Fractal analysis for radioisotope pollution patterns by nuclear power plant accidents

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Abstract: The radioisotope pollution shows two types of patterns: dry and wet deposits for nuclear power plant accidents. Two surface pollution patterns were analyzed by fractal. In Fukushima nuclear power plant accident, surface pollution by wet deposits was estimated to occur. However, actually it was no rain and white crystals were observed on the surface. Then, fractal analysis was carried out for the spatial distribution patterns of radio isotopes on the surface to judge the types of deposits. As a reference, Chernobyl nuclear power plant accident was checked for the spatial distribution patterns of radioisotopes on the surface. The objective patterns by fractal analysis were the surface pollution maps in Fukushima and Chernobyl, Abukuma river watershed map, and NOAA/AVHRR. The calculation of fractal dimensions was carried out with the box counting for binarized images. Fractal analysis results suggested the next conclusions. The radioisotope pollution in Fukushima might occur in dry deposit. The dry deposit might make the pollution pattern similar to the watershed, while the wet deposit might make the pollution pattern similar to cloud images. Moreover, most radioisotope contaminants might flow on the road in the forest valley and deposit on forest without rainfall in Fukushima.

Keywords: NOAA/AVRR, Fukushima, Chernobyl, Fractal

1. Introduction

In Fukushima nuclear power plant accident, surface pollution by wet deposits was estimated to occur. However, actually it was no rain and white crystals were observed on the surface. Then, fractal analysis was carried out for the spatial distribution patterns of radio isotopes on the surface to judge the types of deposits. As a reference, Chernobyl nuclear power plant accident was checked for the spatial distribution patterns of radioisotopes on the surface.

2. Methods

The objective patterns by fractal analysis were the surface pollution maps in Fukushima and Chernobyl,

Abukuma river watershed map, and NOAA/AVHRR. The calculation of fractal dimensions was carried out with the box counting for binarized images.

2.1. Fractal analysis

Fractal is an irregular geometry with self-similar. Fractal is determined by fractal dimensions, which distribute 1 to 2 in two dimensional images. Fractal dimensions each image were measured by box counting method (Mandelbrot, 1982).

2.2. Overlapped maps

The pollution map in Fukushima and caused factor maps were overlapped and the rate of overlapping area was calculated or judged by visual check. The caused maps were a wind direction-speed map, a traffic network map, a land cover map, and a stream network map.

3. Results

3.1. Fractal dimensions

All the maps were shown in Figs 1 to 9. The results of fractal dimensions were shown in Tables 1 and 2. Fractal dimensions were quite different between Fukushima and Chernobyl nuclear power plant accident pollution patterns, respectively 1.83 and 1.53. Fractal dimension for Abukuma river watershed was 1.83, while fractal dimension for the cloud images in NOAA/AVHRR was 1.56 and accumulated rainfall image showed 1.59. It means that the surface pollution pattern in Fukushima corresponded to Abukuma river watershed, while the surface pollution pattern in Chernobyl corresponded to the cloud image in NOAA/AVHRR and accumulated rainfall. The other images are different from the pollution maps each.

3.2. Overlapped ratios

Overlapped pollution with caused factor maps are shown in Figs 10 to 13. Land cover ratios are shown in Table 3. Most of land covers are forest in Fukushima. Except a stream network, three caused maps are overlapped fairly. Therefore, wind trajectory, land cover, and traffic network might cause the pollution of radioisotopes in Fukushima as shown in Table 4. Each land cover has different roughness lengths. Wind flows in the valley, especially on the road. Pollution accumulated on forest and soils.

Table 1 Fractal dimensions each image in Fukushima

Object	Fractal dimension
Fukushima pollution map	1.83
Abukuma river watershed	1.83
Terra cloud (Fukushima)	1.26
Contour map (Fukushima)	1.62

Table 2 Fractal dimensions each image in Chernobyl

Object	Fractal dimension
Chernobyl pollution map	1.53
NOAA/AVHRR cloud	1.56
Accumulated rainfall	1.59

Table 3 Land cover classification (%)

Land cover	Water body	Urban area	Paddy field	Agriculture field	Grass	Deciduous forest	Evergreen forest	Bare land
Percentage	0.3	4.2	6.9	3.0	2.1	49.3	34.1	0

Table 4 Overlapped pollution map with caused factors

Wind trajectory	Traffic network	Land cover	Stream network
Fair	Fair	Fair	Not fair

Table 5 Roughness length (m)

Urban and Forest	Paddy and agricultural field	Flat surface
0.5-2	0.05-0.2	10^{-5}-10^{-2}

4. Discussion

4.1. Deposit types

In general, the surface pollution by the atmospheric diffusion has two types: dry and wet deposits, and the latter type brings more serious pollution. In Fukushima nuclear power plant accident, the wet deposit may be thought to pollute Abukuma highland in the northwest of Fukushima nuclear power plant. In calculation of fractal dimensions, two types pollution corresponded to the images of Abukuma river watershed and NOAA/AVHRR. Dry deposit may be affected by the geomorphology and make the pollution pattern similar to the watershed. On the other hand, wet deposit may be affected by rain clouds directly and make the pollution pattern similar to the cloud. Therefore, in Fukushima accident, dry deposit would occur, while in Chernobyl accident, wet deposit would occur.

4.2. Pollution flow

Pollution might flow with wind on the road in the valley. Land cover roughness lengths range from 10-5 to 2 m, which means that wind speed corresponds from 4 to 15m/s at 10 m height and from 8 to 16 m/s at 50 m height. The wind speed is 2 to 3 times different between roads and forest. The radioisotope might deposit on forest more than roads.

5. Conclusions

Fractal analysis results suggested the next conclusions.

(1) The radioisotope pollution in Fukushima might occur in dry deposit.

(2) The dry deposit might make the pollution pattern similar to the watershed, while the wet deposit might make the pollution pattern similar to cloud images or rainfall distribution.

(3) Most radioisotope contaminants might flow on the road in the forest valley and deposit on forest without rainfall in Fukushima.

References

1） B. B. Mandelbrot, Fractals, Freeman, San Francisco, 1977.

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Fig. 1 Fukushima Cs137 pollution

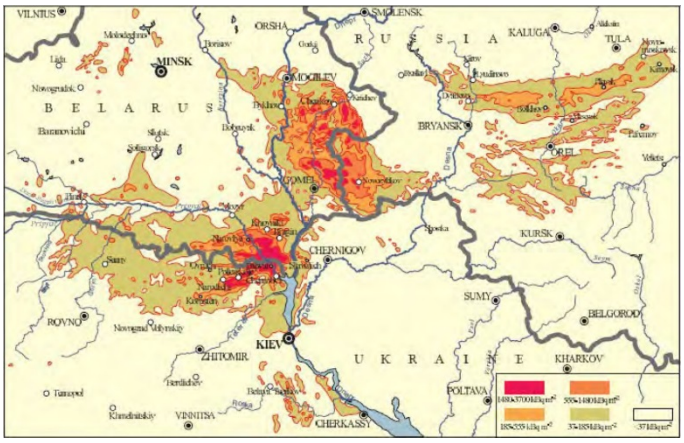


Fig. 2 Chernobyl Cs137 pollution

Fig. 3 Abukuma River watershed

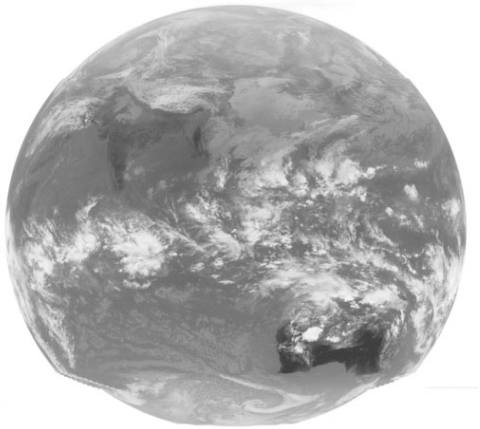
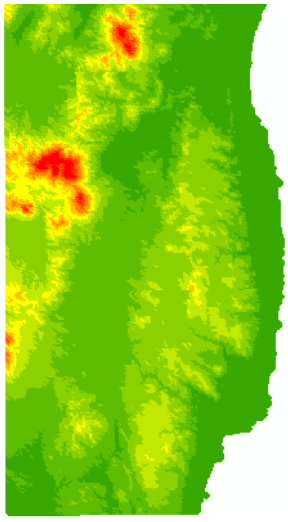


Fig. 4 NOAA/AVRR



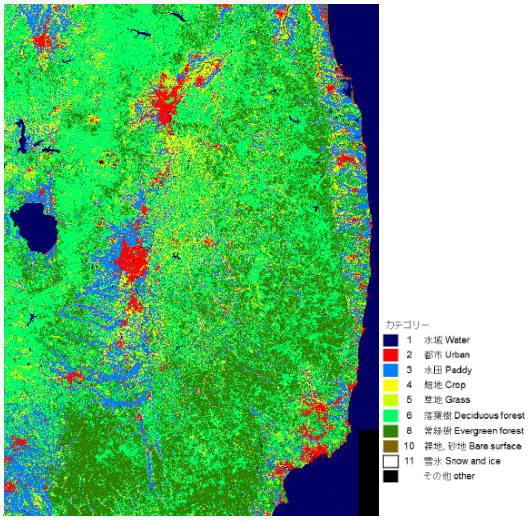


Fig.5 MODIS/TERRA in Fukushima Fig.6 DEM in Fukushima Fig.7 Land cover in Fukushima

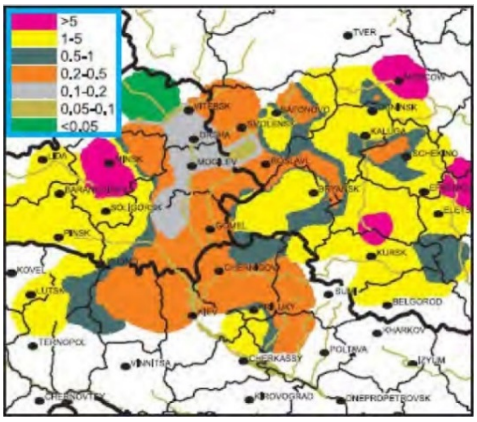


Fig.8 Accumulated rainfall in Chernobyl

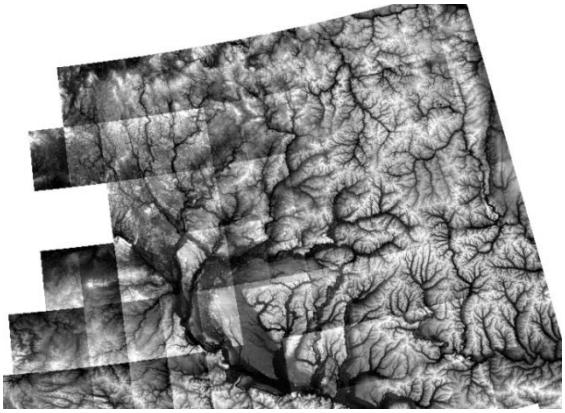


Fig.9 DEM from STRM in Chernobyl

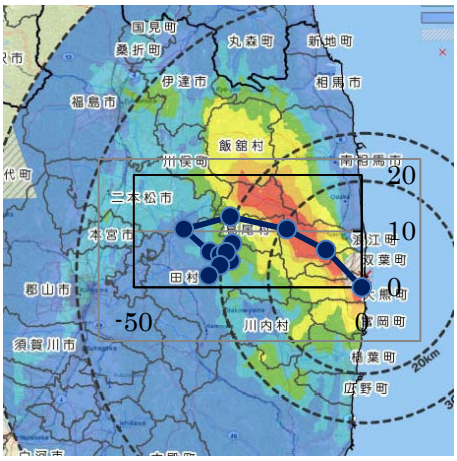


Fig. 10 Overlapped with the wind trajectory

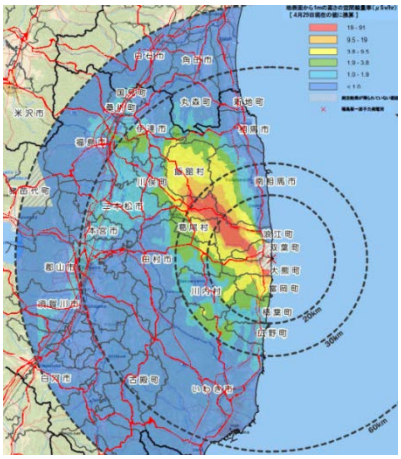


Fig. 11 Overlapped with the traffic network

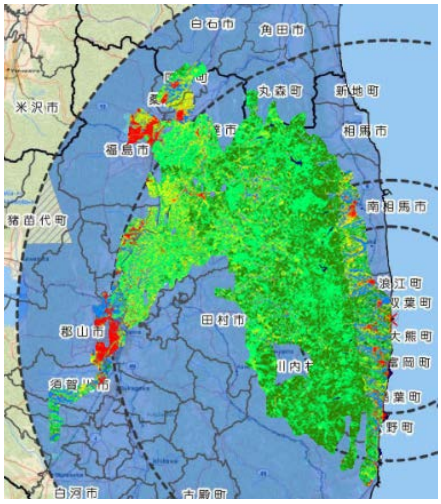


Fig. 12 Overlapped with the land cover

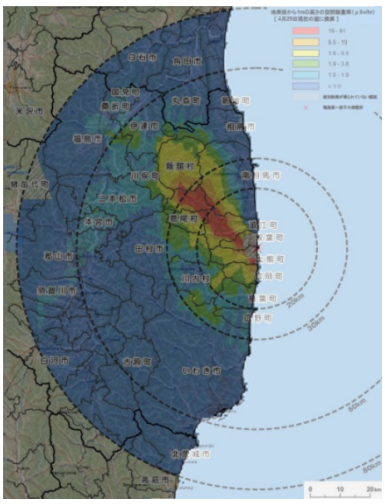


Fig. 13 Overlapped with the stream network