CALCULATION OF THE FAR RANGE ATMOSPHERIC TRANSPORT OF RADIONUCLIDES AFTER THE FUKUSHIMA ACCIDENT WITH THE ATMOSPHERIC DISPERSION MODEL MATCH OF THE NUCLEAR EMERGENCY RESPONSE SYSTEM JRODOS USING THE FREELY AVAILABLE NWP DATA

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Abstract: The paper presents estimates of the planetary dispersion of radionuclides after the nuclear power plant accident at NPP Fukushima, obtained using the long-range atmospheric dispersion model MATCH included in the European nuclear emergency response system JRODOS. We developed software tools to run the long-range transport model MATCH in JRODOS, using freely available numerical weather prediction (NWP) data of the Global Forecasting System (GFS) of NCEP model and/or calculated with the WRF model. The calculation results indicate that the JRODOS/MATCH model, combined with the GFS data can be used in practice to estimate the effects of long-range transport of radionuclides after accidental releases. The comparison of the results of calculations of JRODOS/MATCH with the standalone MATCH operated by Swedish Meteorological and Hydrological Institute (SMHI) driven by ECMWF NWP data is presented.

Key words: *Long range atmospheric transport, ^{137}Cs, ^{131}I.*

INTRODUCTION

The experience of the accident at nuclear power plant Fukushima once again clearly demonstrated the need for automated decision support system for the evaluation of the radionuclides transport in air and water environment on the basis of operational numerical weather prediction (NWP) data. The famous example is the EU nuclear emergency response system RODOS developed from 1991 (Raskob, W., 2007) and it's recently developed redesigned version (Ievdin, I. et al., 2010). That system is installed in the emergency crisis centres in many European countries. At the time of the accident at Fukushima NPP the RODOS system, as well as the other systems such as the NARAC system (Sugiyama, G., et al. 2011) was quickly adapted for prediction of the pollution in case of release to the environment (Ievdin, I. et al., 2012, Dvorzhak, A., et al., 2012). Operational forecasts of radionuclides were produced by the JRODOS system only in the near zone up to 300 km from the plant. However shortly after the accident it became necessary to calculate the global atmospheric transport of radionuclides (Takemura, T., et al., 2011). During the accident, the JRODOS system was not fully prepared for the solution of this problem because existing in the JRODOS model of the far-range transport of radionuclides MATCH (Robertson, L. and Langner, J., 1999, Robertson L., 2010), worked only with the data from NWP model of the Danish Meteorological Institute HIRLAM and with the ECMWF data. Freely available data of the Global Forecasting System (GFS) operated by NCEP and distributed through the NOMADS platform (Rutledge, G. et al., 2006) could not be used by JRODOS for MATCH calculations. Therefore, one of the priorities of the JRODOS system development after the accident was the creation of the possibility of launching a far-range transport model MATCH based on the freely available NWP data of the GFS model and/or calculated with the famous WRF mesoscale meteorological model.

PREPARATION OF NWP DATA

In order to run MATCH on the particular NWP data set it is necessary to bring the NWP data to the format of HIRLAM model. In particular the following steps are to be fulfilled: 1) interpolate the data for NWP model on vertical levels HIRLAM; 2) convert from an existing set of meteorological parameters to parameters which are output by HIRLAM; 3) write data into the format of the World Meteorological Organization GRIB. The software tools for the conversion of the NWP data of the GFS model and calculated with WRF to the formats required by MATCH were developed. Created software tools will be included in a future updates of the JRODOS system.

Testing MATCH calculations based on data from WRF and GFS models was performed as follows. First, we calculated meteorological fields with WRF at distances up to 400 km from the Fukushima NPP on the grid with a spatial resolution of 0.15 degrees. Atmospheric dispersion was calculated on the basis of the WRF data using

MATCH and the RIMPUFF- based local scale model chain LSMC of RODOS. Comparison of the results of both calculations showed good agreement of cloud's shapes, and point values of the integrated concentration in air which coincided with an accuracy of about 10%. However, the average lebels dry deposition of Cs-137 calculated with both models differed by the factor of about 2; this probably could be explained by differences in the parameterizations of dry deposition.

At the next step we compared the results of MATCH, calculated using the WRF data with 15 km resolution, and calculated using the GFS model data with 1 dec. deg. resolution. Note that the same GFS data were used in the calculations of WRF to define the boundary and initial conditions. Due to differences in the spatial resolution of both models (0.15 degrees for WRF model, and 1 deg. for GFS) point comparisons were not possible. However, the direction of propagation and concentrations in the surface layer integrated over time and over space coincided with good accuracy. This testing has confirmed the correctness of the preparation of NWP data for MATCH.

RESULTS OF CALCULATIONS

Below we present results of calculations obtained in 3 runs:

1. (Run 1) JRODOS-MATCH results with the *adapted* source term of Stohl et al (2012) and using GFS meteorological data
2. (Run 2) JRODOS-MATCH results with the conservative source term used in operational JRODOS applications for Fukushima + GFS data
3. (Run 3) SMHI-MATCH (standalone) results with the *full* source term of Stohl et al (2012) and using ECMWF meteorological data

Runs 1 and 2 had been performed with the limited-area version of MATCH which is integrated in JRODOS while run 3 had been performed with the hemispheric version. In runs 1, 2 the GFS data at 1 dec. deg. resolution had been used while the ECMWF data for run 3 were available at 0.2 dec. deg. resolution.

In the 1st run the adaptation of the source term of Stohl et al. (2012) had to be made because of limitations of MATCH in JRODOS: only 4 release intervals with 1 release height/interval are allowed. The period of release had been splitted in 4 periods (see Table 1) with periods 1 and 3 covering the time of the most significant peaks of release and the average height of the center mass of the plume had been calculated for each of the periods.

Table 1. Source term of Stohl et al (2012) modified by usage in JRODOS.

No.	Start	End	Q [Bq]	H [m]
1	11.03, 18h	13.03, 0h	4.1E15	300
2	13.03, 0h	14.03, 3h	2.4E15	132
3	14.03, 3h	15.04, 12h	1.7E16	108
4	15.03, 12h	20.03, 12h	9.3E15	120

In the 2nd run the total amount of emission of Cs-137 was specified equal to $2.6 \cdot 10^{16}$ Bq released at 50 m height during 48 h starting from March 14, 2011, 0 h. This source term was used in operational runs of JRODOS during the phase of accdent (Ievdin, I. et al., 2012) and it was obtained from published by that time estimates of different agencies. This estimate appeared to be a compromise between the less conservative estimate ($1.2 \cdot 10^{16}$ Bq) of the Japanese Agency of Nuclear and Industrial Safety (NISA) and the more conservative estimates ($2.1 \cdot 10^{16} - 5.31 \cdot 10^{16}$ Bq) obtained on the basis of solving the inverse problem in (Stohl, A. et al., 2012).

Figures 1 and 2 show the calculated spatial distribution of the instantaneous concentrations of Cs-137 in the surface layer. As it is seen from the presented results in all 3 runs model predicts well the plume arrival time as reported by CTBTO stations (large circles). The fine structure of the plume leading to plume arrival at the Midway station, located between western and eastern parts of the plume (Figure 2) is not predicted in Run 2 in which source term was oversimplified and as consequence of this plume arrival to Midway station in Run 2 is delayed.

Figure 3 shows the total deposition calculated with MATCH in 3 runs (by March, 30). Shapes of deposition distribution in Runs 1 and 3 overall agree between each other. Results of Run 2 disagree with the results of Runs 1 and 3 close to Fukushima due to oversimplification in source term in Run 2. According to measurement data taken by USGS (Wetherbee, G.A. et al., 2012) the average level of deposition on the US territory is well reproduced by the results of MATCH presented in Fig. 3.

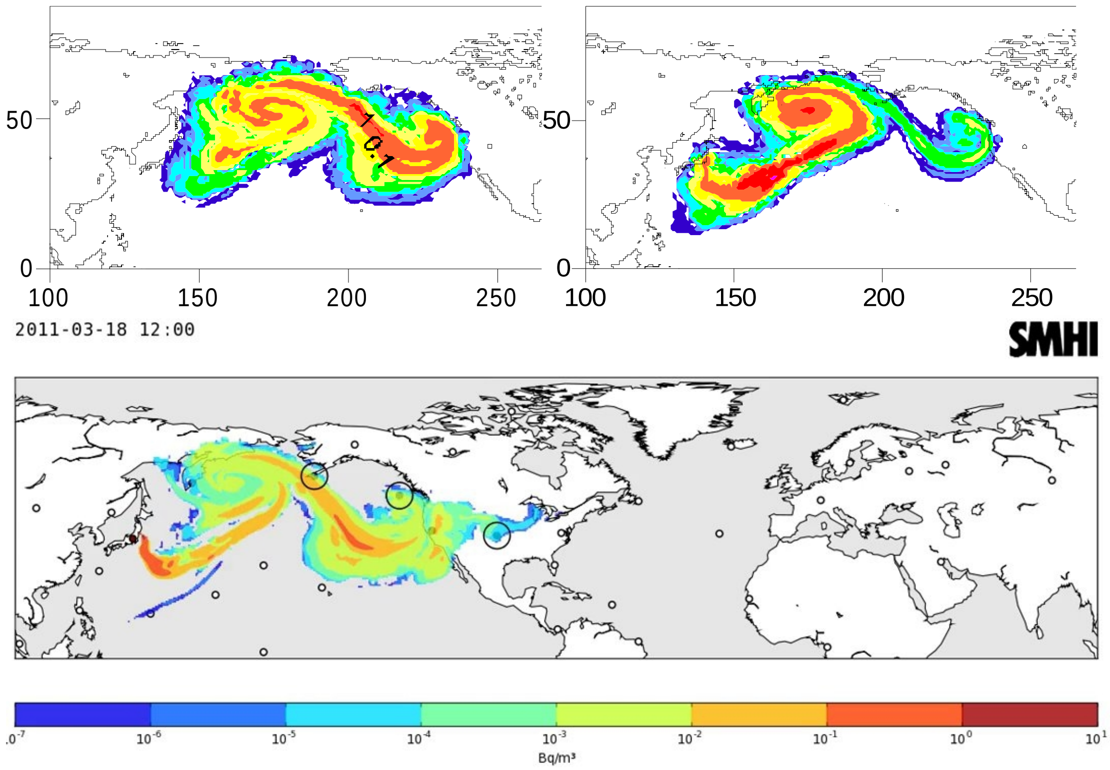

Figure 1. Instantaneous concentrations of Cs-137 (Bq/m^3) following the accident at Fukushima NPP, calculated with MATCH near the USA territory by 18 March, 2011, 12 h (upper left – Run 1, upper right – Run 2, bottom – Run3). Small circles designate the positions of CTBTO stations. Large circles appear near those stations that reported plume arrival at the time for which plume is shown.

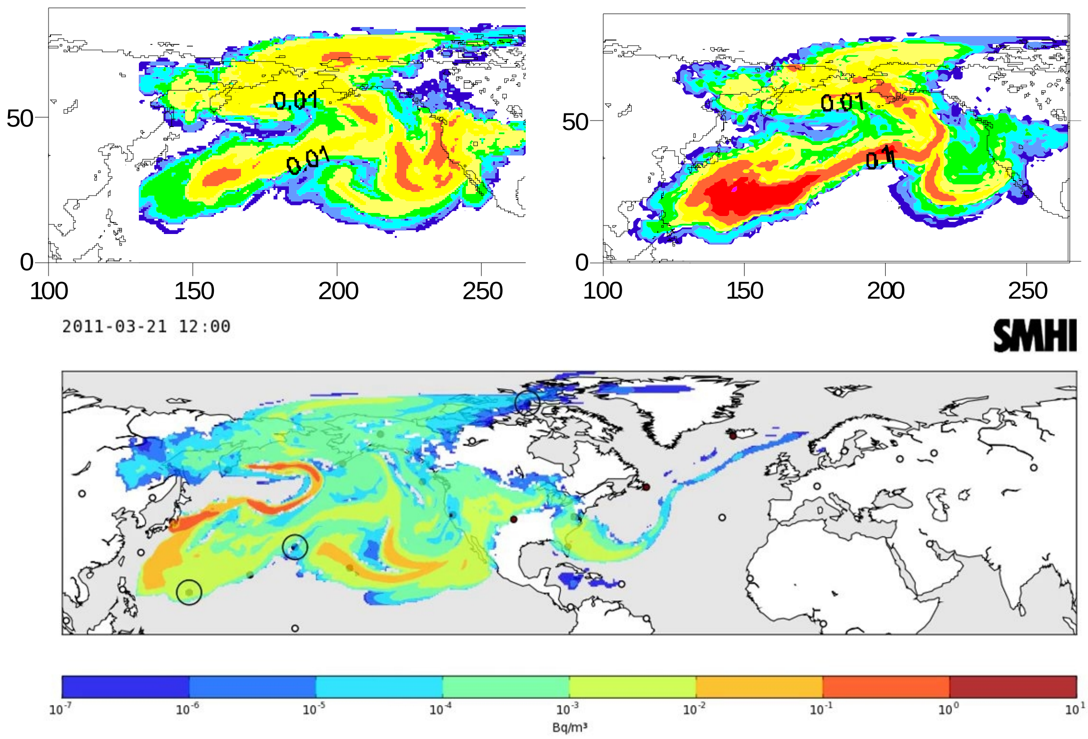

Figure 2. Instantaneous concentrations of Cs-137 (Bq/m^3) following the accident at Fukushima NPP, calculated with MATCH near the USA territory by 21 March, 2011, 12 h (upper left – Run 1, upper right – Run 2, bottom – Run3). Small circles designate the positions of CTBTO stations. Large circles appear near those stations that reported plume arrival at the time for which plume is shown.

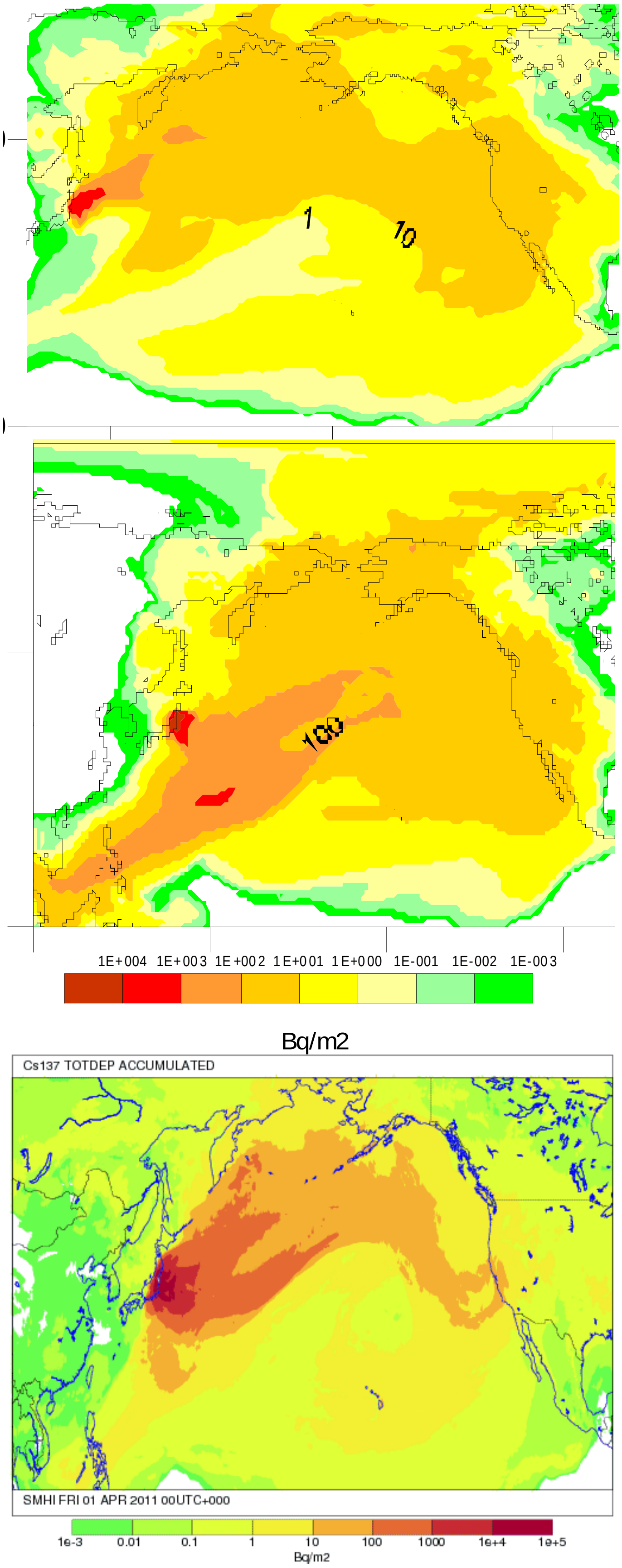

Figure 2. Deposition of Cs-137 (Bq/m^2), calculated with MATCH in Northern Hemisphere by 30 March, 2011 (upper – Run 1, middle – Run 2, bottom – Run3).

CONCLUSIONS

Software tools had been developed which allowed running the MATCH model in JRODOS, using freely available NWP data of the Global Forecasting System operated by NCEP, as well as NWP data calculated with WRF.

MATCH driven by both ECMWF and GFS NWP data well predicts complex shape of the plume (as far as this can be judged by plume arrival times reported by CTBTO stations). On average MATCH is also able to reproduce the deposition of Cs-137 at the West Coast of USA as compared to USGS measurements.

Simplifications in source term of Stohl et al (2012) (only 4 release intervals and 1 point release per each interval) don't preclude MATCH of producing useful results which are in the far-field of comparable quality (in terms of plume shape) with the results obtained by using full source term of Stohl.

In future developments it would be beneficial to integrate hemispheric version of MATCH in JRODOS and also to enable the more detailed source term description

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