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Integration of dispersion and radio ecological modelling in ARGOS NT

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INTRODUCTION

The Danish ARGOS NT system is in operation in Denmark and 5 Baltic Sea states. Based on radiological data from 40 advanced early warning station – PMS stations – and various others monitoring sources and atmospheric dispersion capability the ARGOS NT system provide an excellent basis for nuclear decision support.

ARGOS NT[1]) is a dynamic PC/workstation based system that is modified regularly in order to cope with new requirements. The new version 2.0 includes update atmospheric models and GIS module and in year 2000 a dose module including radio ecological calculations is integrated in ARGOS NT.

I BACKGROUND

Denmark has no nuclear power reactor of its own, but within a distance of 200 km from its border 10 reactors is operating and 1 million people are living within a distance of 40 km from one of the reactor sites, at greater distance at larger number of safe and less safe reactor is present.

On this background the development of the ARGOS NT (Accident Reporting and Guiding Operational System NT) was started in 1993 and implemented as a graphical Windows NT application. Prolog Development Center A/S develops the programs in cooperation with The Danish Emergency Management Agency. External modules are developed by Risoe National Laboratory and GSF (se chapter IV).

ARGOS NT plays today a central role in the Danish nuclear emergency system and other countries around the Baltic Sea. As a part of The Danish bilateral assistance program concerning nuclear safety, radiation protection and nuclear emergency preparedness the program was installed in Lithuania, Latvia, Estonia, Poland and Russia (Sosnovy Bohr) - The role of ARGOS NT, as a general tool in the Nuclear Emergency Management, differs from country to country. ARGOS NT is expected to be installed in Ireland in year 2000.

II SYSTEM DISCRIPTION

The ARGOS NT system is a client server based application with all data collected in a central SQL-database. Data are entered on-line by the users or automatically imported into the program; centrally placed experts must approve manually entered data. The radiological data includes:

- *γ-dose* rates and spectres from on-line monitoring stations
- γ-*dose* rates from European countries monitoring systems (EURDEP-data)
- γ-dose rates from mobile units
- Air concentrations from mobile units
- Isotopes in environmental samples
- γ-dose rates measures by helicopters
- Isotope specific surface concentrations measured by helicopters (spatial resolution: ≈ 200m).

The radiological data are presented on a special developed map module in ARGOS. This very fast map module works with a standard map format and can zoom from Earth-size down to meters. The raw radiological data are presented on the map as colour points and active bars (Se figure 1.). Precipitation from weather radar stations is presented as bitmap overlaid on the map. Dispersion and radio ecological calculations are presented by colour coded bitmaps and/or ISO lines and is dynamically updated.

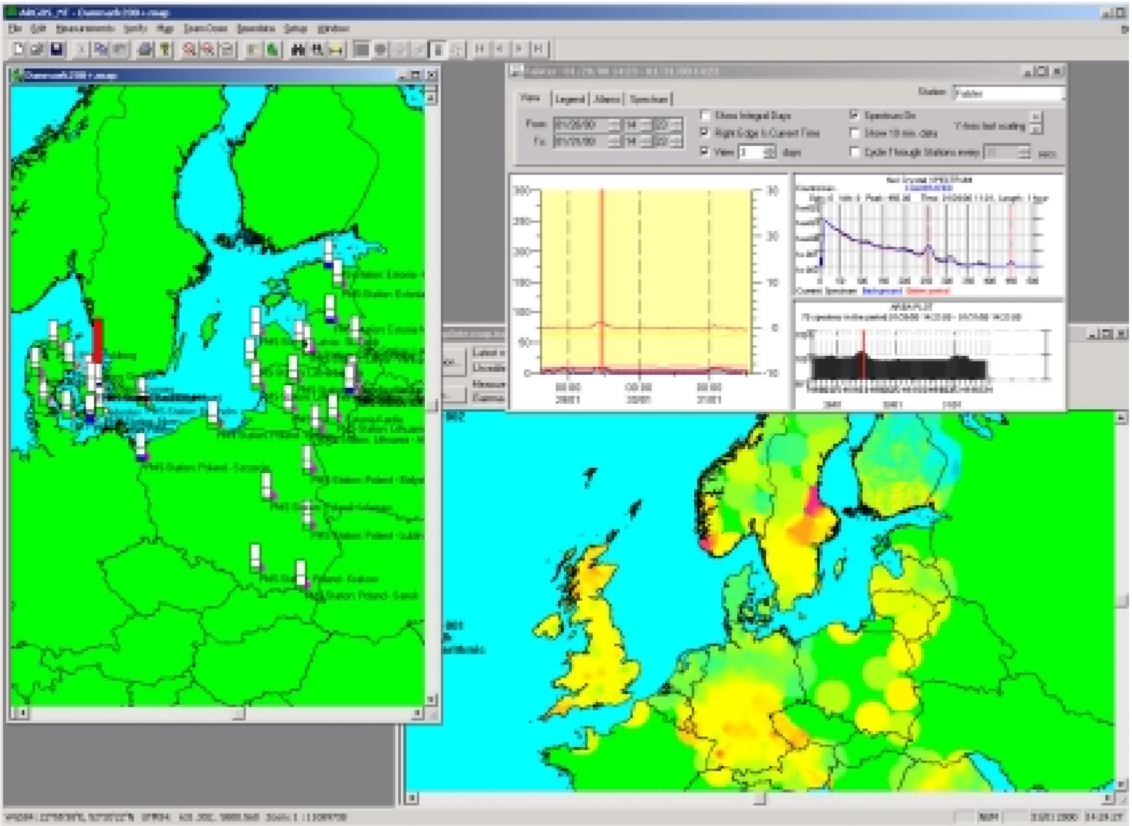

Figure 1. Monitoring result is presented as bitmap on European Scale (EURDEP data) or as bars indicating stations status (Green – Normal, Blue- Rain and Red –Alarm [test station on map]).

III MODELING IN ARGOS NT

In ARGOS NT no complicated physical modelling is performed inside the main ARGOS code, modelling is executed by external codes interacting with ARGOS by in- and output files. All data used in the system is stored in the ARGOS SQL database and ARGOS provides data to the models.

The advantage of this operation mode is easy and economically affordable to maintain the code. A software company then maintains the ARGOS NT code and the modellers maintain the models. During model development only the models change and by this way the expertise of scientist can be used in an optimum way – past experience with scientist making user interface is deterring.

At present ARGOS NT runs with two models the atmospheric dispersion model LSMC/RIMPUFF and the food chain and dose assessment model ARGOS-FDM.

IV ARGOS-FDM FOOD CHAIN AND DOSE ASSESSMENT MODEL

A recent development of ARGOS NT is the installation of a module for simulating food chain transfer and assessment of doses from all relevant exposure pathways. This has been done in cooperation with another radiological decision support system, the Real-time, On-line Decision support system for nuclear Emergencies, RODOS (1), which has been developed by a consortium of many contractors funded by the European Commission: The food chain and dose module FDM of ARGOS NT is essentially the same as developed for the RODOS system. This provides consistency in the modelling and assessment techniques among both systems which is an important factor for coherent multinational emergency management.

The food chain model and dose assessment methodology is mainly based on the radio ecological model ECOSYS [2] . Since this model has initially been developed for the radio ecological conditions of Germany the food chain and dose module ARGOS-FDM has been designed in a way, which allows adapting the model to the conditions of the areas for which it is to be applied. This means, a variety of so-called radio ecological regions with more or less homogeneous climatically and agricultural conditions can be defined, and the same set of model parameters is used for all locations within a region. The list of feed and foodstuffs considered for ingestion dose assessment can be defined individually for each region, and all model parameters like crop growth data, transfer factors, feeding habits, human food consumption rates etc. can be adjusted for each region. Within the RODOS project such adaptation work has been performed for several countries of Central and East European countries; adaptation to further countries where ARGOS NT is to be applied (Scandinavia, Baltic countries) is still an ongoing task.

Basically, the ARGOS-FDM module estimates the deposition to crops and soil from the activity concentration in air and the wet deposition predicted by the atmospheric dispersion module. But if in an area nuclide specific measurements of deposited activity are available, can they be used as an alternative starting point for the food chain calculations. If only data on total deposition is available, as e.g. it is the result of aerial gamma dose rate measurements, the uncertainty of the results is very high: Especially the food contamination and the resulting ingestion dose in the first year after deposition depends very much on the amount of activity which is retained by the foliage of the crops; it depends strongly on the type of deposition (wet/dry). The more additional information (e.g. rainfall, contamination of crops) is available at a certain location, the more reliable are the results on food contamination and radiation exposure. A scoring system is under development, which assigns a reliability class to the results, which can be presented to the user together with the results.

Output of ARGOS-FDM are the time dependent radioactive contamination of a variety of foodstuffs as well as present and future doses and dose rates from internal (ingestion, inhalation) and external (from the plume and from deposited radio nuclides) exposure pathways. Organ specific doses and effective doses can be provided for different age groups of the average population. If data on population numbers and food production is available, rough estimates of collective doses can be given.

Deposition Monitoring

As part of the Danish nuclear emergency preparedness, an airborne gamma ray spectrometer system has been developed for mapping nuclear fallout deposition. This application is more complicated than standard airborne gamma ray surveying for geological mapping and requires different data processing procedures. A new approach to processing airborne spectral gamma ray data referred to as Noise-Adjusted Singular Value Decomposition (NASVD) has been developed, Jens Hovgaard (3). This method has the advantage that no nuclide-specific knowledge of the deposition is required. Tests at international exercise show that the implemented software for rapid post processing of data works excellent for detection of radioactive sources and deposition.

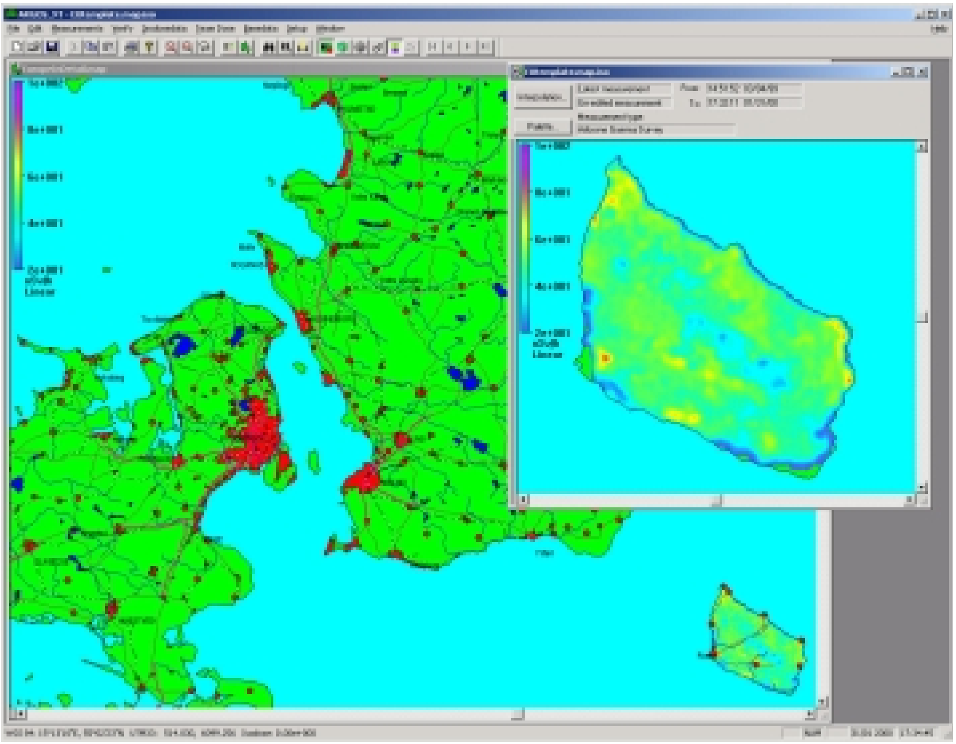

Figure 2. Results of airborne deposition measurements with 500 m resolution.

In the Danish Nuclear Management two airborne system, with 16 l NaI(Tl) crystal volume, is operational and a special program automatically extract data from the system for import into the ARGOS system with the horizontal resolution of the data is in the order of 50-5000 m. Isotope specific depostion maps that can be produced from the airborne data are well suited for use in ARGOS-FDM. Denmark has also provided car borne system for the 5 Baltic Sea States countries with 4 l crystals and similar software. A similar car borne system is also operational in Denmark.

V ATHMOSPERIC DISPERSION

DMI-HIRLAM

The HIgh-Resolution Limited-Area Model (HIRLAM) (Källén et al., 1996) [4] is a numerical weather prediction (NWP) model. The horizontal grid is a rotated spherical coordinate system, while the vertical coordinate is a terrain influenced hybrid coordinate (Simmons and Burridge, 1981) [5]

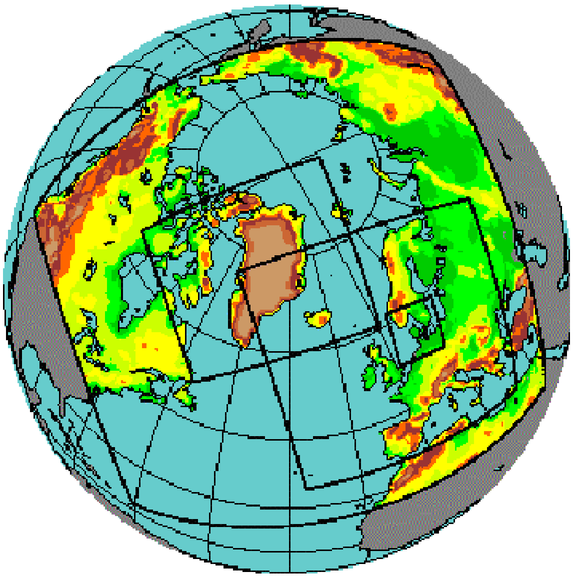

Figure3. Areas in the DMI-HIRLAM model

At the Danish Meteorological Institute (DMI), HIRLAM runs in an operational mode four times a day on four different areas, cf. Fig. 1. The meteorological boundary fields for the large-area version are obtained from the global model run by the European Centre for Medium-Range Weather Forecast (ECMWF). The versions covering Europe and Greenland are nested in the larger version, which provides the boundary values. The horizontal resolution is 0.45° (about 49 km) for the large-area version, and 0.15° (16 km) for the Europe and Greenland versions. A 0.05° (5.5 km) version covering Denmark and its surroundings is further nested in the Europe version.

The model versions are run with the same vertical resolution, presently involving 31 hybrid levels. The density of levels is greatest in the atmospheric boundary layer. As an example, there are nine model levels available for resolving a boundary layer with a height of 1500 m.

The HIRLAM forecasting system consists of data assimilation, analysis, initialisation, forecast, post-processing and verification. The model versions are run with their own six-hourly data-assimilation cycle.

Local Scale Model

The local scale model system used in ARGOS NT, **LSMC,** is a comprehensive meteorological dispersion forecast module for emergency response. The dispersion system Ehrhardt et al., 1997 (1) consists of nested meteorological model chains that combine local and long-range atmospheric dispersion. **LSMC** is designed to produce estimates of actual and forecasted (+48 hour) ground-level air concentrations, wet and dry deposition, and ground-level gamma dose rates on all scales.

In the present **ARGOS** version only numerical data from HIRLAM is used. For real-time calculations within 30 km from the release site, on-line measured data from local meteorological stations may be used.

Meteorological Data

LSMC comprises a meteorological pre-processor (**pad**), which calculates deposition parameters, stability parameters and wind fields based on the data provided by the HIRLAM model. The HIRLAM data set used consist of data from 13 layers of the HIRLAM model. These layers (no. 20 to 31) cover the height interval from 30 to approx. 2000 meters above ground. The grid spacing used by HIRLAM is approx. 16 km. The data used are: Precipitation intensity, boundary layer height, surface sensible heat flux, surface momentum flux, land cover, surface roughness and wind speed and direction (for all 13 layers).

These data are pre-processed and interpolated by **pad** to yield data input fields for RIMPUFF. Typically the fields are interpolated to a grid spacing of about 1 to 2 km. The wind fields are interpolated either by the linearized flow model **Lincom** or by $1/R^2$ weighting. **Lincom** is only used out to 50 km from the source when the variability of the wind field is low. **Lincom** can be turned off**.** The 13 layer wind fields are used by RIMPUFF for calculations of wind shear.

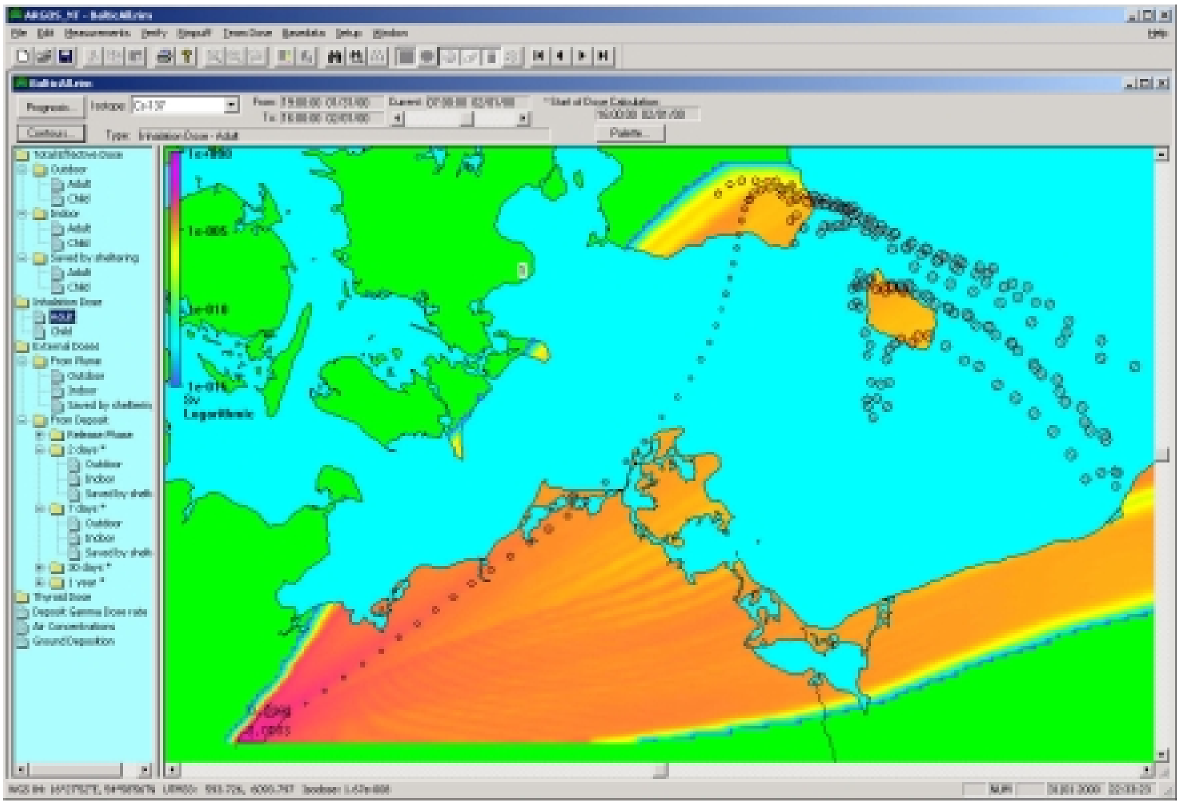

Figure 4. Atmospheric dispersion. The effect of trifurcations is clearly visible.

Dispersion calculations

RIMPUFF calculates the puff's location on the specified grid by computing their movement during finite time steps. The actual (time averaged) wind vector (wind direction and wind speed) at the puff centre is used to advect the individual puffs. To compute the growth and buoyant lift of the puffs, the turbulence parameter fields provided by **pad** are used.

The stability parameters provided for **RIMPUFF** pertains to the so-called similarity parameterisation, which gives a continuous atmospheric stability spectrum. The similarity parameters are the most realistic stability parameterisation under most atmospheric conditions. However, when considering large travel times/distances and/or inhomogeneous wind- and turbulence fields, several other items must be considered:

Splitting of puffs: A more realistic handling of vertical and horizontal wind shear is obtained by splitting the puffs when they reach a certain size. The splitting methods are called trifurcation in the vertical (3 new puffs) and pentafurcation (5 new puffs) in the horizontal. In all cases, mass and momentum is conserved. The splitting method is optimised in order to avoid unnecessary puff splitting.

Vertical growth of puffs: In RIMPUFF it is assumed that puff centre height increases with increasing vertical dispersion. This will eventually lead to that the puffs get above the boundary layer. A special turbulence parameterisation for puffs above the ABL (Atmospheric Boundary Layer) is used. As the ABL height changes with time, the puffs are allowed to move in and out of the ABL.

Plume rise: RIMPUFF uses basically Briggs formula. For some situations, especially large energy releases, a set of newly developed Russian plume rise formulas (Sorokovikova, 1999) [6]are used, These formulas can handle explosive heat releases, which may lead to a plume rising above the ABL. Humidity and temperature profiles from HIRLAM are used.

Dry deposition is calculated using the source depletion method. The isotope specific dry deposition parameters are calculated using the so-called surface resistance method. This means that the parameters mainly depend on turbulence and land use. Typically it is so that compared to an open grass field there is large deposition over forest areas and low deposition over cities. Land use data may be obtained from satellite pictures.

Gamma dose and concentration calculations are also made by **RIMPUFF**. Decay of isotopes as well as production of daughter elements during air transport and after deposition on the ground is taken into account. The gamma doses from the puffs are calculated using the finite cloud model and assuming that the puffs are spherical. For deposited material, the gamma doses are calculated assuming a semi-infinite plane source. Based on the output from RIMPUFF, ARGOS NT calculates external doses and separately for adults and children: Effective- , inhalation-, thyroid doses and also the avoidable doses from sheltering are calculated.

RIMPUFF may be used out to about 250 kilometres from the source. With some carefully tuning RIMPUFF can calculate trajectory like results on even longer distances. Further away from the source the DMI long-range dispersion model (**DERMA**) is used

Long Range modelling in ARGOS NT

ARGOS NT have no long range model because of the large amount of data required - The daily production of output data from the Europe version of the DMI-HIRLAM model is 6 Gigabyte.

Long-range modeling is then executed with the *DERMA* (The Danish Emergency Response Model of the Atmosphere) model at DMI and the results are imported into ARGOS NT for display and radiological calculations.

DERMA is a three-dimensional Lagrangian long-range dispersion model (Sørensen, 1998; Sørensen *et al.*, 1998)[7] using a puff diffusion parameterization. DERMA utilizes Numerical Weather Forecast data from the DMI-HIRLAM model or from the global model of ECMWF.

A feasibility study has been initiated on the possibility to transfer results of a RIMPUFF local-scale calculation to DMI and used as initial conditions for the DERMA run.

As indicated in the earlier sections it is not possible to transfer all data for 3D-modeling to the ARGOS system so alternatively result are transferred from DMI the ARGOS systems. Starting in the year 2000 and running for 3 years, DMI provides a 24 hours service for the Estonia, Latvia, Lithuania and Poland. On request dispersions calculations are executed and results are put on a FTP server. HIRLAM data for the local areas are also available 4 times pr. day and is routinely transferred to the countries.

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