of Release: 2006-10-04, 04:00 UTC
Duration of Release: 6h
Height of Release: 100 m
Nature of Release: Unknown
Time horizon of forecast: 2006-10-05, 12:00 UTC
#
Nuclide 1: I-131
Release rate: 1.5E+15 Bq/h

It should be noted that the emission scenario within the ENSEMBLE exercise differs somewhat from the pure MetNet exercise (see 4.6.1).

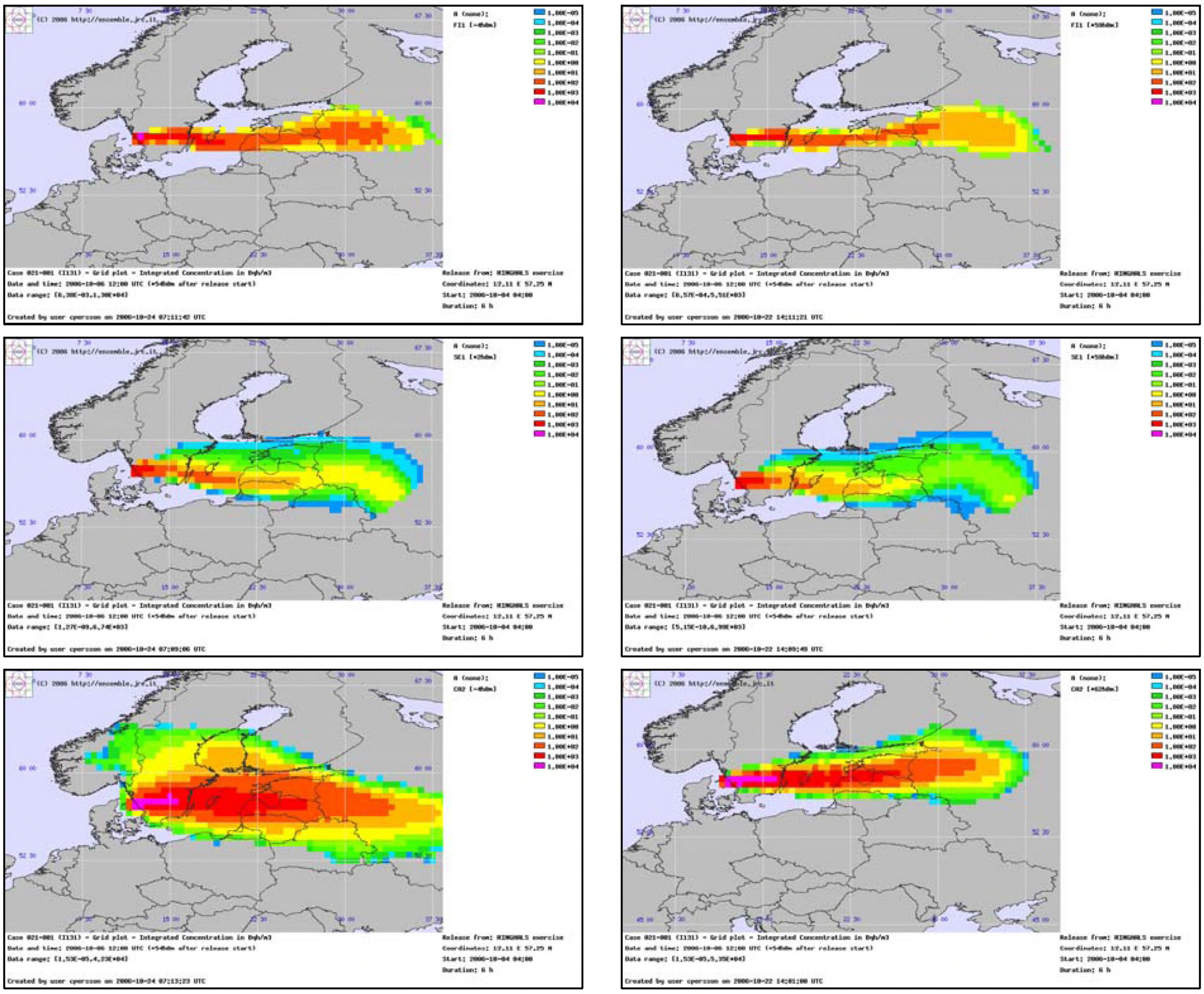
4.7.2 Weather situation

Same as for the above presented "Falken", see 4.6.2.

4.7.3 Model results

Atmospheric transport model results based on +60h weather forecasts, produced short after the first alarm, and model results based on weather analyses obtained two and half days afterwards are presented in Figure 9.

Forecast +60h **Analysis**



Not available

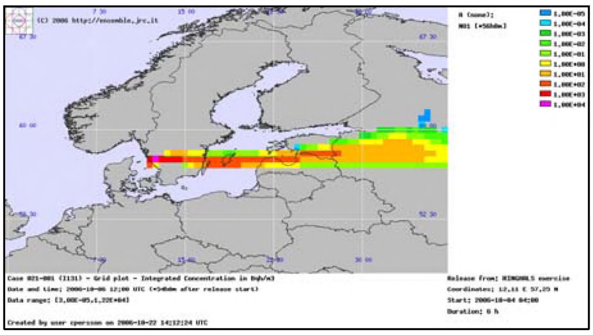


Figure 9. *Results for case 1, time integrated concentration of I-131 in ground level air valid 2006-10-06 12UTC (56h after release start). Maps in the left column refer to results based on +60h weather forecasts, and maps in the right column refer to results for the same time but based on weather analyses. Upper row) Finland; Second row) Sweden; Third row) Canada; Fourth row) Norway. Norway did not perform forecast calculations.*

There is quite a good agreement between the different models and also between results based on 60h weather forecasts and results based on weather observations. The plume during the whole studied period was simulated to move eastward in a rather strong westerly wind. However, the forecast from the Canadian atmospheric transport model, which is based on a global weather forecast model, is probably influenced by the low pressure passing in the area of the NPP just before the simulated emission started. The Canadian +60h model forecast indicates a partial transport also towards northwest and Norway. That is however not present in the Canadian calculations based on weather analysis, where all models agree fairly well.

The ENSEMBLE software has also been used to illustrate the uncertainty of +60h forecast results as well as results based on meteorological analyses obtained 2.5 days later. In Figure 10 probability maps referring to time integrated air concentrations above a given threshold, based on four different models (Finland, Sweden, Norway and Canada), are presented. Yellow indicates one model above threshold, and purple indicates all four models above threshold. Since no forecast was available from Norway we included two models from Finland in the probability forecast map in order to have same number of models in both cases.

Such a probability map can be easily produced, as soon as the model results have been up-loaded in the ENSEMBLE system, and can be valuable for judging the uncertainty of model results.

Forecast **Analysis**

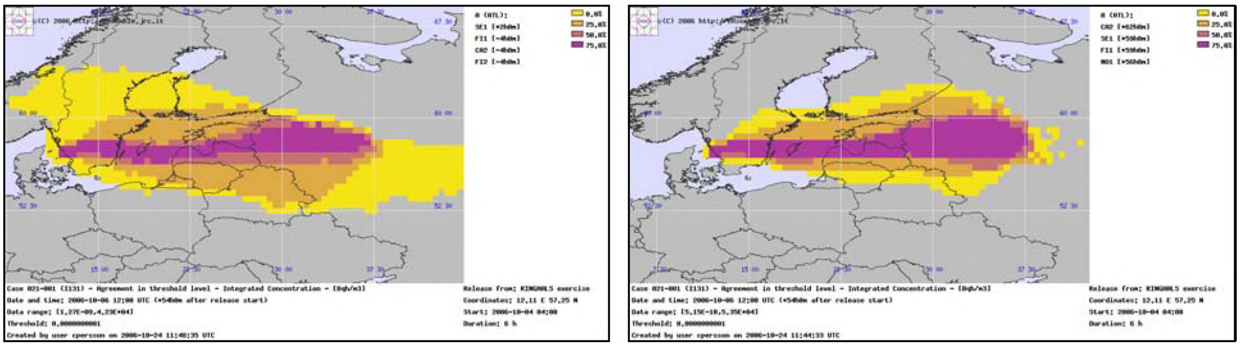


Figure 10. *Probability maps, based on four different model results, for time integrated air concentrations above a given threshold. Yellow indicates one model above threshold, and purple indicates all four models above threshold. Left map refer to +60h forecasts and right map to model calculations based on meteorological analyses made afterwards.*

Figure 11 shows the use of another tool in the ENSEMBLE software. Comparisons between pairs of models are performed on a grid to grid basis. From the left scatter plot it is shown that the Swedish and Canadian models agree fairly well concerning total deposition of I-131 except for grids with the very largest deposition values. Those grids are obviously influenced by substantial wet deposition, for which the Swedish model gives quite large values. From other investigations it is plausible to assume that the Swedish model somewhat overestimate the wet scavenging of I-131 in this study.

From the right hand scatter plot in Figure 11 it is shown that the Norwegian and Finnish models agree very well for larger values of integrated concentration. For lower values the Finnish model has a “cut-off” which is about two orders of magnitude larger than for the Norwegian model.

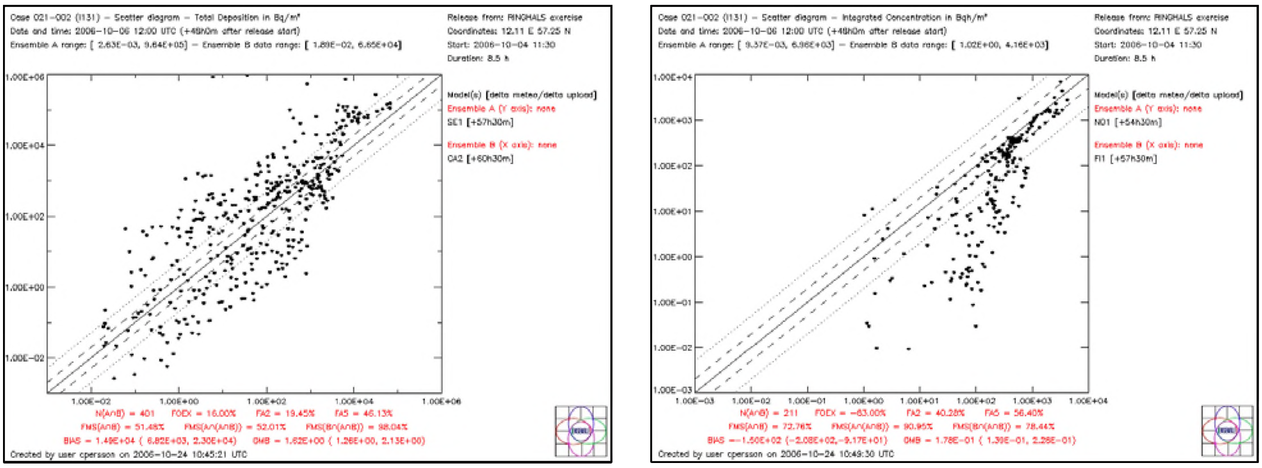


Figure 11. *Scatter plots comparing: Left) Accumulated deposition for Swedish and Canadian models; Right) Integrated air concentration for Norwegian and Finnish models. All compared values refer to 48h after release.*

The tools illustrated in Figure 10 and 11 can be of great value for e.g. probability studies and deeper investigations of observed differences between models.

4.8 Volcano in Iceland

4.8.1 Emission scenario

A volcanic eruption occurred in Iceland the first week of November 2004. The eruption in Grímsvötn, located in the western side of the Vatnajökull glacier started in the evening the 1st of November and was declared finished the 7th.

The eruption started approximately at 20:00 UTC November 1st. At 23:05 UTC the plume had melted through the icecap and was detected by the C-band weather-radar located on the southwest cost of Iceland. From that moment until 08:30 UTC November 3rd the volcano was most active, and after that ceased dramatically. In the afternoon the 4th no ash was observed from the volcano and the eruption was declared finished on November 7th.

Volcanic ash is a serious threat to land stock and to aviation both on land and in air. The size of ash particles can be from few µm up to several meters in size. The smallest particles can travel thousands of km from its origin within short timeframe depending on the wind speed and direction, and those particles are the most dangerous for aviation. Therefore it is very important to calculate the spread of ash in the atmosphere to prevent accidents and great damage.

The MetNet alarm was issued 2004-11-02 14.34 UTC. No specific emission rate or particle spectrum was given. The participants were asked to present influence areas for the volcanic ash cloud assuming the volcanic emission to be continuous and starting 2004-11-01 at 23UTC.

4.8.2 Volcanic threat to aviation – general information

Volcanic ash, composed by mineral rocks and sharp glass fragments may cause serious damages to airplanes, as abrasion, erosive of the exterior, accumulation of ash into surface openings, and power loss of the engines. Even though the threat has always been there, ever since the starting days of airplanes in 1903, it was not recognized as such until late 1970s, when wide-body jet aircrafts became more common. This is mainly because the melting point of ash lies within the operating temperature of the engines, which may result in complete engine stop. No onboard equipment can identify ash clouds, per today. During the last two decades more than 100 jet aircrafts flew into drifting ash clouds, and several of those incidence resulted in loss of power on all engines followed by a free drop of several thousands of feet before regaining power. Happily no loss of life occurred, however the damage cost was enormous. In addition to the hazard to aviation in-flight, there is also on-ground hazard to airplanes as mentioned above. Fine ash on runways can easily penetrate into engines of the aircrafts, and wet ash disturbs the braking and turning performances of aircrafts, as slippery ash reduces the coefficient of friction between tires and the runway surface. From 1980 to 1998 35 airports in 11 countries had to close down or reduced their activity, due to ash fall. This results in loss of income for the airports and the aviation administration.

In the beginning of the 1990s nine Volcanic Ash Advisory Centres (VAACs) where established around the world. Their responsibility is to locate (position and height) volcanic ash clouds and forecast the atmospheric transport and dispersion of the clouds in their respective areas. For this purpose trajectory- and dispersal models are used. Ash clouds can be identified from satellite images, and in addition information from weather radars is valuable.

Monitoring volcanoes is essential, as was clearly shown in the year 2000 Hekla eruption. The eruption was predicted quit accurately, and approximately 30 minutes prior the eruption start it was announced to the meteorologist, aviation administration, national civil defence and the radio. This made it possible to calculate trajectories, give out warnings and reroute the airplanes in danger, in addition to a general warning to the public.

Future predictions indicate increasing air traffic in the coming years, which will lead to an increasing threat from volcanic eruptions. To minimize the hazard and the damage to airplanes a very good communication between the volcano-, meteorological-, aviation- and pilot communities is needed.

Volcanic eruptions in Iceland are rather frequent, they occur on average every four to five years. According to volcanologists at the University of Iceland the Grímsvötn volcano is entering an active era with expected eruptions every two to seven years. Fortunately trajectories and dispersion models used in e.g. the MetNet project can be used to calculate the spread of volcanic ash. Poor man’s ensemble, which is gained from the MetNet network, will not only result in better advisory from the VAAC´s centers (distributed to the meteorological offices and aviation authorities) but also an input into the local meteorological offices for better preparedness during such event.

4.8.3 Weather situation

The meteorological situation during the most active phase of the Grímsvötn eruption was as follows:

On November 1st a low was moving towards west of Iceland from the south, and a high pressure system was over the British Isles moving towards southern Scandinavia. On November 2nd, 00 UTC, the low was west of Iceland, which led to strong southerly to south-south-westerly winds over Iceland, especially over the eastern part where Grímsvötn is located. The low was stationary west of Iceland until the 3rd, and measurements from rawinsondes show that the winds, from the surface up to approximately 15 km height, were southerly to south-south-westerly during that period. The wind speed was between 15 to 40 m/s, with the strongest winds at 5 to 10 km height (upper troposphere). Hence, the plume moved towards north and northeast.

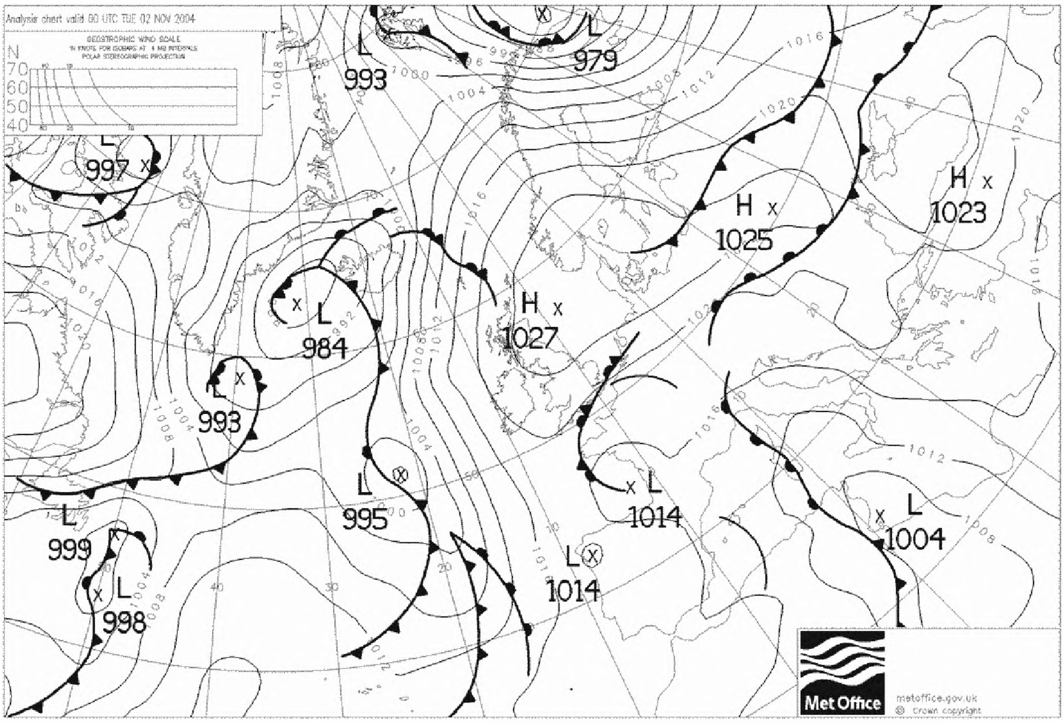


Figure 12. *Weather analyses chart valid 00 UTC November 2nd 2004 covering North Atlantic and Europe. From UK Met Office.*

4.8.4 Model results

Prior and during a volcanic eruption in Iceland a certain working procedure takes place between the Icelandic Meteorological Office, Icelandic Aviation Authorities and the Volcanic Ash Advisory Center in London (located at the UK met. office). In addition there is a good collaboration with Toulouse VAAC (located at Meteo France) as it is very likely that the ash plume will reach their area of responsibility which covers Scandinavia, Europe and Africa.

During the Grímsvötn eruption the other Scandinavian meteorological institutes participating in MetNet calculated the spread of the plume, which moved towards Northern Scandinavia (Figure 13). Similar results, with the ash plume affecting the Northeast Atlantic and Northern Scandinavia area, were gained from all models. At SMHI, as an experiment, the MATCH-Bomb model (nuclear 10 ktonnes bomb, Persson et al. 1997) was run in addition to the ordinary MATCH-Reactor model, since the volcanic emission scenario has similarities to a 10 ktonnes nuclear bomb. However, in the real-time situation it was not possible to apply the Bomb-model for a continuous emission as given in the alarm message.

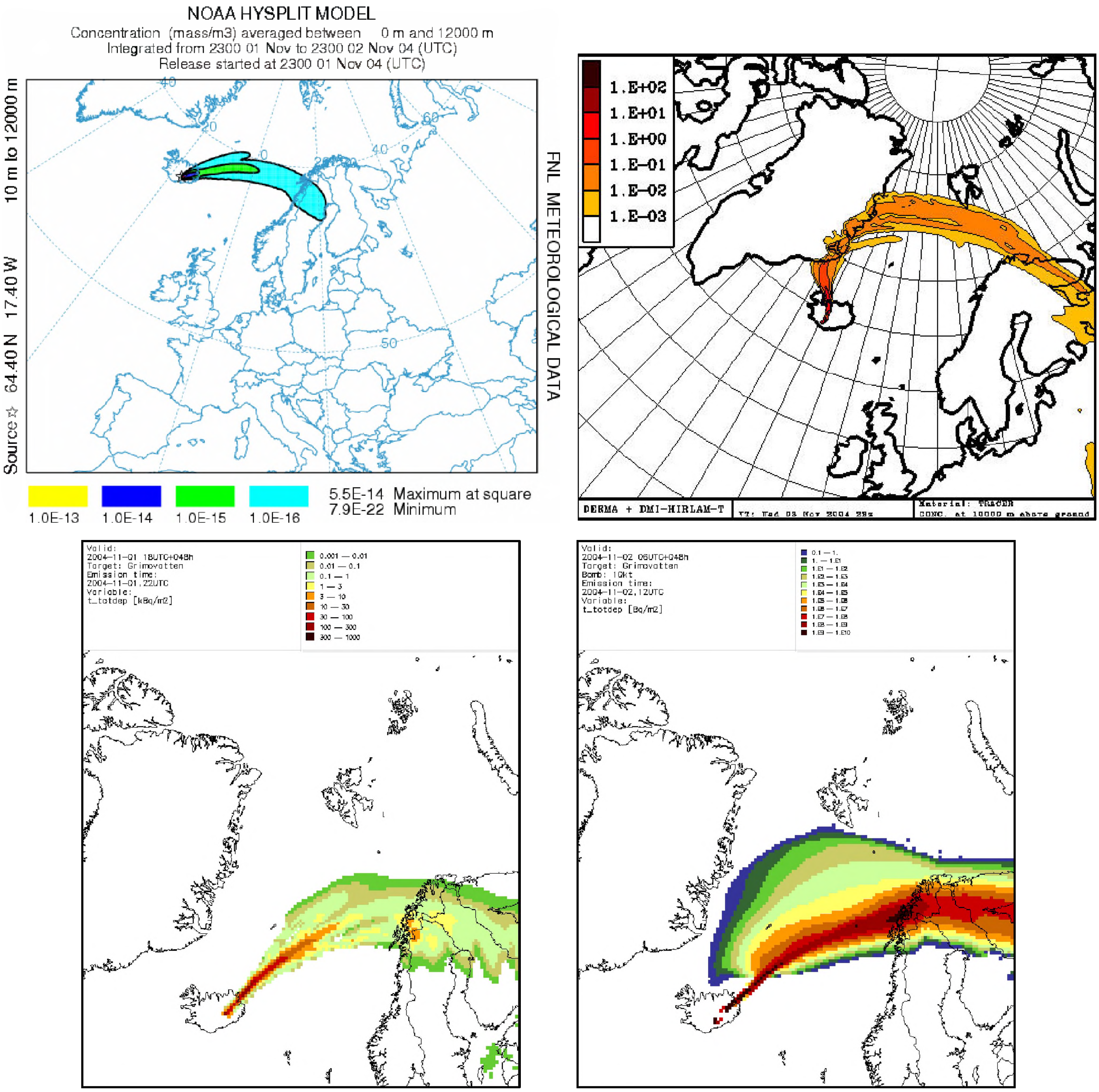


Figure 13*. Real-time forecasts of ash distribution from the volcanic eruption at Grímsvötn, Iceland, November 2004. Upper left: Integrated air concentrations from 2004-11-01 23UTC to 2004-11-02 23UTC as an average from ground up to 12000 m height (IMO); Upper right: Instantaneous concentration at 10 000 m height at 2004-11-03 22UTC (DMI); Lower left: Accumulated deposition (wet+dry) at 2004-11-03 18UTC based on the MATCH-Reactor model (SMHI); Lower right: Accumulated deposition (wet+dry) at 2004-11-04 06UTC based on the MATCH-Bomb model and with an assumed explosion time at 2004-11-02 12UTC (SMHI). – All results are given in relative units. Please observe that the maps are not fully comparable.*

4.9 The Buncefield oil fire

On Sunday 11 December 2005 a major explosion occurred in the Buncefield oil depot on the edge of town Hemel Hempstead located approximately 30 km northwest of central London. The accident happened around 06:00 UTC with the fires ignited by the blast continuing to burn for several days. The fire was finally extinguished on Wednesday – four days after the start. The incident became the largest industrial blaze to date. The fire produced a plume containing a large quantity of soot (black carbon). The fire was a large scale incident with potential impacts on health and on the environment both locally and at the European scale (Jones at al. 2006). The pictures of the fire in the early stage are shown in Figure 14.

Figure 14. *These images were taken on the morning of the explosion, early after the first explosion. They look fairly dark and dawn was beginning to show about an hour after the blast. Source: http://www.buncefield-oil-fire-hemel-hempstead.wingedfeet.co.uk/*

4.9.1 Emission scenario

The following emission scenario was used for all MetNet models taking part in the simulation of this event:

MetNet alarm issued 2005-12-12 12.04 UTC

Source location:	"London" (Lon 0 deg 28 min 26 s W, Lat 51 deg 45 min 14 s N)
Date and time of release:	2005-12-11 06:00 UTC
Source term rate:	$1.0\times10^{+11}$ Bq/s
Duration of release:	48h
Height of release:	300m
Substance:	Cesium-137

In this simulation Cesium-137 was used as an indicator for the released material soot, since the emergency models were not prepared for simulation of black carbon, which was the actual released during the accident. Thus, only an approximate simulation of the physical behaviour of black carbon in the atmosphere was done. This indicates, that in future also soot and perhaps other contaminants should be taken into account in the MetNet models, in addition to radio nuclides.

4.9.2 Weather situation

During the accident, the lower atmosphere was stable with not much of vertical mixing. There was a significant vertical wind shear with north-westerly wind at the low level and north-easterly winds at the higher levels. Because of the extremely powerful buoyancy and light winds, the plume penetrated the boundary layer top rising to approximately 3000 m. (This was however not known when the MetNet alarm was formulated, indicating a plume rise of only 300m). The stable stratification acted as a trap for the plume prevented it from returning closer to the surface (Webster et al., 2006 and Jones, 2006). Two pictures of the plume in relatively early phase are shown in Figure 15. The satellite picture of the plum taken approximately 24 hours after a fire start is shown in Figure 16.

Figure 15. *Pictures of the plume taken in the early phase of the accident. Source: http://www.buncefield-oil-fire-hemel-hempstead.wingedfeet.co.uk/*

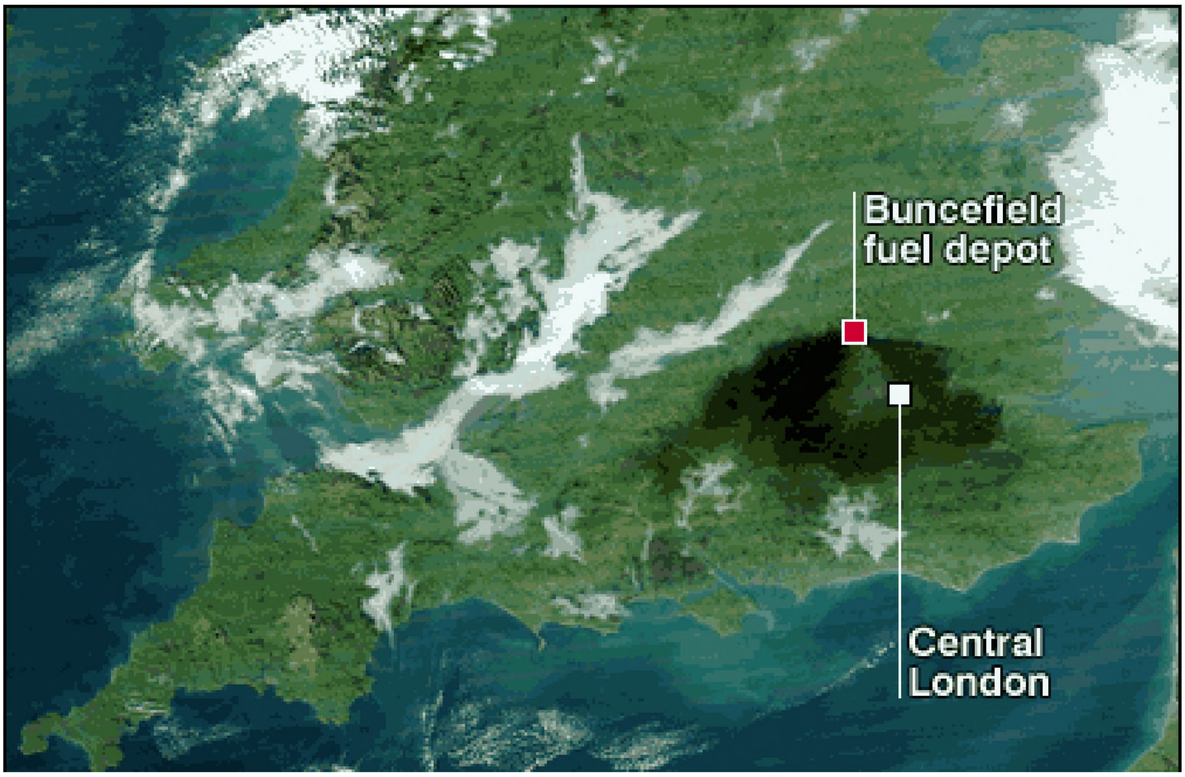


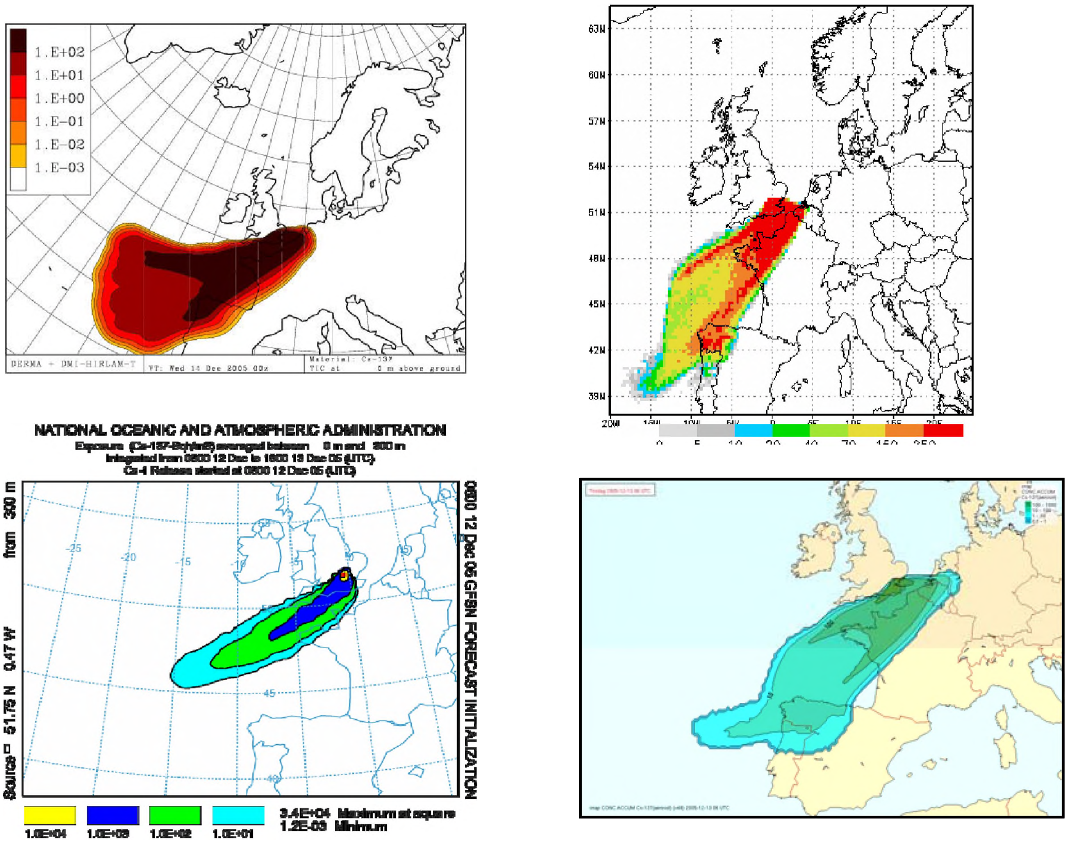
Figure 16. *Satellite image of the plume taken approximately 24 hours after the first explosion. Source: http://www.buncefield-oil-fire-hemel-hempstead.wingedfeet.co.uk/*

The wind shear is well illustrated in Figure 16 by presence of two plumes, the lower one heading south-east and upper one heading south west.

4.9.3 Model results

Examples of forecast results from the MetNet models are presented in Figure 17, where time integrated concentrations valid 42 hours after start of emission are shown. Since the actual soot emissions and observed plume rise were not included in the calculations, here Cs-137 is only used as an indicator, the presented maps can be used only for estimating the meso- and large scale influence areas. No comparisons can be made to observed air concentrations.

Despite the limits of the model design with respect to large oil fires the forecast fields of time integrated concentrations, which are similar for all MetNet models, reflect well the plume behaviour illustrated by the satellite image presented in Figure 16. The lower part of the release was transported towards the south-east and the upper part towards the south-west and further away because of the stronger winds at higher levels.



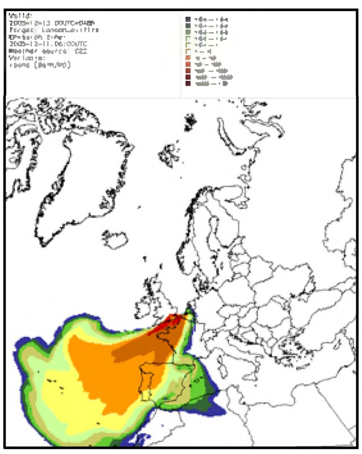


Figure 17. Forecast time integrated concentration calculated by MetNet models valid 42 hours after start of emission. Upper left) DMI; Upper right) FMI; Middle left) IMO; Middle right) Met.no; Lower left) SMHI.

5 FUTURE USE OF THE NORDIC METNET NETWORK

Among the Nordic Meteorological Institutes there is a need for a further developed emergency preparedness concerning many types of hazardous emissions to the atmosphere and for applications from local to continental scales.

5.1 Benefits for NORDMET

In 2006 a proposal for continuity of the MetNet project under the NORDMET umbrella, was presented for the NORDMET council. The NORDMET umbrella is a co-operation within many fields between the Nordic Meteorological Institutes. The project was accepted and MetNet will therefore continue to develop in the coming future.

The NORDMET council sees the continuity of the MetNet project as very positive as the development of a real-time preparedness including atmospheric transport models, systems for producing probability or ensemble forecasts, software for presentations of results and real-time back-up facilities is both very time consuming and costly. It is therefore of great value that an operational Nordic network among the meteorological services can be established for a close co-operation concerning atmospheric transport emergency preparedness in the future. The co-operation within NKS-MetNet has been fruitful and possibilities for a better and more economic efficient Nordic emergency preparedness in the future can be envisaged. In order to establish a better and more economic efficient operational Nordic emergency preparedness in the future, it is sensible to use the already obtained progress within NKS-MetNet as a platform for future Nordic work.

The main tasks and goals of the MetNet project under the NORDMET umbrella are:

- MetNet-Emergency is a forum for exchange of data and information for general emergency preparedness.
- Maintain the web-pages as a back-up facility in emergency situations.
- Improve the harmonisation of the layout and information issued, by among others e.g. taking into use an algorithm already established by the HIRLAM group to view animation in a user friendly way.
- Strengthen the collaboration with the Radiation Protection Agencies (RPAs).
- Strong link back to NKS and national RPA in each Nordic country during the act as a NORDMET activity.
- Interact with other NORDMET activities, such as the HIRLAM and Warning groups.
- Interact with WMO activities dealing with emergency response, European activities such as ENSEMBLE and other relevant international activities or groups, for instance the Volcanic Ash Advisory Centres (London, Toulouse and Montreal VAAC).
- Participation in regular exercises as part of the NORDMET activity, - or integrated as part of European and/or Nordic RPA exercises/activities.
- Description of some relevant emission scenarios.
- Decide how to automize the model runs for exercises/accidents, i.e. transforming the existing models into robust operational models.
- Extending the use of the models to other threats than emissions from nuclear power plants, as e.g. nuclear explosion, chemical including big fires, biological and geophysical emissions of airborne substances which can be of danger for the society on different geographical scales.

5.2 Benefits to the Nordic radiation protection authorities and to NKS

The main tasks and goals of a future MetNet project under the NORDMET umbrella, as given above, include several activities of advantage to the Nordic radiation protection society. Of special importance should be:

- MetNet-Emergency as a forum for exchange of data, information and technical solutions for an improved general Nordic emergency preparedness
- The web-pages as a back-up facility in emergency situations
- An improved Nordic harmonisation of the layout and information issued
- Strengthen the collaboration between the Nordic Meteorological Services and RPAs
- Strong link back to NKS and national RPA in each Nordic country during the act as a NORDMET activity
- Interaction with international activities in connection to DSSs such as ARGOS, ENSEMBLE and RODOS
- Participation in regular European and/or Nordic RPA exercises/activities.

5.3 Benefits for Nordic non-nuclear emergency authorities

The regional-scale atmospheric dispersion models in use for the MetNet backup facility may well be used also for decision support relating to emergency preparedness for other types of harmful events than radioactive releases. These involve various sorts of hazardous materials released in large quantities as a result of chemical disasters, biological emergencies, terror acts, and ashes from volcanic eruptions. With a long-term perspective, the realm of MetNet could be extended to cover also preparedness for such events.

Chemical disasters include industrial accidental releases of hazardous material in the form of gases or aerosols, as well as fires producing toxic smoke and gases. An example is the explosions and subsequent fires occurring at the Buncefield Oil Storage Depot, Hemel Hempstead, UK, in December 2005. At least one of the initial explosions was of massive proportions and there was a large fire, which engulfed a high proportion of the site. Over 40 people were injured; fortunately there were no fatalities. Significant damage occurred to both commercial and residential properties in the vicinity and a large area around the site was evacuated on emergency service advice. The fire burned for several days, destroying most of the site and emitting large clouds of black smoke into the atmosphere. This event was used as a MetNet preparedness exercise, cf. section 4.9.

Biological emergencies include spread of naturally occurring animal and human diseases, and the use of biological warfare agents e.g. in terror actions. Airborne spread of contagious aerosols at sufficient concentration to infect may take place over long distances provided that the following requirements are fulfilled:

1. High liberation of contagious material (virus, bacteria, fungi etc.) to the atmosphere,
2. High degree of stability of the contagious material in the atmospheric environment,
3. Small infectious inhalation doses required to infect.

Due to the possibility of carrying out experiments on animals, animal diseases are well studied. Airborne animal diseases involve e.g. Foot-and-Mouth Disease (FMD) (Sørensen et al., 2000, 2001; Mikkelsen et al., 2003), and Aujeszky's Disease. FMD epidemics are known to be associated with large economic consequences. FMD exists on a permanent basis in parts of the world. It is thus fairly easy to get hold of infected animal products, and since FMD is not infectious to human beings, it is straightforward to handle and transport the material.

Thus, there is a potential for using animal products infected with e.g. FMD as a means of terror.

Terror acts may involve atmospheric releases of radioactivity by nuclear or "dirty" bombs, or biological or chemical warfare agents by different release contraptions. Such terror acts may also involve combined releases. Biological warfare agents are live microscopic organisms including viruses, bacteria, and mycotoxin producing fungi. By e.g. inhalation a human being can acquire an infection dose, which subsequently may propagate in the body causing sickness or death. For some agents, e.g. pneumonic plague and small pox, secondary infection from person to person may take place. In such cases even a small initial bio-terror attack may end up involving a large number of infected people. Other agents like anthrax are not associated with secondary infection.

Biological warfare agents may be spread by use of different release contraptions. These comprise e.g. envelopes containing say 10 g anthrax spores, firework type rockets carrying a load of 100 g up to 100 m above ground where the rocket disintegrates and disperses the load, aggregates spreading aerosols from airplanes or helicopters, and missiles carrying around 500 kg of agents. It has been estimated that 100 kg anthrax spores dispersed under optimum conditions from an airplane in the Middle East may cause between one and three million deaths.

Volcanic eruptions imply safety risks for civil and military aviation. This is due to that fact that the plume of volcanic ashes and sulphur dioxide has harmful and corroding effects on airplanes. These effects may occur even at such low concentrations that the plume is not visible to the pilot, and in worst case they may result in a crash of an airplane. Therefore, it is of great interest to the airline companies to redirect air travel routes to avoid contact with the ashes. Thus, precise information, including ash plume simulations, is valuable.

6 METNET IN RELATION TO ARGOS SYSTEM

The Accident Reporting and Guidance Operational System (ARGOS) (Hoe *et al.*, 1999; 2002) is a Microsoft Windows based nuclear decision-support system developed by the Danish Emergency Management Agency (DEMA) and the Prolog Development Center A/S (PDC) ARGOS is currently used in nine countries: Canada, Denmark, Estonia, Ireland, Latvia, Lithuania, Norway, Poland and Sweden.

For local-scale modelling of atmospheric dispersion (0–100 km from the source) ARGOS makes use of the RIMPUFF system (Mikkelsen *et al.*, 1997), which is developed at the Risø National Laboratory and implemented in ARGOS. In Denmark, RIMPUFF utilises high-resolution data (currently 5 km) extracted from DMI-HIRLAM for a geographical domain covering Denmark and surroundings. Other participating countries have similar arrangements, where often meteorological data is obtained from the national meteorological institute.

ARGOS has been interfaced with regional- and global-scale atmospheric dispersion models running on remote powerful computers at national meteorological services. In Denmark, DERMA has been interfaced with ARGOS, in Norway SNAP and in Sweden MATCH. The integration of the regional-scale dispersion models in the ARGOS system is effectuated through automated online digital communication and exchange of data between the ARGOS system and an operational ftp server hosted by the national meteorological service. The ARGOS system prepares and uploads a description of the release. This automatically triggers the dispersion model to run on operational server using this information as well as data from each of the various operational numerical weather prediction (NWP) models available at the meteorological service thereby providing a mini-ensemble of dispersion forecasts. The NWP models include e.g. the high-resolution limited-area model HIRLAM and the global model run at the European Centre for Medium-Range Weather Forecasts (ECMWF).

While running, the dispersion model system issues status messages to ARGOS, and finally, results are made available. In fact, it is “invisible” to the ARGOS user that the long-range dispersion calculation is performed on a remote on-line connected computer.

In Figure 18 an example is given of the visualisation by the ARGOS system of a radioactive plume modelled by DERMA.

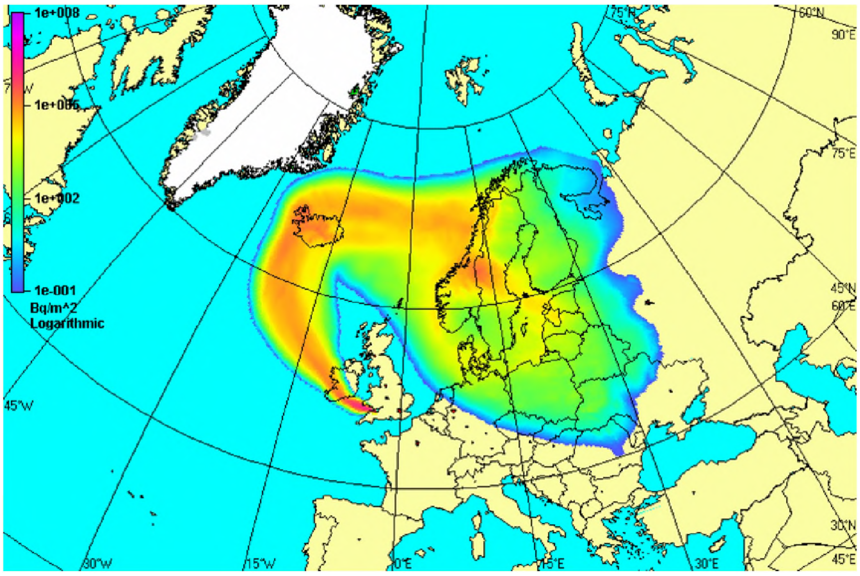


Figure *18. A regional-scale DERMA plume (total deposition of radionuclides) as visualised by ARGOS.*

In case ARGOS were in operational use in each Nordic country, it would have been sufficient by MetNet to exchange raw ARGOS formatted data extracted from the output of the national regional-scale dispersion models as a backup for the other Nordic countries. Such data can be imported into the ARGOS systems in use by the national radiation protection authorities, where the dispersion results can be used for visualisation and enter as input in dose calculations. However, since ARGOS is not used by all Nordic countries, it is necessary to exchange selected figures, which can be readily used for backup and model comparison, depicting, say, total deposition and time-integrated concentration. Unfortunately, of course, such figures cannot be used for dose modelling purposes. It has been decided by the MetNet forum that those partners using ARGOS (DMI, met.no and SMHI) on a voluntary basis may add also ARGOS formatted results of the dispersion models to the MetNet backup web sites, cf. e.g. the lower row in the table on the DMI site, http://nks.dmi.dk.

7 METNET IN RELATION TO ENSEMBLE SYSTEM

Four of the MetNet countries: Denmark, Finland, Norway and Sweden are also active participants of the international ENSEMBLE project. The ENSEMBLE project addresses the problem of achieving a common coherent strategy across European national emergency management when national long-range dispersion forecasts differ from one another during an accidental atmospheric release of radioactive material. ENSEMBLE makes use of new decision-making procedures and web-based tools for real-time reconciliation and harmonization of dispersion forecasts from meteorological and emergency centres across Europe during an accident. The project is coordinated by the European Commission - JRC/Institute for Environment and Sustainability located in Ispra, Italy.

The focus of the project is mainly on Europe, but in principle the simulation of an accident taking place in any part of the world is also possible, depending on availability of meteorological data for the participants. The list of participants to the ENESEMBLE project includes mostly European institutions, but also institutes from USA, Canada and Japan are participating. Altogether about 20 institutes participate, based on a MoU where all participants contribute on their own expenses. A detailed description of the project and a full list of participating institutes can be found on http://ensemble.jrc.it/.

There are many advantages for the MetNet partners in taking part in the ENSEMBLE project. Some of them are:

- **Task oriented, ready to use software**. Excellent tools for modellers have been developed in the frame of the ENSEMBLE project. These (for experts) user friendly tools include statistical routines and specific graphics for displaying model results. They are available on the web for participants of ENSEMBLE. One important advantage of the ENSEMBLE tools is a possibility of displaying and comparing different model results in the same grid system.
- **Better estimation of uncertainty**. The results of ENSEMBLE models (more than 20) can give much better estimate of the uncertainty of the computed results then a small (five models) group of MetNet models.
- **International forum and network**. One of the advantages of the MetNet project is a creation of the Scandinavian network and forum for exchanging the information, mostly for scientist, but also for administrators and decision makers involved in the issues related to nuclear and other accidents involving long range transport of air pollution in the atmosphere. Both the forum and the network, is even further world wide extended by the ENSEMBLE project.

The above list indicates that a close cooperation between MetNet and ENSEMBLE projects is very profitable for both sides. As an example, the results of the four MetNet models are presented in Figure 19 in the ENSEMBLE graphics for the simulation of hypothetical accident in Stockholm.

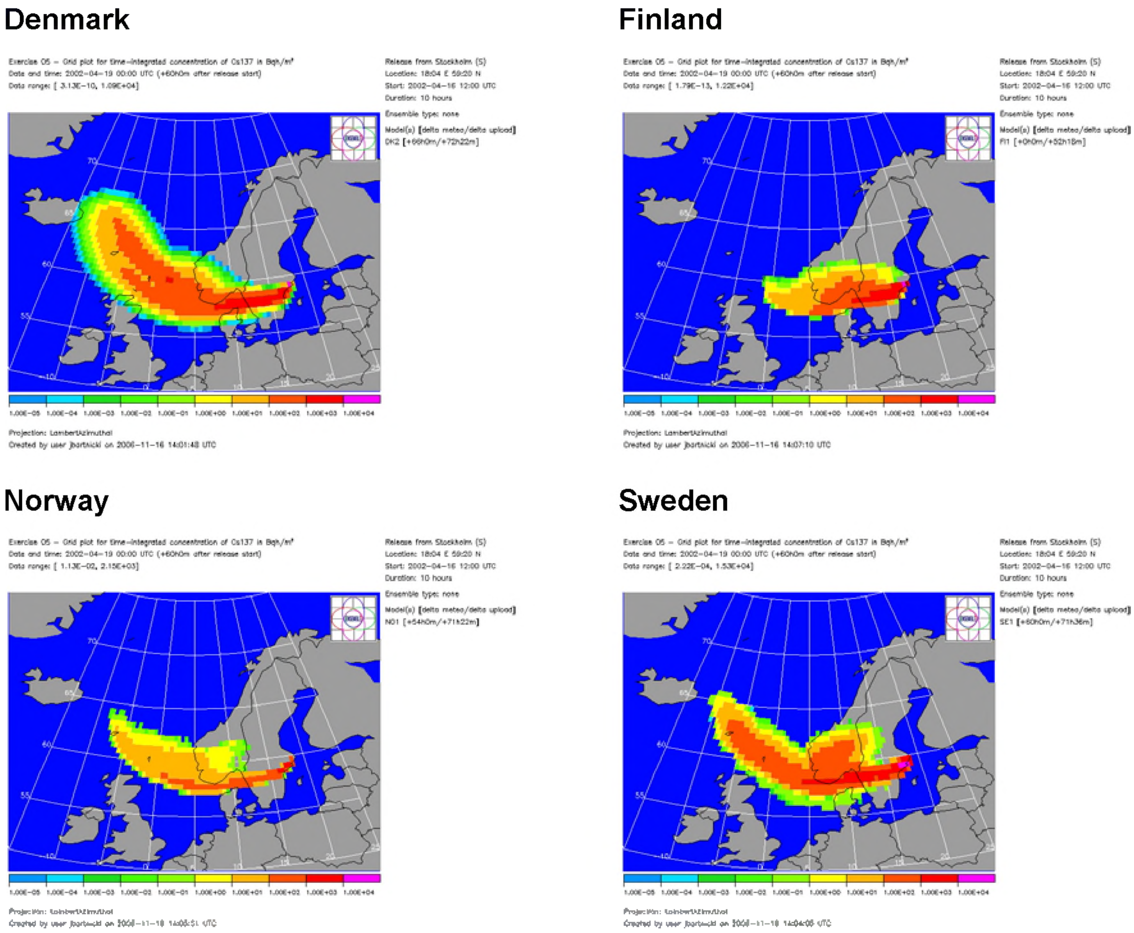


Figure 19. *Comparison of MetNet model results using the ENSEMBLE software for a hypothetical radioactive release from Stockholm.*

There are however some limitations of the ENSEMBLE system of today with regard to the responsibility for emergency preparedness the Nordic meteorological institutes have to fulfil:

- ENSEMBLE has at present no guaranteed preparedness for unplanned emergency calculations.
- The present situation with all modelling participants contributing at own expenses, regulated by a MoU, can sometimes cause problems with only few participating institutes due to lack of resources at the individual institutes.
- The ENSEMBLE software is very suitable for trained expert users but too complex for a wider use by decision makers.

8 METNET IN RELATION TO RODOS/EURANOS SYSTEM

RODOS is at present only used by one of the MetNet countries. As long as no more of the Nordic countries use the RODOS system, it will be of limited interest for MetNet to adjust its products to that system. But changes, which are not known by the MetNet group to-date, can alter the situation in the future.

9 METNET IN RELATION TO PREVIEW PROJECT

The EC-financed Preview project is an on-going project, end-date January 1^{st} 2009, with a limited part devoted to emergency preparedness by means of ensemble forecasts, but with no links to real-time applications. Methods and systems developed by the Preview project might be of interest for a future MetNet.

10 CONCLUSIONS

Experience and conclusions from the NKS-MetNet project can be summarized as follows:

- Despite well organised emergency systems at each individual meteorological institute unexpected things due to the human factor can happen – and do sometimes happen – in emergency situations when time is a critical factor.
- Technical problems with hardware, software or meteorological data are not frequent, but do happen. This is true although the development of course always shall endeavour a robust system.
- An obvious example of the points above was the national Swedish emergency exercise "Havsörn", when only two out of five institutes could present good quality atmospheric transport calculations during the first few hours. Despite those problems correct information, based on the MetNet network, was transmitted at an early stage to the decision-makers in the Havsörn exercise. This shows that the NKS-MetNet partners can act as an operational unit - in case of an emergency situation.
- The presence of forecasts based on several different models increase the possibility for the decision makers to judge the reliability of the forecast and, as a consequence of that, also the actual value of the forecast. Application of such software as available in the ENSEMBLE system to create a multi-model ensemble forecast map, as was shown in one MetNet exercise, can be an efficient way to present such information to end-users.
- In unexpected emergency situations (cf. 4.8 "volcano" and 4.9 "big oil fire") the possibility to obtain immediate contact and support within the network is extremely valuable.
- In general the different Nordic models agreed fairly well during the performed exercises. Looking at details it is however possible to gain valuable information from using a multi-model ensemble forecast based on results from all models available within the network.
- The network is bringing the Nordic emergency dispersion modellers closer together and promote closer co-operation.
- The current NKS MetNet project has fulfilled its main harmonization goal by bringing the Nordic emergency modelling towards more unified approaches of the results presentations and introduced a voluntary unification of the model output formats.

- At the current stage, it seems to be feasible to keep the Nordic network of Web sites and continue its development regardless of presence of a third-party large-scale DSS, whether it is ARGOS, RODOS, ENSEMBLE or any other. The level of complexity of such systems is much higher than that of the MetNet sites and their availability and friendliness for various users is and will be far beyond that of the simple service developed by MetNet.
- Foreseen future close cooperation of the modelling groups with the DSS developers and further efforts of harmonization in individual countries and across Europe may eventually help in determining a common platform supported by all Nordic and European models. Until this goal is achieved the Nordic network of Web sites would form a solid basis for operational cooperation and mutual backup of the emergency modelling.

11 ACKNOWLEDGEMENTS

The NKS-MetNet project was performed with funding from NKS and the participating Nordic Meteorological Services. The emergency preparedness work at each Meteorological Service is dependent on several people, also from outside the MetNet group, as well as on good contacts with representatives of the different Nordic Radiation Protection Agencies (SSI, STUK, DEMA, IRPI and NRPA) who are acknowledged. Special recognition is given to representatives of SSI and STUK as well as to Stefano Galmarini, JRC Ispra and Réal D'Amours, Canadian Meteorological Service for support in connection to performed MetNet exercises. The MetNet group is also grateful to Sigurður Emil Pálsson, Programme Manager of NKS-B, for improving the contacts between meteorological modelling activities and the radiation protection end-users.

12 REFERENCES

See Appendix 2, MetNet Literature List.

13 APPENDIX 1 – MetNet Address and Web List

Immediate access to the MetNet address list of responsible persons at the Nordic Meteorological Institutes and Nordic Radiation Protection Agencies and to the list of password protected Web-pages, one at each Nordic Meteorological Institute, is fundamental for the MetNet network in emergency situations. Access to that type of information is however restricted and not available in the official version of this report.

14 APPENDIX 2 – MetNet Literature List

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Abstract	The current NKS-MetNet project was initiated to strengthen the Nordic collaboration within the field of real-time atmospheric transport modelling for nuclear emergency preparedness and to improve its contacts to the Nordic radiation protection authorities. A backup facility for the network has been established regarding exchange of operational real-time long-range dispersion model calculations. The facility consists of national password protected Web sites, at which some few basic results (maps) of atmospheric dispersion model calculations (forecasts) in emergency situations (or exercises) can be made available to the network. Technical problems at one institute will not influence the calculations or presentations from the other participants, which makes the system robust. The project has fulfilled its main harmonization goal by bringing the Nordic emergency modelling towards more unified approaches of the presentations of results and introduced a voluntary unification of the model output formats. It was left optional to upload raw data in a format enabling import into one of the Decision Support System (DSS) ARGOS or RODOS. However, implementation of either of these formats is feasible only in case of availability and utilization of the systems by the end-users in the specific country. Within the Nordic countries to-date most but not all of the models are capable of producing the ARGOS-compatible results. Another format of the output data supported by almost all MetNet participants is ENSEMBLE – a standard developed within the scope of the EC ENSEMBLE project that currently continues on a voluntary basis, regulated by a joint MoU, and covers nearly all European emergency-engaged services. It seems to be feasible to keep the Nordic network of MetNet Web sites also in a near future and continue its development regardless of presence of a third-party large-scale DSS, whether it is ARGOS, RODOS, ENSEMBLE or any other. Foreseen future close cooperation of the meteorological modelling groups with the DSS developers and national Radiation Protection Agencies may eventually help in determining a common platform supported by all Nordic and European models. Until this goal is achieved the Nordic network of Web sites would form a solid basis for operational cooperation and mutual backup of the emergency modelling.
Key words	Air concentration, atmospheric, back-up, deposition, dispersion, emergency, forecast, meteorology, model, network, Nordic, nuclear, preparedness, radioactivity, real-time, transport, Denmark, Finland, Iceland, Norway, Sweden.

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