POLLUTION FORM IN NUCLEAR DISASTERS DEPENDING ON METEOROLOGICAL CONDITIONS

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ABSTRACT: Four nuclear disasters occurred in Hiroshima, Ural, Chernobyl, and Fukushima, and showed four different pollution forms. On August 6, 1945, an atomic bomb was fallen down over Hiroshima city. An fire ball fired this city with victims of 166,000 and black rain polluted the victims. From an aerial photo by B29, the shape of black rain was estimated and fitted with the victim testimony. In Russia, two serious disasters occurred in Ural on September 29, 1957 and Chernobyl on April 26, 1986. Radioisotopes distributed with 20 million Ci in Ural and 24 billion Ci in Chernobyl, Russia. These radioisotope distribution areas were compared in form. Both pollution patterns were quite different. The form of nuclear pollution depends on mainly the terrain and rainfall forms: low pressure and cold front. On the other hand, in Japan, atomic bombs were dropped at Hiroshima and Nagasaki on August 9, 1945, and nuclear power plant accident occurred in Fukushima on March 11, 2011. In these accidents, rains and snow fell down with big amount of radioisotopes. The terrain and meteorological conditions determined pollution forms each nuclear disaster mainly.

1. INTRODUCTION

Four nuclear disasters occurred in Hiroshima (1945), Ural (1957), Chernobyl (1986), and Fukushima (2011), and showed four different pollution forms. At 8:15 on August 6, 1945, Enola Gay fell down an atomic bomb over Hiroshima city and the death number was 166,000. After the exposure, the comprehensive research was carried out: meteorology, radio isotopes, and medical researches (Science Council of Japan, 1953). But the delayed effects for the victims continued and judicial actions repeated: Black Rain case, which requested the wide range of black rain (Yagasaki, 2017). Here, from the original data and aerial photos (Committee for the compilation of materials on the damage by the atomic bombs in Hiroshima and Nagasaki, 1979), the shape of black rain was estimated and examined.

In Russia, two serious disasters occurred in Ural (Medvedev, 1979; Brown, 2013; Hirokawa, 1992) and Chernobyl (Imanaka, 1998; Fujita, 1992). Radioisotopes distributed with 20 million Ci in Ural and 24 billion Ci in Chernobyl, Russia. These radioisotope distribution areas were compared in form. Both pollution patterns were quite different from Hiroshima and Fukushima. The form of nuclear pollution depends on mainly the terrain and rainfall forms: low pressure and the cold front.

2. METHODS

2.1 Meteological data

Meteorological data in Hiroshima were obtained from Committee for the compilation of materials on the damage by the atomic bombs in Hiroshima and Nagasaki (1979). Meteorological data in Chernobyl were obtained from Fujita (1992). Meteorological data in Fukushima were obtained from Meteorological Agency, Japan. Meteorological data in Ural were not obtained.

2.2 Aero photographs

An aerial photo by B29 (Fig. 1) and the estimate of black rain range of the court evidence (Fig. 4) were used for the research. The former was shot at 80km South-south-east from Hiroshima city after one hour bomb drop. The photo was cut with the black rain range, digitized, and adjusted horizontally. Finally, the two figures were superimposed and examined.

2.3 Image processing

An aerial photo by B29 was processed by extension, rotating, binarization, and superimpose with Photoshop. All images for pollutions were analysed by Fractal. Fractal dimensions D were calculated by the next equation.

$$D=\log N/\log R \quad (1)$$

where N: the number of image pixels, R: the long size of images in pixel.

2.4 Simulations

Pollution estimate was calculated by a particle model and an atmospheric dispersion model (Saito and Ogawa, 2016; Saito, 2017).

3. RESULTS

The black rain area was estimated by image processing. Two plants in Russia were constructed through the gigantic rivers. But, Hiroshima and Fukushima were located in small rivers. Both Russian pollution forms were quite different with fractal dimensions, 1.43 and 1.53 from Hiroshima and Fukushima with 1.89 and 1.83. The former was related with meteorological conditions. The latter was related with river watershed shapes.

3.1 Black Rain in Hiroshima

As shown in Fig. 1, the atomic cloud appeared with 10.6km height and 17.5 km wide, while the black rain cloud extended 35km north-north- west with 1500m height. This part was cut and digitized, and extended horizontally to

fit the range of the estimated black rain in the court evidence in Fig. 4 (Fig. 5). Finally these two figures were superimposed (Fig. 6), and corresponded the victim testimony. Fractal dimension of black rain cloud was 1.89.

3.2 Nuclear Disaster in the Urals

In Maiak plutonium plant as shown in Fig. 7, nuclear waste was stored in the underground tanks as Fig. 8, but chemical explosion occurred in sunny weather to emit nuclear waste in laminar flow to northeast as Fig. 9. Fractal dimension of pollution was 1.43.

3.3 Chernobyl nuclear power plant disaster

In Chernobyl nuclear power plant as shown in Fig. 10, nuclear explosion occurred on April 26 in 1986 to emit 10 tons of radioisotopes in turbulent flow to west and north with rain as Fig. 11. Rain occurred on April 28 by the cold front. Pollution continued from April 26 to 28. First, east wind brought radioisotopes to Europe in dry deposit on April 26 to 28. Next, south wind brought radioisotopes to the border between Belarus and Russia in wet deposit at night on April 28. The cold front moved with cumulonimbus clouds from west to east in Belarus on April 28. Finally a third of Belarus land was polluted by serious radioisotopes to make many Chernobyl children. Fractal dimension of pollution was 1.53.

3.4 Fukushima nuclear power plant disaster

In Fukushima, the great earthquake with magnitude 9.0 occurred as an epicenter of Sanriku offshore and brought Tsunami to Fukushima Daiichi nuclear power plant on March 11, 2011. Three reactors lost the external power and became meltdown. Hydrogen explosions occurred four times and emitted great amount of radioisotopes. However, nuclear explosions never occurred. On March 15, the third reactor emitted radioisotopes to the air and snow clouds came over Fukushima from west. The wind direction was southeast. The northwest part of the nuclear power plant was polluted severely with distance of 40km. The fractal dimension of pollution was 1.83, similar to the watershed shape as shown in Fig. 14.

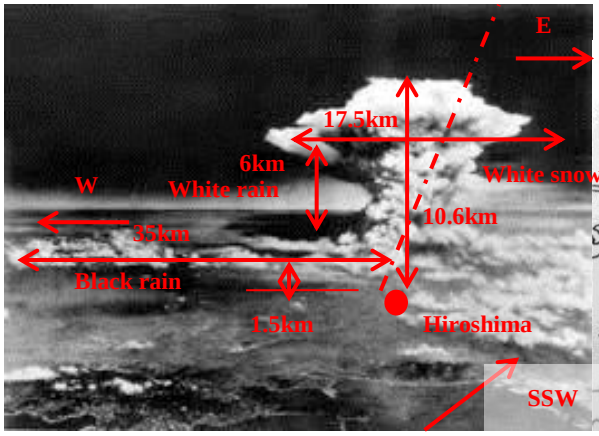

Fig. 1 Atomic cloud: aerial photo by B29.

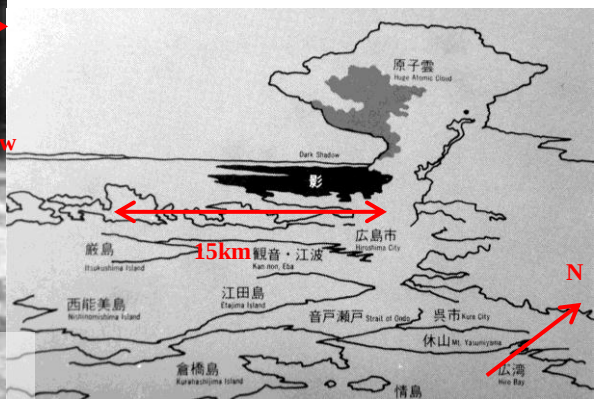

Fig. 2 Stereo-map of atomic cloud (Yagasaki, 2017)

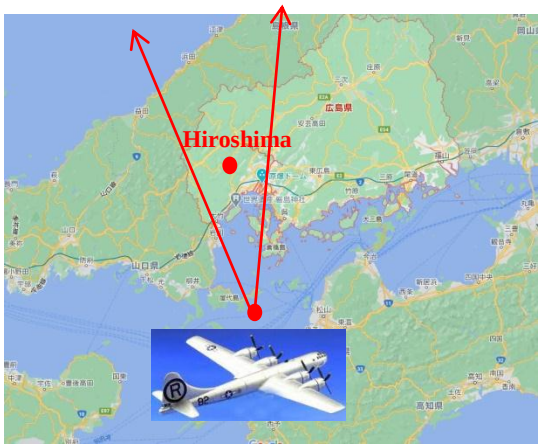

Fig. 3 Shot position and the angle of field.

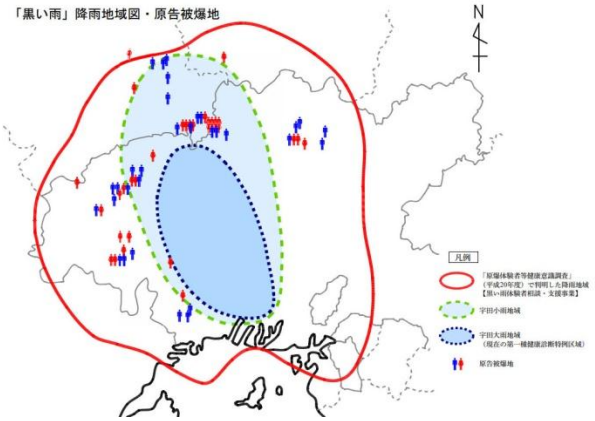

Fig. 4 Range of black rain (Yagasaki, 2017)

Fig. 5 Black rain shape estimate from the aerial photo

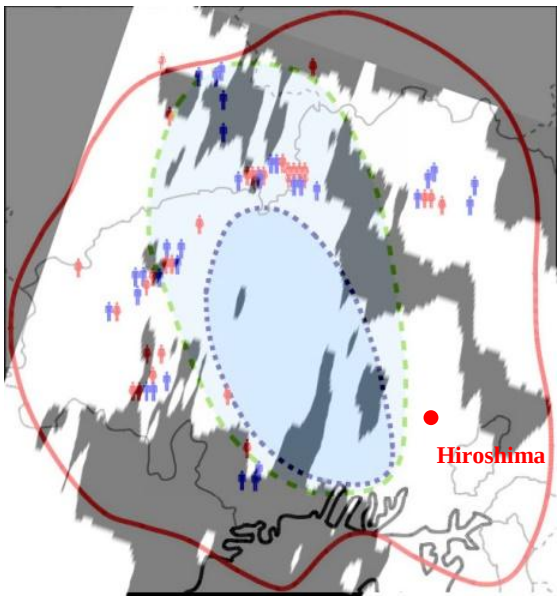

Fig. 6 Superimpose of black rain figures

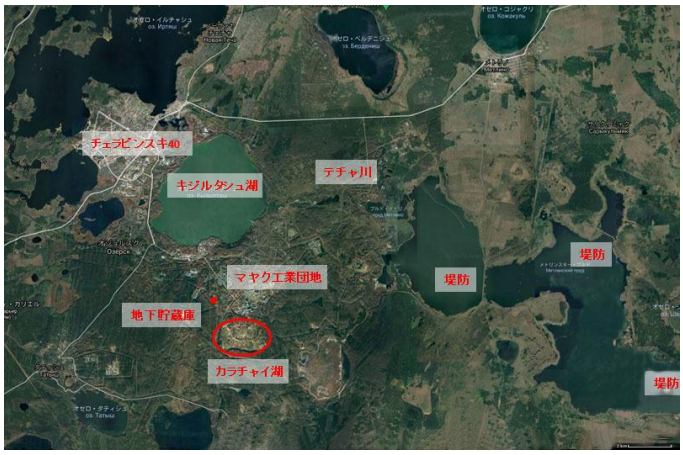

Fig. 7 Maiak plutonium plant and its underground tanks.

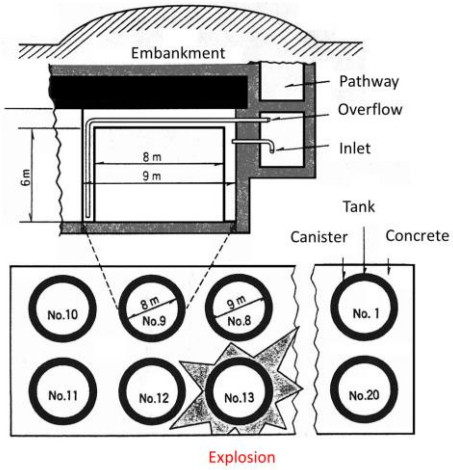

Fig. 8 Underground tanks in Maiak plutonium plant.

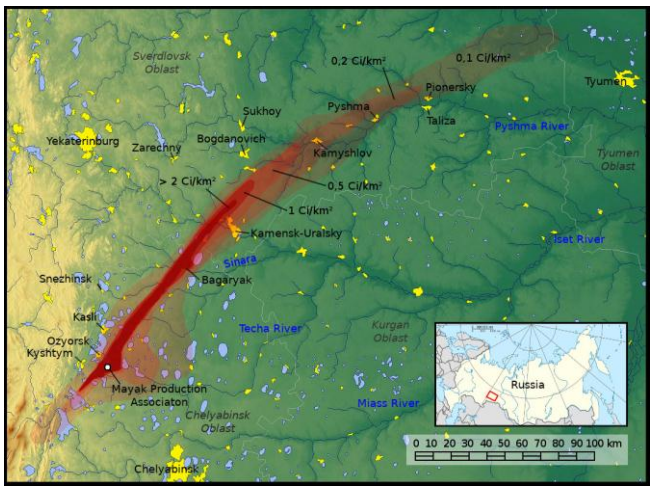

Fig. 9 Pollution map of Maiak plutonium plant.

Fig. 10 Chernobyl Nuclear Power Plant

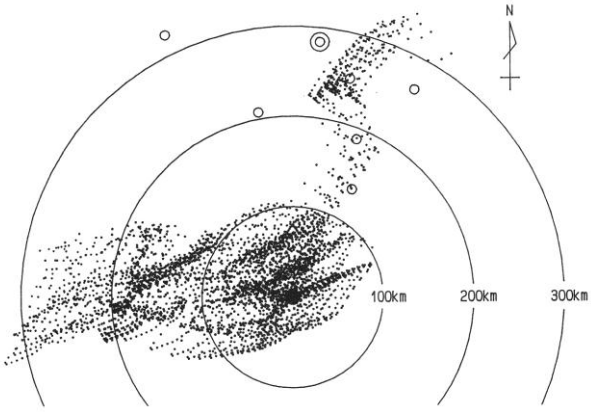

Fig. 11 Pollution map estimated from meteorological data.

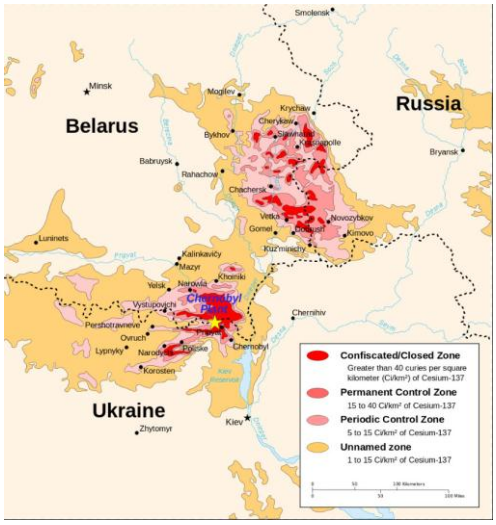

Fig. 12 Pollution map of Chernobyl Nuclear Power Plant

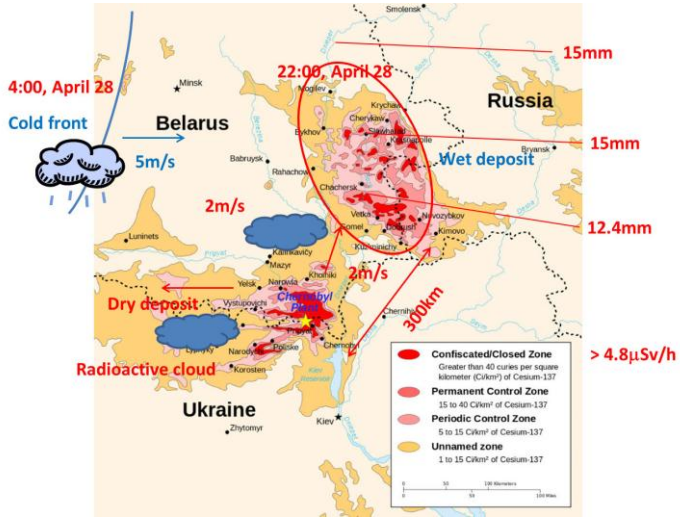

Fig. 13 Meteorological conditions in Chernobyl

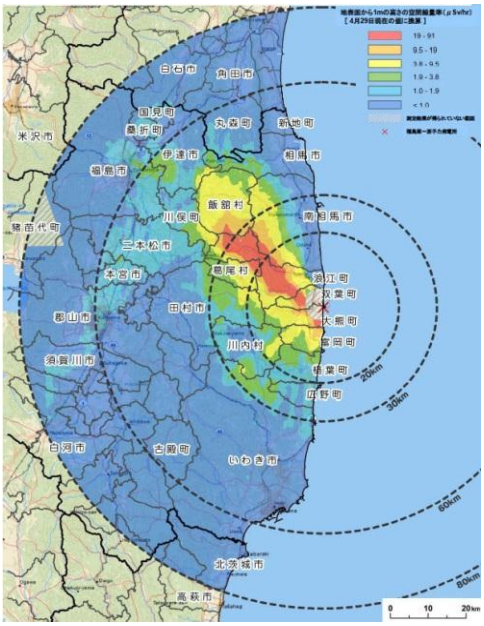

Fig. 14 ^{137}Cs pollution distribution in Fukushima

4. DISCUSSION

4.1 Black rain

After the bomb drop, the radioisotopes flew isotropically from the fire ball and distributed on the ground and in the atmosphere. The radioisotopes were oxidized and became white crystals like snow. On the other hand, vapour and fire made cloud over the ground. As a result, cumulus cloud appeared over 1.5 km height in the atmosphere and brought black rain. Moreover, the fire ball generated cumulonimbus cloud and made white rain.

4.2 Meteorological conditions

Four nuclear disasters were compared in total. Three of them were in wet deposit. Fractal dimensions were quite different. Hiroshima and Fukushima are the basins of middle scaled rivers, while Ural and Chernobyl are the plains of big rivers. Chernobyl pollution might be made by continuous rainfall on the cold front for Chernobyl radioisotopes.

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Table 1 Physical characteristics of four nuclear disasters

Location	Rainfall	Wind speed	Deposit	Flow type	Fractal dimension
Hiroshima	50mm	3m/s	Wet	Laminar	1.89
Fukushima	8mm	0.9m/s	Wet	Turbulence	1.83
Ural	0mm	>3m/s	Dry	Laminar	1.43

Chernobyl	15mm	2m/s	Wet	Turbulence	1.53

5. CONCLUSIONS

From the aerial photo by B29, the black rain shape was estimated and fitted with victim testimony in Hiroshima. Two plants in Russia were constructed through the gigantic rivers. In Maiak plutonium plant, nuclear waste was stored in the underground tanks, but chemical explosion occurred to emit nuclear waste in laminar flow to northeast. In Chernobyl nuclear power plant, nuclear explosion occurred to emit radioisotopes in turbulent flow to west in dry deposit and north with rain by the cold front. Both pollution forms were quite different with fractal dimensions, 1.43 and 1.53. In Fukushima after gigantic earthquake hydrogen explosion occurred at the third reactor, Fukushima Daiichi nuclear power plant to emit serious radioisotopes to the basin of the Abukuma River under snow weather. Four nuclear disasters were compared in total. Three of them were in wet deposit. Fractal dimensions were quite different. Hiroshima and Fukushima are the basins of middle scaled rivers, while Ural and Chernobyl are the plains of big rivers. The form of nuclear pollution mainly depends on the terrain in Japan and the weather conditions in Russia.

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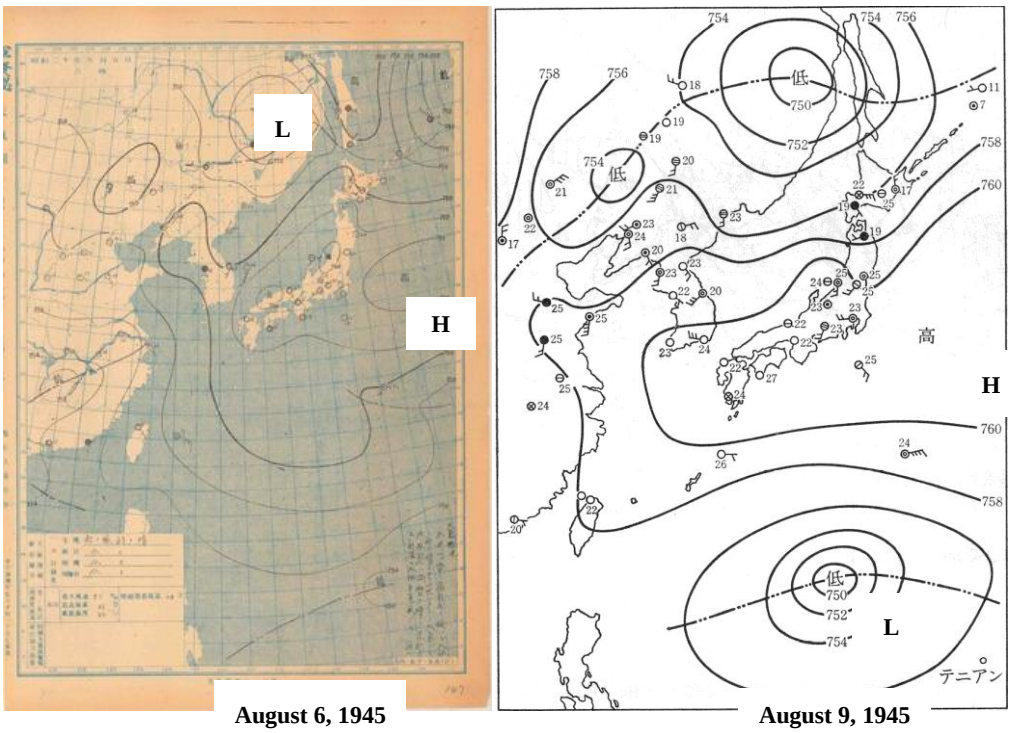
APPENDIX: Meteorological conditions

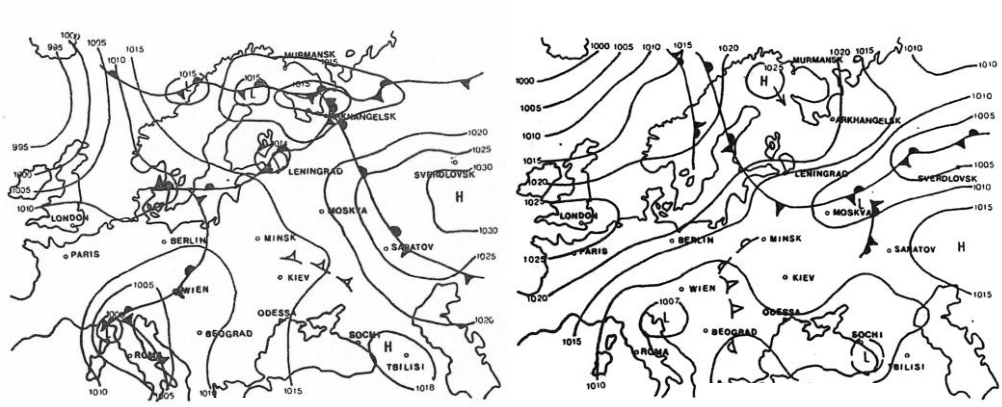
A1：Weather map of Hiroshima and Nagasaki, 1945



August 6, 1945 **August 9, 1945**

Fig. 15 Weather map of Hiroshima and Nagasaki, 1945.

A2: Weather map of Chernobyl, 1986



April 28, 1986 **April 30, 1986**

Fig. 16 Weather map of Chernobyl, 1986

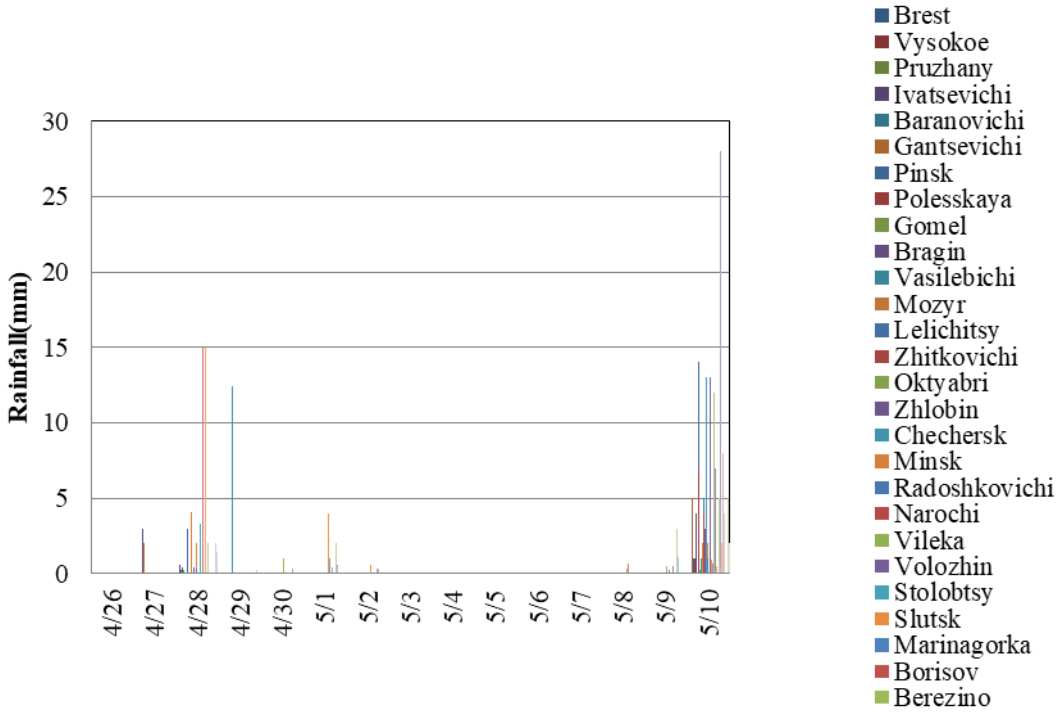


Fig. 17 Rainfall in Belarussi, April 26 to May 10, 1986

A3: Weather map of Fukushima, 2011

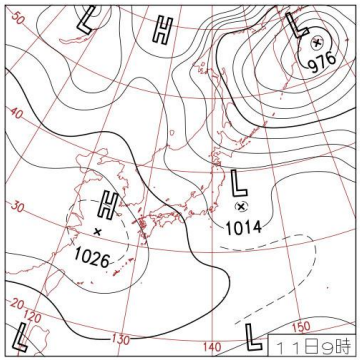


Fig. 18 Weather map in Japan, March 11, 2011