Operational Use of Atmospheric Dispersion Models for Emergency Response in Denmark Assessing Consequences of the Fukushima Daiichi Accident

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Abstract: For emergency response in Denmark, both short-range and long-range atmospheric dispersion models were applied in real time during the nuclear accident at the Fukushima Daiichi nuclear power plant in 2011. The models employed are the RIMPUFF and DERMA models, which are in operational use for Danish nuclear emergency preparedness. Whereas the RIMPUFF model is integrated in the ARGOS decision-support system, the DERMA model is run at the DMI high-performance computer facility and interfaced with ARGOS using automatic procedures. In order to carry out detailed atmospheric dispersion modelling, numerical weather prediction model data were extracted in real time at highest possible spatial and temporal resolution from the global meteorological model run at the European Centre for Medium-Range Weather Forecasts (ECMWF). The data obtained cover a geographical domain in the range 110–180°E and 10–70°N (corresponding to about 6,500 km times 6,500 km) at a resolution of 0.125°. In addition, global coverage data were available at a resolution of 0.5°. In real time, the models were applied using source terms which were either best guesses at that time or hypothetical worst-case scenarios. Later, refined source terms were derived and used by the dispersion models, the results of which are compared with monitoring data. Results of the two atmospheric dispersion models are presented.

Key words: Emergency response, atmospheric dispersion, Fukushima

1 Introduction

As in many countries far from Japan, the response in Denmark to the accident at the Fukushima Daiichi nuclear power plant in 2011 was more challenging than anticipated. The demand for general information to the press and to the Danish public, including the embassy in Tokyo, citizens in Japan and ship traffic in the area, soon become an obvious challenge to the preparedness. Accordingly, accurate prediction of risk areas was a high priority.

At the onset of the accident, the ARGOS decision-support system was operational for East Asia regarding only long-range atmospheric dispersion calculation. However, already the day after the accident, it became possible also to carry out meso-scale modelling based on the American NOMAD data. This was followed the next days by including high-resolution data for orography and land use. After a few days, the system was also provided with high-resolution numerical weather prediction (NWP) model data.

For emergency response in Denmark, atmospheric dispersion models at different scales were applied in real time during the accident. The models employed are the RIMPUFF model and the Danish Emergency Response Model of the Atmosphere (DERMA), which are in operational use for Danish nuclear emergency preparedness. Whereas the RIMPUFF model is integrated in ARGOS, the DERMA long-range model is run at the high-performance computing facility at the Danish Meteorological Institute (DMI) and interfaced with ARGOS using automatic procedures. In order to carry out detailed atmospheric dispersion modelling, NWP model data were extracted in real time at highest spatial and temporal resolution from the global NWP model run at the European Centre for Medium-Range Weather Forecasts (ECMWF). The data obtained cover a geographical domain in the range 110–180°E and 10–70°N (corresponding to about 6,500 km times 6,500 km) at a resolution of 0.125°. In addition, coarser global-coverage data were available at a resolution of 0.5°.

In collaboration with the Danish Emergency Management Agency (DEMA), DMI contributed with atmospheric dispersion modelling, delivery of meteorological data, general meteorological information including forecasting, and expert guidance. As a special service, the DMI Maritime Service guided ship traffic in the area in order to avoid the risk of radioactive contamination by the plume from the power plant.

In real time, the atmospheric dispersion models were applied using source terms which were either best guesses at that time or hypothetical worst-case scenarios. Later, refined source terms were used.

2 Decision Support System and Atmospheric Dispersion Models

ARGOS (Hoe *et al.*, 1999, 2002; ARGOS, 2011) is an information system for enhancing crisis management for incidents involving CBRN releases. The target is accidents as well as terrorist initiated events related to CBRN industries, transport of hazardous materials etc. ARGOS is a prognostic tool as well as a database system for collection and presentation of data relevant for emergencies in an easily understandable form. ARGOS facilitates decision support, improving of situation awareness and information sharing among the emergency response organisations. As a simulation instrument, ARGOS is also valuable for training of the response organisation. ARGOS is currently used in 13 countries: Australia, Bosnia-Herzegovina, Brazil, Canada, Denmark, Estonia, Ireland, Lithuania, Montenegro, Norway, Poland, Sweden, and New Zealand.

RIMPUFF (Mikkelsen *et al.*, 1997), which is developed at the Risø National Laboratory for Sustainable Energy, Technical University of Denmark, is the primary short-range model for ARGOS. RIMPUFF comprises a meteorological pre-processor, which calculates time and height dependent fields of meteorological parameters (deposition, stability, wind etc.) based on data provided by numerical weather prediction models or by in-situ meteorological observations. Wet deposition may be estimated from weather radar information.

DERMA (Sørensen *et al.*, 2007) is a comprehensive numerical global and meso-scale atmospheric dispersion model developed at the Danish Meteorological Institute (DMI). The model is used operationally for the Danish nuclear emergency preparedness, for which the Danish Emergency Management Agency (DEMA) is responsible. Besides, DERMA and RIMPUFF are both employed for veterinary emergency preparedness (Sørensen *et al.*, 2000, 2001; Mikkelsen *et al.*, 2003; Gloster *et al.*, 2010), where they are used for assessment of airborne spread of animal diseases, e.g. foot-and-mouth disease. DERMA may also be used to simulate atmospheric dispersion of chemical substances, biological warfare agents and ashes from volcanic eruptions, and it has been employed for probabilistic nuclear risk assessment (Lauritzen, 2007).

3 Source Term Estimate

DEMA does not use any advanced Source Term Model. Based on calculation from JNES (Japan Nuclear Energy Safety) with the MELCORE code (Source Code calculation), the release fraction was estimated. The release profile and timing were estimated from the onsite monitoring results and the MELCORE profiles. Generally, the release profile was longer than indicated by the MELCORE results, e.g. the main release from unit 2 was in total 12 hours. The inventories of the reactors were calculated based on the inventory in BWR rectors from ABB; see also Bannai (2011). In Fig. 1 gamma monitoring results from the station located at the Fukushima Daiichi gate are shown.

Data from the TEPCO monitoring site at Fukushima Daiichi were inserted into ARGOS by DEMA. Subsequently, the results in the EURDEP format were distributed to other users.

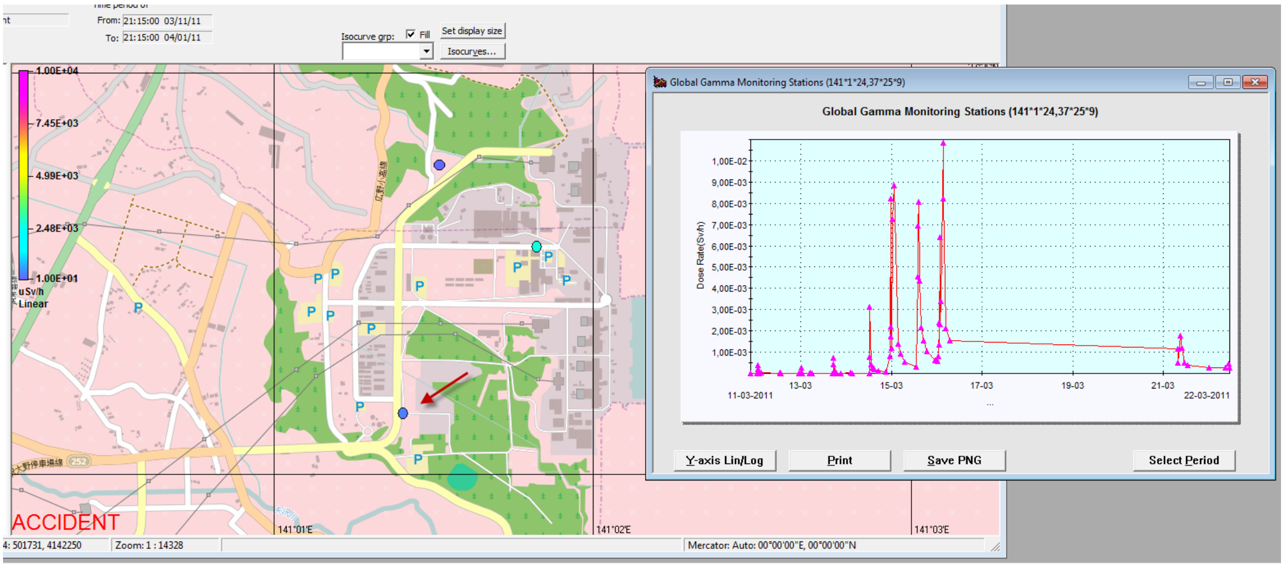


Figure 1 Monitoring at the Fukushima Daiichi gate.

4 Results

In Fig. 2, the total deposition of Cs-137 is shown in units of Bq m^{-2} as calculated by the atmospheric dispersion model RIMPUFF. The results agree well with aerial monitoring data (IAEA, 2011).

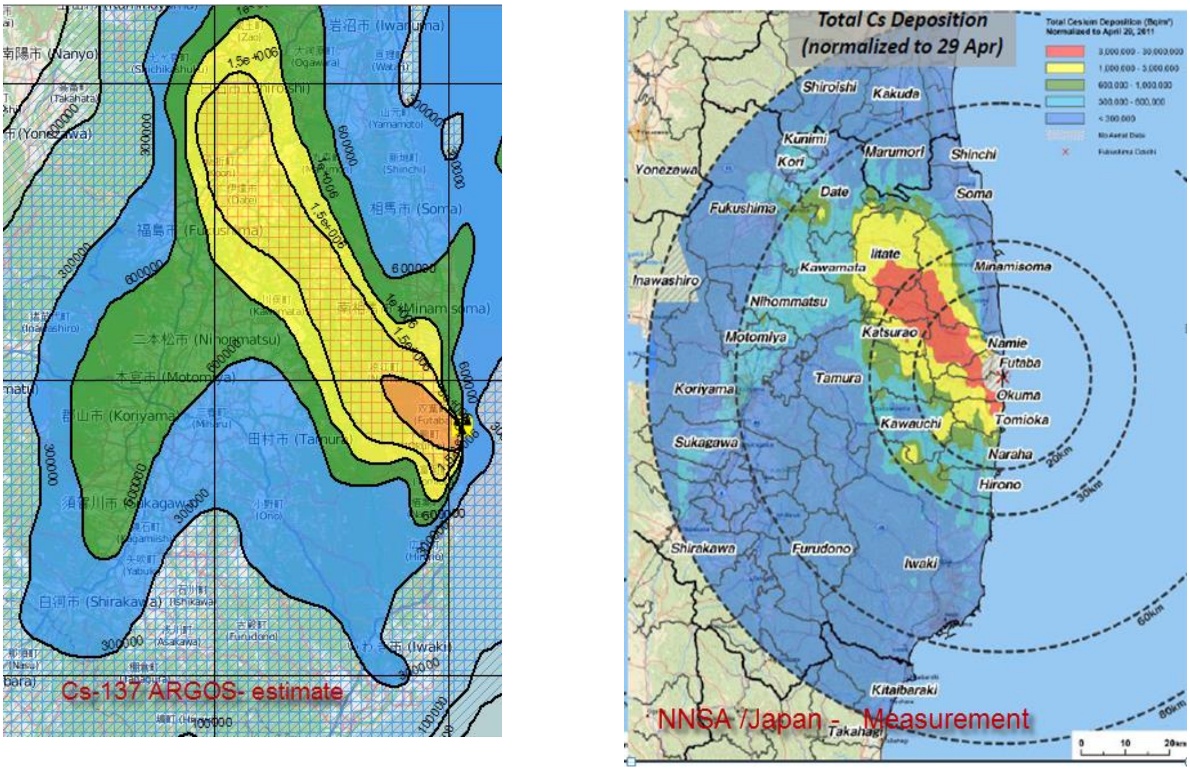


Figure 2 Total deposition of Cs-137 as calculated by RIMPUFF using the above source term compared with the Joint US-Japan Arial Measurement Data from NISA and DOE (NNSA).

In Fig. 3, the ground-level time-integrated concentration in units of Bq s m^{-3} as calculated by DERMA is shown. At first, the atmospheric dispersion was predominantly towards east moving northwards trough the Bering Strait. In the North Pole region, subsidence of radioactivity took place adding to the ground-level concentration. Eventually, the dispersion continued to Scandinavia; however, at very low concentration.

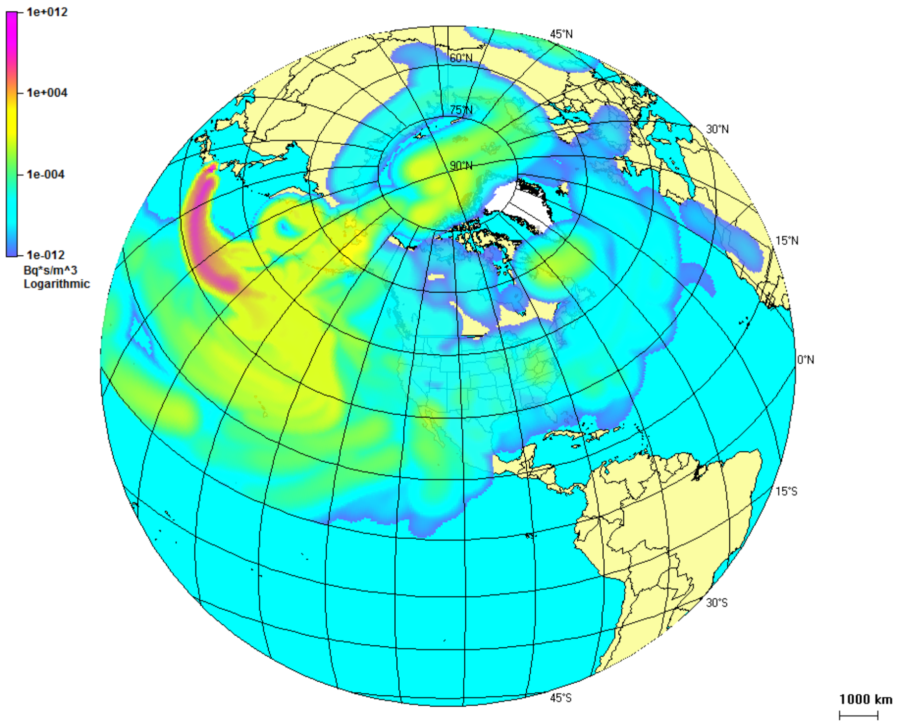


Figure 3 Time-integrated ground-level concentration of Cs-137 as calculated by DERMA using the above source term.

A number of different source terms have been applied. For instance, DERMA results obtained by using the source term given by Chino *et al.* (2011) are given in Figs. 4 and 5.

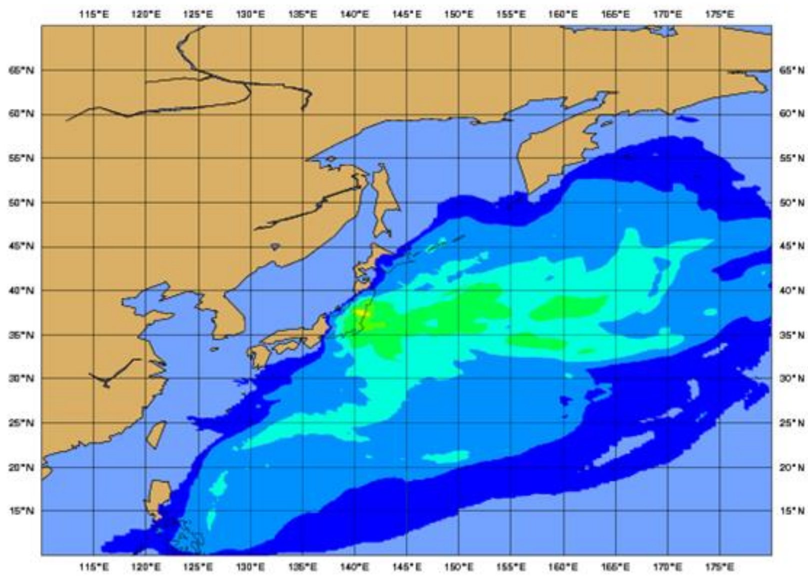
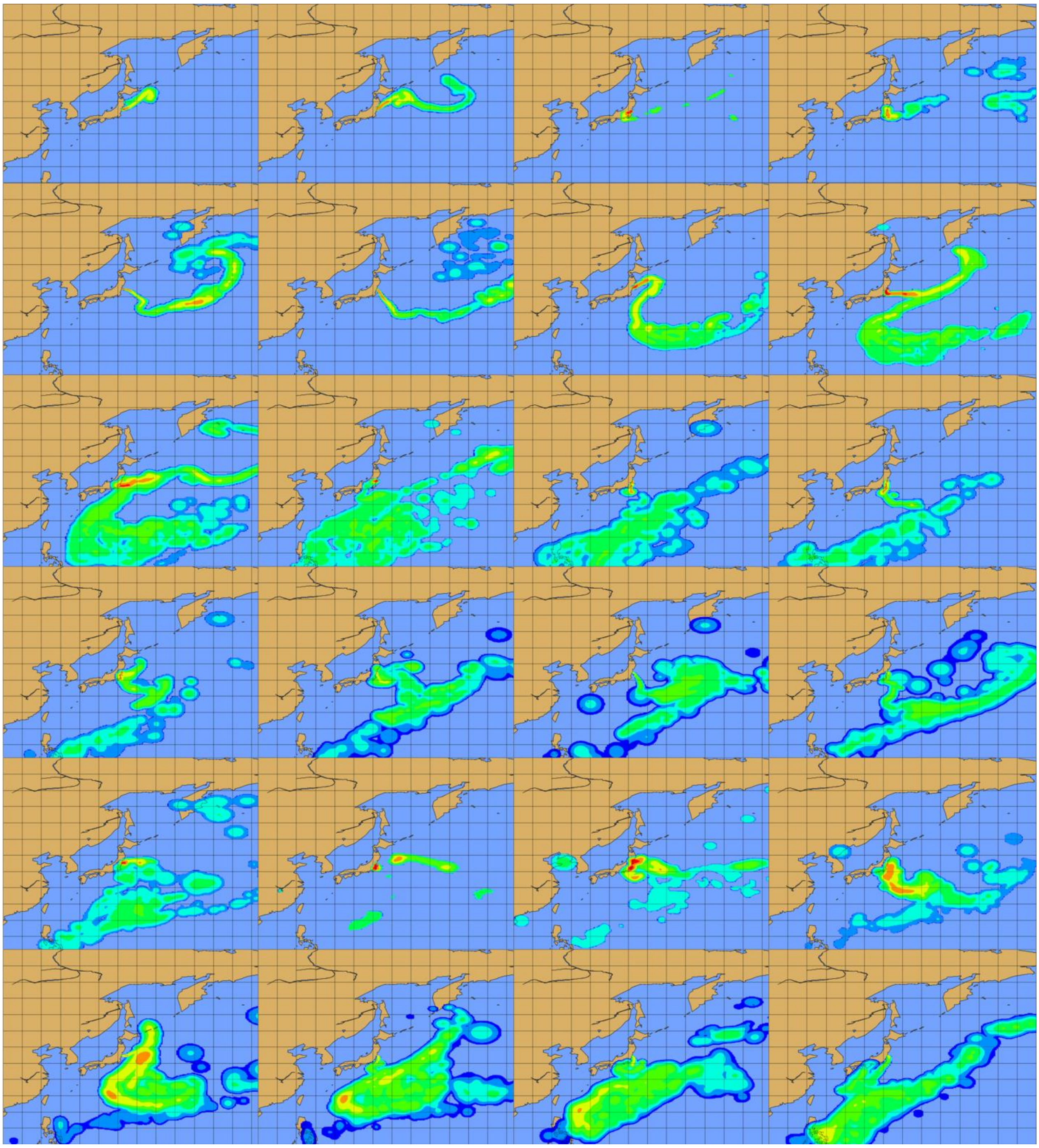


Figure 4 Deposition of Cs-137 as calculated by DERMA using the source term by Chino *et al.* (2011).



Figur 5 Time series of instantaneous ground-level concentration of Cs-137 on 13 March, 14 March, …, 5 April 2011 as calculated by DERMA using the source term by Chino *et al.* (2011).

5 Risk zone

Denmark issued a general travel advice for not entering the 80 km zone around Fukushima Daiichi based on the general emergency in the area. The radiological situation was implicitly included in this advice. A severe scenario with a large fuel pond release from unit 4 was included in the assessment using ARGOS for dose estimates based on RIMPUFF dispersion calculations. Results from dispersion calculation by DERMA and ARGOS were published twice a day on a closed web, which could be assessed by Danish and other authorities including the Danish Embassy in Japan. Because of the large uncertainties of the actual source, no dose estimates were published in real time, cf. Fig. 6.

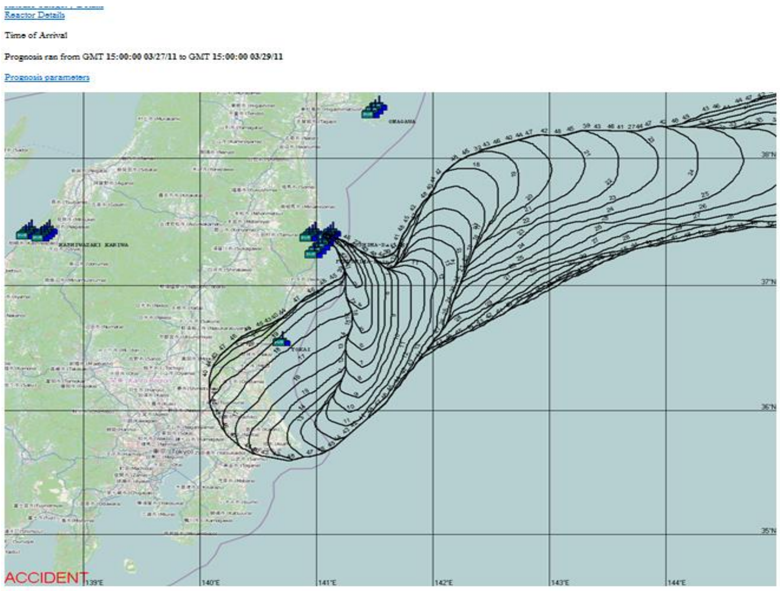


Figure 6 Publication from RIMPUFF four times a day on a closed web showing "Time of Arrival" plots.

6 Conclusion

For emergency response in Denmark, it was possible to use the existing ARGOS system for the Fukushima Daiichi accident with minor data adjustments. The combination of long- and short-range atmospheric dispersion models proved to be an important tool for estimating risk areas not only for Japan, but also for the Danish ship transport to and from Japan during the accident.

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Maps used by ARGOS: Open Street Map (OSM)