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The ability to use FLEXPART in simulation of the long-range radioactive materials dispersed from nuclear power plants near Vietnam border

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Abstract: FLEXPART is a Lagrangian transport and dispersion model suitable for the simulation of a large range of atmospheric transport processes. FLEXPART has been researched and applied in simulation of the long-range dispersion of radioactive materials. It can be applicable to the problem of radioactive materials released from the nuclear power plants impact on Vietnam. This report presents simulation of radioactive dispersion from the accident assumed Fangchenggang and Changjiang nuclear power plants in China with the FLEXPART, using meteorological data from the National Centers for Environmental Prediction (NCEP). The results of simulations and analyzing showed good applicability of FLEXPART for a long-range radioactive materials dispersion. The preliminary simulation results show that the impact of the radioactive material dispersion in Vietnam varies by the well-known characteristics of the monsoon of our country. Winter is the time when the dominant northeast winds up radioactive dispersion most towards our country, its sphere of influence extends from the Northeast (Quang Ninh) to North Central (Da Nang).

Keywords: *FLEXPART, NCEP, Lagrangian model, Nuclear power plant, Changjiang, Fangchenggang, Long-range, Radioactive dispersion*

I. INTRODUCTION

The long-range radioactive materials dispersion model

Through the accidents occurred at the Chernobyl nuclear disaster in 1986 or the Fukushima Daiichi nuclear disaster in 2011, the atmospheric dispersion problem of radioactive masterials from nuclear power plant (NPP) accidents are not only concerned by the countries in the world, but it's also very concerned in Vietnam.

Currently, there are many models of radioactive dispersion that are being studied and developed in the world[1]. It's using the available meteorological data system to solve the problem of the long-range radioactive dispersion. Many of the dispersion models are being developed and accepted for use in many countries as well. Such as:

- U.S: The common models and are recommended for use by the U.S. Environmental Protection Agency (U.S. EPA)

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such as AERMOD, CALPUFF, HYSPLIT, BLP, CALINE3, CTDMPLUS, OCD. Other models are ADAM, AFTOX, ISC3, PANACHE, SCIPUFF, SDM, PUFF-PLUME…

- EU: The common model such as AEROPOL (Estonia), ATSTEP (Germany), BUO-FMI (Finland), DISPERSION21 (Sweden), GRAL (Austria), HAVAR (Czech Republic), MSS (France), PLUME (Bulgaria), EK100W (Poland)… Especially, FLEXPART (Austria/Germany/Norway) was used in this report.

The FLEXPART model was developed by Andreas Stohl and is provided as open source[2], the FLEXPART model is currently concerned by the government agencies, organizations and scientists for applied research and development. FLEXPART is a Lagrangian transport and dispersion model suitable for the simulation of a large range of atmospheric transport processes, with dry and wet deposition process or radioactive decay. It can be applicable to simulation of radioactive masterials dispersion or air pollutants. The meteorological input data are based on the European Centre for Medium-Range Weather Forecasts (ECMWF)[3] or the United States National Centers for Environmental Prediction (NCEP)[4]. The next version of FLEXPART[5] is currently being developed by the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in collaboration with the Geophysical Institute at the University of Alaska Fairbanks (UAF), Central Institution for Meteorology and Geodynamics (ZAMG) and Vienna Applied Science, Software and Technology (AWST).

In Vietnam, the atmospheric dispersion problem of radioactive masterials are also being studied by organizations and scientists, such as Institute for Nuclear Science and Technology, Dalat Nuclear Research Institute, Hanoi University of Science - Vietnam National University, Hanoi University of Science and Technology… However, the study of these organizations is mostly used Gaussian model to calculate radiation dispersion. The downside of this model is simulated short-range, it's suitable for scenarios of the short-range atmosphere release of radioactive materials, e.g., impact assessment of nuclear power plants to the population zone around the plant. FLEXPART (FLEXible PARTicle dispersion model) use a Lagrangian transport and dispersion model[6], it's a new direction in research on the radioactive dispersion model combined with the meteorological data system provided by NCEP and ECMWF. It can be applicable for the radioactive dispersion scenarios affecting Vietnam. Hence, there is early warning information or fast incident response.

The Nuclear Power Plants near Vietnam border

The nuclear power plants near the border with Vietnam were largely built in China. As of November 2016, the People's Republic of China has 36 nuclear reactors operating with a capacity of 31.4 GW and 20 nuclear reactors under construction with a capacity of 20.5 GW[7]. In this report presents the results of simulated radioactive dispersion from Fangchenggang and Changjiang nuclear power plants (two plants nearest the Vietnam border).

Fig. 1. Nuclear power plants in China

The Fangchenggang Nuclear Power Plant is currently under construction in Fangchenggang, autonomous region of Guangxi in the People's Republic of China. The plant is located about 45 kilometes from the border with Vietnam. A total of six reactors are planned to operate at the Fangchenggang site. All reactors are pressurized water reactors (PWR). Units 1 and 2 are both CPR-1000s and commercially operating starting on 1 January 2016 and 1 October 2016, respectively. Units 3–4 are planned to be based on Hualong One reactor, Unit 3 has started construction in December 2015. Unit 5-6 are both AP1000 and currently no information construction.

The Changjiang Nuclear Power Plant is built on China's Hainan Island, about 250km from the border with Vietnam. A total of four reactors are planned to operate at the Changjiang site, All reactors are pressurized water reactors (CNP-600) with a capacity of 610 MW. Unit 1 and unit 2 are commercially operating starting on 25 December 2015 and 12 August 2016, respectively.

Fig. 2. Satellite image of Fangchenggang NPP[8]

Fig. 3. Satellite image of Changjiang NPP[8]

II. SIMULATION OF THE LONG-RANGE RADIOACTIVE MATERIAL DISPERSION FROM THE NUCLEAR POWER PLANTS NEAR VIETNAM BORDER

This report presents the results of simulation of radioactive dispersion from the accident assumed Fangchenggang and Changjiang nuclear power plants in China impact on Vietnam with the FLEXPART. We assume the incident radiation release at both plants occur in level 7 major accidents on the International Nuclear Event Scale (INES)[9]. We have been simulating radioactive dispersion through all months of the year. After that, we determine the characteristics of the radioactive isotope dispersion from both plants through months. In previous studies of our team, we use FLEXPART to simulation of the long-range radioactive masterials dispersed from Fukushima Daiichi nuclear disaster. After that, we have compared it with the simulation results of Stohl[10], and compared with CTBTO[11] and Vietnam[12] monitoring data. Therefore, we can see this application of FLEXPART for the long-range radioactive materials dispersion into the atmospheric.

Table I. The input parameters for simulation of radioactive dispersion

	Fangchenggang NPP	**Changjiang NPP**
FLEXPART Version	FLEXPART v9.02	FLEXPART v9.02
Operating system	Red Hat Enterprise Linux Server 5.5 and Ubuntu 14.04 LTS	Red Hat Enterprise Linux Server 5.5 and Ubuntu 14.04 LTS
Radionuclide	Cs-137, I-131, Xe-133	Cs-137, I-131, Xe-133
Meteorological data	NCEP CFSv2 25/10/15 – 30/9/16	NCEP CFSv2 7/11/2015 – 30/9/16
Time of simulation	1 month	1 month
Time of release	1 month	1 month
Latitude/ Longitude	21.666, 108.566	19.460, 108.899
Total number of particles to be released	1 million particles	1 million particles
Height of level	500m	500m

A. Source of meteorological data

The meteorological data be provided by the United States National Centers for Environmental Prediction (NCEP) Climate Forecast System Version 2 (CFSv2)[13]. Data format is GRIB2, it's available at 0.5 degree horizontal resolutions from 0E to 359.5E and 90N to 90S (720 x 361 Longitude/ Latitude). The meteorological data used in the report were collected starting at the time when the first unit of Fangchenggang and Changjiang nuclear power plants were connected to the electricity grid from 25 October 2015 and 7 November 2015 to current, respectively.

B. Simulation of the radioactive dispersion from the nuclear power plants

In this report, we use FLEXPART combined with the meteorological data collected from NCEP. The input parameters for simulation in the table above. Table I gives some important input parameters for simulations of radioactive dispersion from Fangchenggang and Changjiang nuclear power plants to Vietnam. We focus on simulation of dispersion Cs-137 isotope for each month, starting at the coordinates of the two nuclear power plants. We use FLEXPART version 9.02 for simulation calculations on supercomputer of the Institute for Nuclear Science and Technology (RHEL 5.5) and personal computers (Ubuntu LTS 14.04). The FLEXPART output data is processed by QuickLook that was written in the Python language and developed by Radek Hofman[14]. Through that, we obtained the simulation results of the Cs-137 isotope from both plants to Vietnam.

C. Simulation results

Figure 4 is a few pictures simulated of radioactive masterials dispersion from the Fangchenggang nuclear power plant for the months (11, 1, 3, 4, 5, 7) of 2015-2016. We see clearly characterized radioactive dispersion for each month of the characteristics of the Vietnam monsoon.

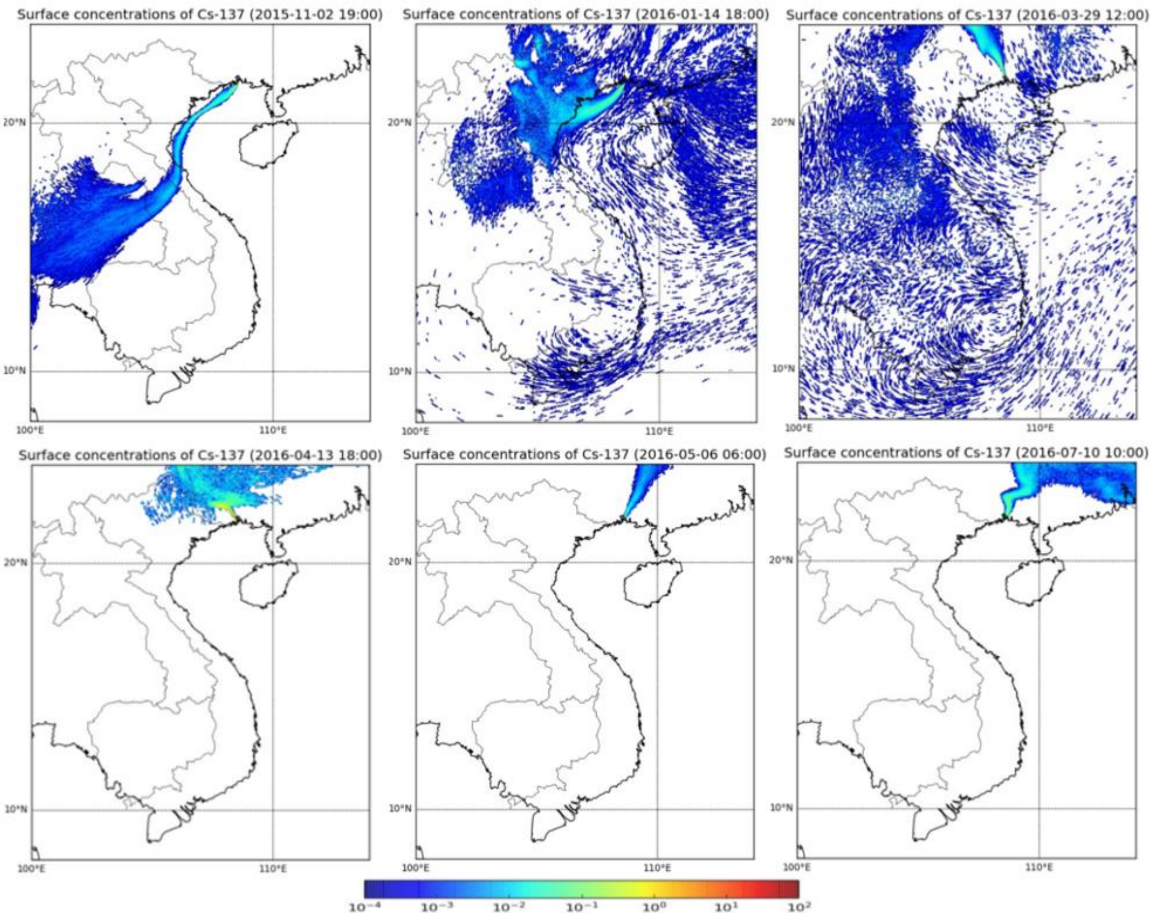

Fig. 4. Some images simulated radiation release from the Fangchenggang NPP

For example, the beginning of winter in November has the wind blowing from the Siberian high-pressure, it makes radioactive dispersion towards Northeast that impacts most coastal provinces in the Northeast, Red River Delta and North Central Coast Vietnam. Or at the end of winter in March, the Siberian high-pressure is largely replaced by the Asiatic low-pressure, has the wind blowing from the sea to the land combined with trade winds blowing through the Gulf of Tonkin that makes radioactive dispersion towards Southeast and also impacts most coastal provinces in the Northeast, Red River Delta and North Central Coast Vietnam. When the seasons change to Summer, this time the wind blows from the North Indian Ocean in early summer, that makes radioactive dispersion towards Southwest, so it does not affect much our country in this time. e.g. in May-July 2016 in the figure 4.

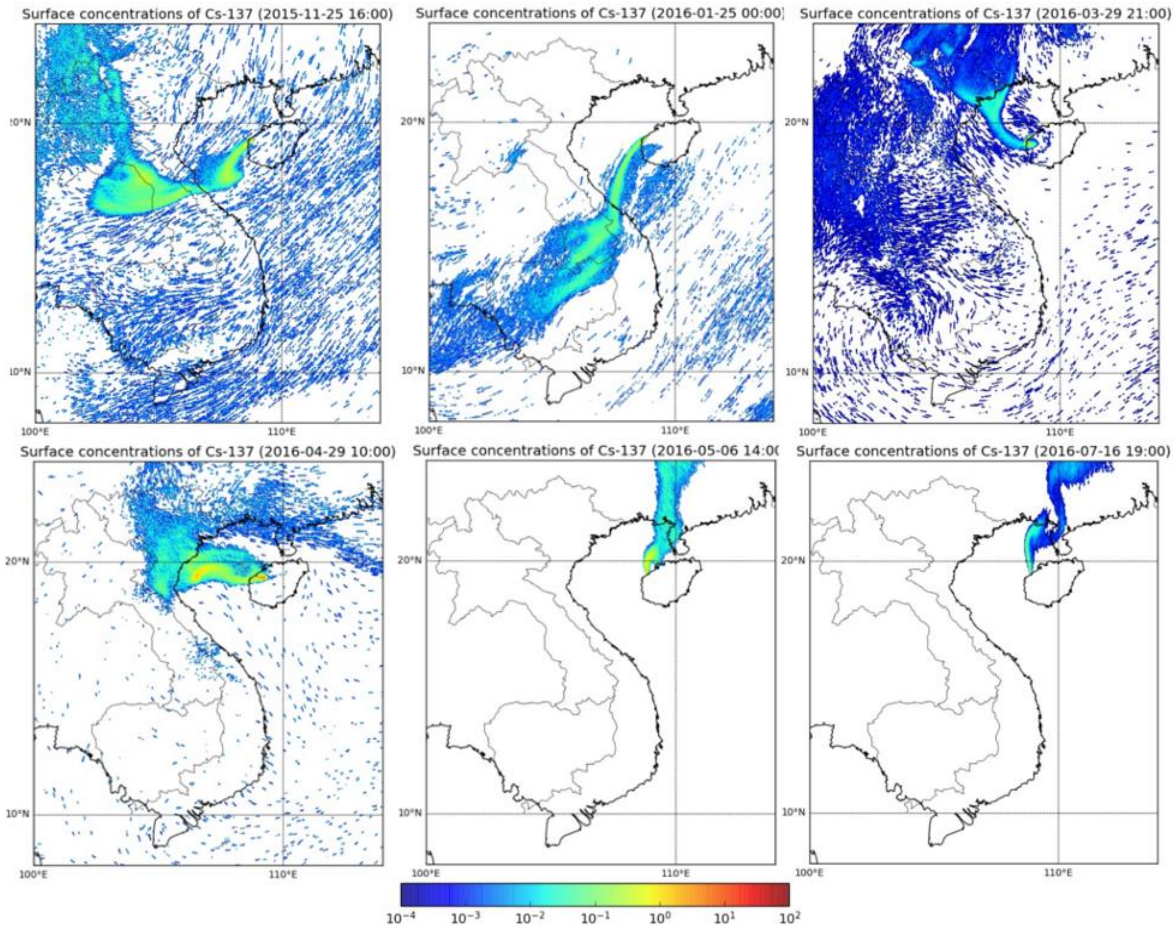

Fig. 5. Some images simulated radiation release from the Changjiang NPP

Similarly, to simulate dispersion from the Changjiang nuclear power plant, caused by two plants locatted near Vietnam border, thus the radioactive dispersion follow the characteristics of the monsoon of our country. The radioactive dispersion also affect our country on the winter and less impact on the summer from Changjiang NPP.

Through the simulation results, the radioactive dispersion from two nuclear power plants of China to our country has a large frequency and sphere of influence in the winter months due to the northeast monsoon prevails. During the summer season, the radioactive dispersion to our country has a small frequency and sphere of influence due to the southwest monsoon prevails. Most affected areas in the winter are the coastal provinces from the Northeast (Quang Ninh) to North Central (Da Nang).

The characteristics of the Cs-137 radioactive isotope dispersed from Fangchenggang and Changjiang NPP in the first nine months of 2016

Calculations based on the simulation results obtained from FLEXPART, from which we draw the map of the total activity concentration of the Cs-137 radioactive isotope (Bq/m^3) to our countries. Figure 6, 7 below shown the characteristics of the Cs-137 isotope in the first nine months of 2016. The amount of radioactive material being released from the Fangchenggang and Changjiang NPPs, respectively.

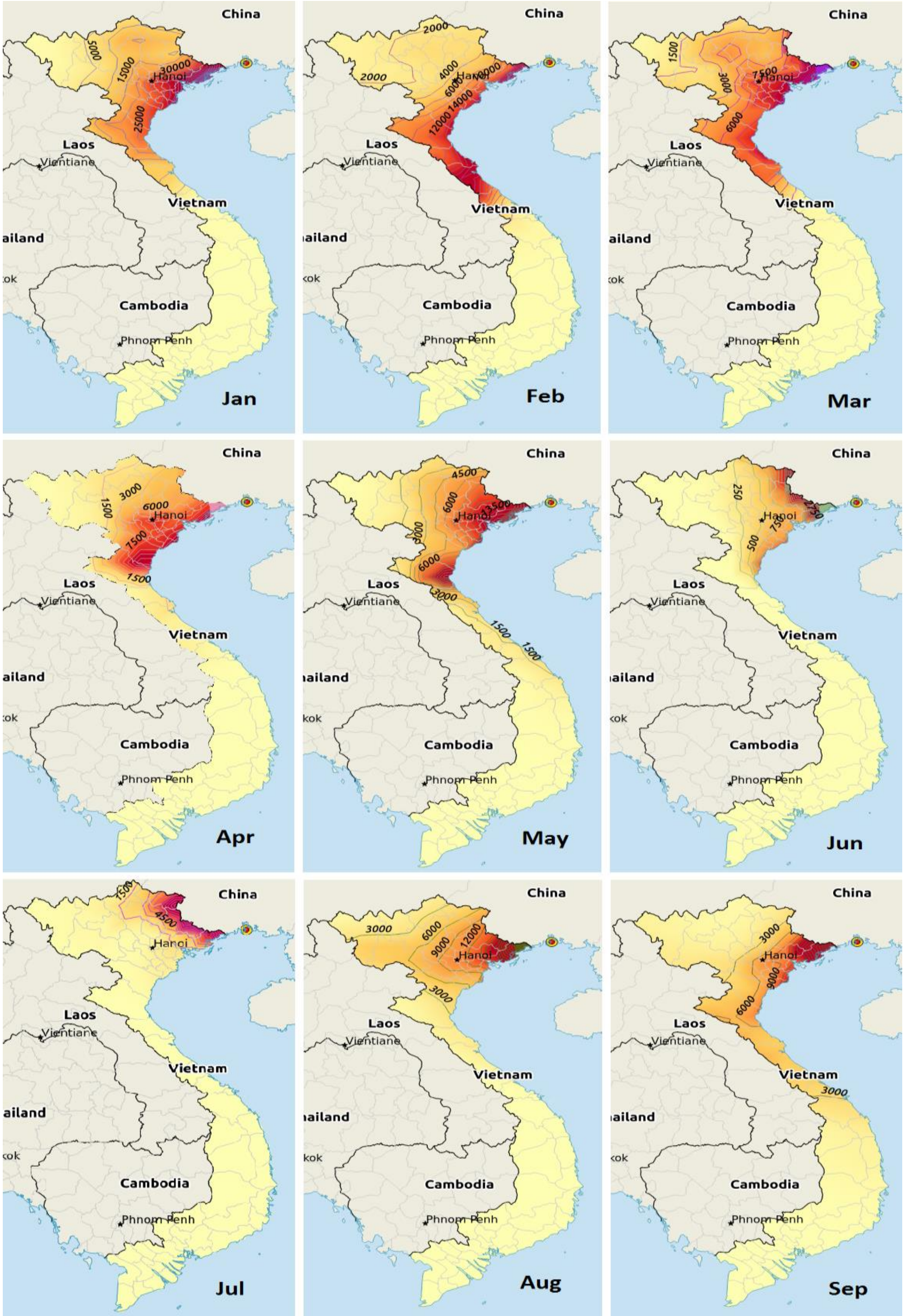

Fig. 6. The characteristics of the Cs-137 radioactive isotope dispersed from Fangchenggang NPP

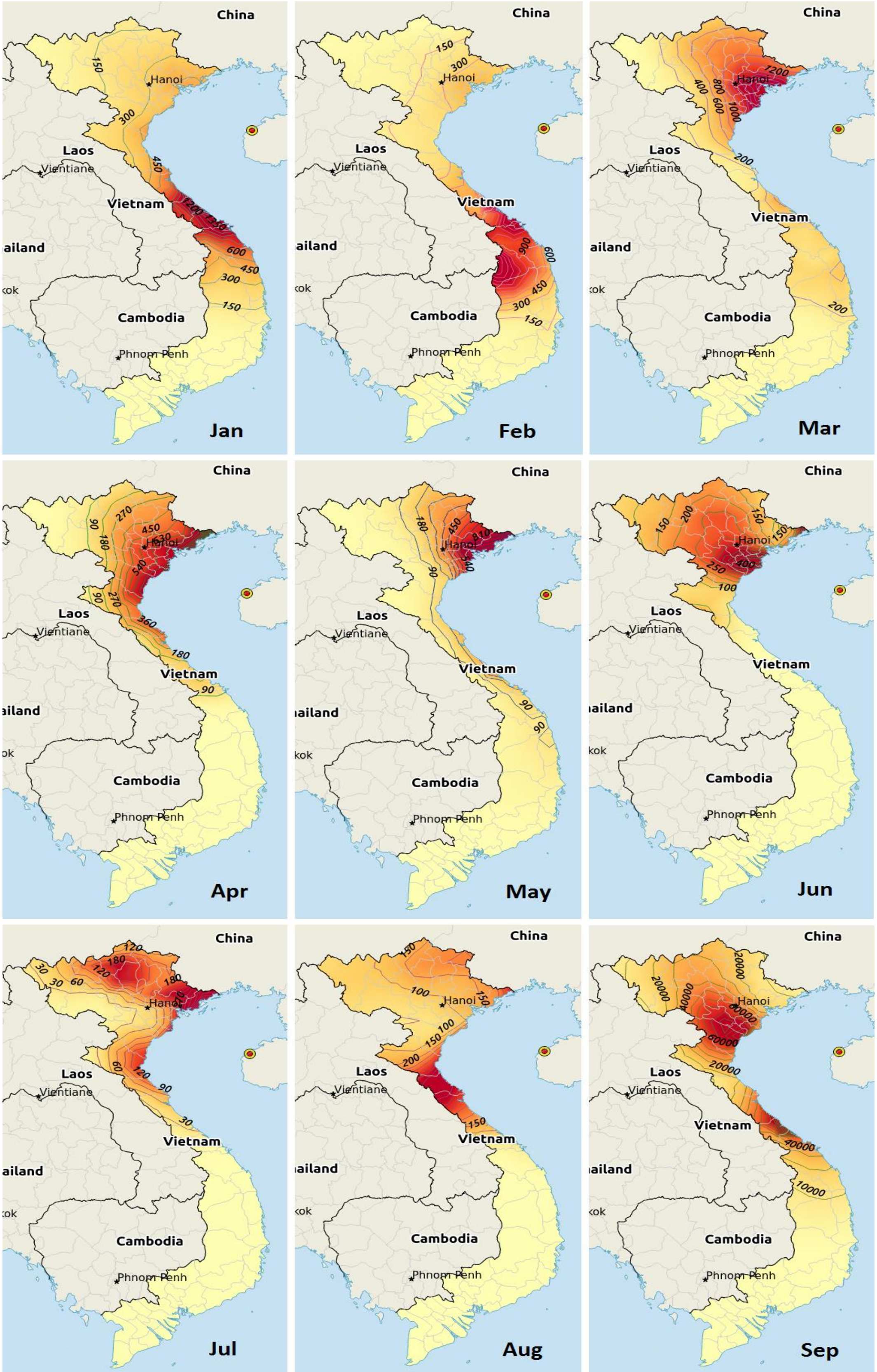

Fig. 7. The characteristics of the Cs-137 radioactive isotope dispersed from Changjiang NPP

III. CONCLUSIONS

Currently, our team is continuing to study more tools to help simulate the long-range radioactive dispersion, and choosing the dispersion models that are accepted for use in many other countries, organizations and scientists as well. Our research focuses primarily on the Lagrangian particle dispersion model - FLEXPART. The results of simulations and analyzing showed good applicability of FLEXPART for the long-range radioactive materials dispersion into the atmosphere. Specifically, there are two nuclear power plants near the Vietnam border, the preliminary simulation results show that the impact of the radioactive material dispersion in Vietnam varies by the well-known characteristics of the monsoon of our country. Through the simulation results, the radioactive dispersion from two nuclear power plants of China to our country has a large frequency and sphere of influence in the winter months due to the northeast monsoon prevails. During the summer season, the radioactive dispersion to our country has a small frequency and sphere of influence due to the southwest monsoon prevails. Most affected areas in the winter are the coastal provinces from the Northeast (Quang Ninh) to North Central (Da Nang). Hence, there is early warning information of radioactive dispersion or fast nuclear incident response.

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