Dose increase around March 20th, 2011

1. Background

A dose increase was observed around March 20th and 21st, 2011, at the Fukushima Daiichi Nuclear Power Station (NPS). On or about those days, a dose increase was also detected in parts of the Kanto region. Recommendations were given for refraining from tap water intake (primarily for babies and small children) because of the increased radioiodine concentration. It is necessary to identify the cause of this dose increase observed around March 20th and 21st, and to clarify the detailed behavior of radioactive substances released to the environment.

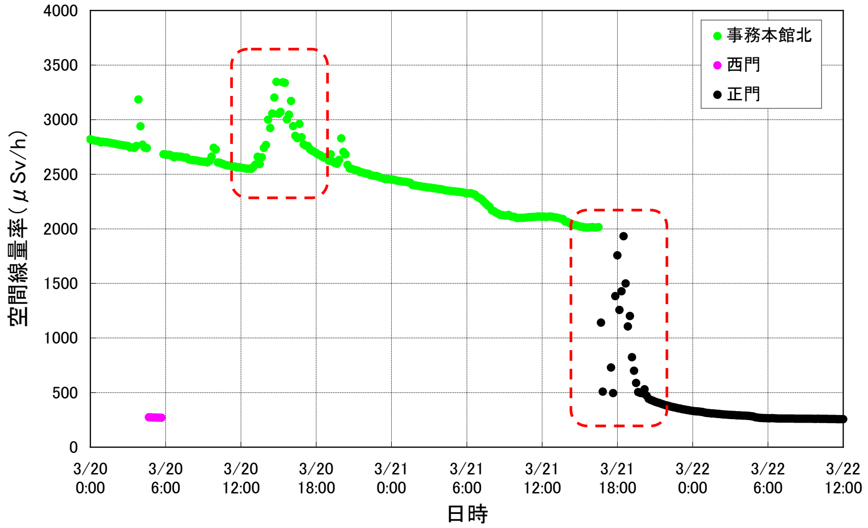
It should be noted that the MAAP analysis has been terminated at about one week at most after the accident. This is because the uncertainties in the analysis become larger as the analysis time is extended, and the reliabilities of the results are significantly lowered.

With this background, this report examines the cause of the dose increase observed on March 20th and 21st, based on the plant parameters at that time, conditions of the plant surroundings and responses to the accident.

2. Dose increase observed on March 20th and 21st

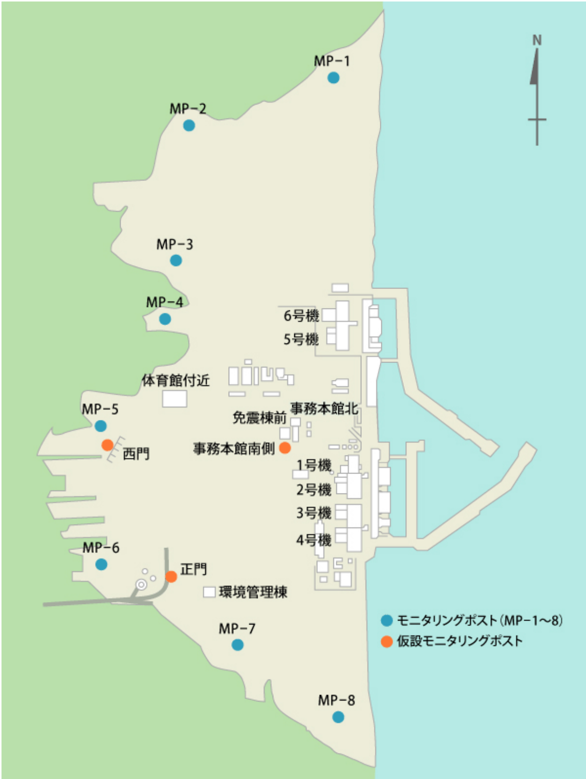
Figure 1 shows the dose level change observed during March 20th and 21st in the area surrounding the Fukushima Daiichi NPS. The dose increase in question is described by the data enclosed within the dotted red lines. On March 20th the dose rose about 800 μ Sv/h in two hours from 12:50 to 14:50 in the north area of the main administration building. The dose remained above 3000 μ Sv/h till about 16:00, then began to decrease. On March 21st the dose jumped to about 1400 μ Sv/h in 100 minutes from 16:50 to 18:30 near the main gate. The dose decreased thereafter and returned to the level before the dose increase.

Figure 2 shows the locations where the dose was measured.



空間線量率	Air dose rate
事務本館北	North side of the central administration building
西門	West gate
正門	Main gate

Figure 1　Dose increase on March 20th and 21st, 2011



１号機	Unit-1
免震棟前	Front of seismic isolation building
体育館付近	Near the gymnasium
環境管理棟	Environmental management building
モニタリングポスト	Monitoring post
仮設	Temporary

Figure 2　Approximate locations of dose measurement

3. Possible incidents causing the dose increase

Possible incidents which might have caused the dose increase shown in Figure 1 are:

(i) A newly occurring incident that released radioactive materials

(ii) A detection dose increase caused by a change of wind directions

4. Possibility of a newly occurring incident that released radioactive materials

The following are the results from examination of Possibility (i) of Item 3 above.

4.1. Examination based on the changes of plant parameters observed

Should a new incident releasing radioactive materials occur, plant parameters would show some changes. Figures 3 to 11 show the changes of plant parameters (reactor water level, reactor pressure, primary containment vessel (PCV) pressure, and CAMS readings) of Unit-1 to Unit-3.

原子炉水位	Reactor water level
原子炉圧力	Reactor pressure
格納容器圧力	PCV pressure
D/W 圧力	D/W pressure
S/C 圧力	S/C pressure
線量率	Dose rate
日時	Date / Time

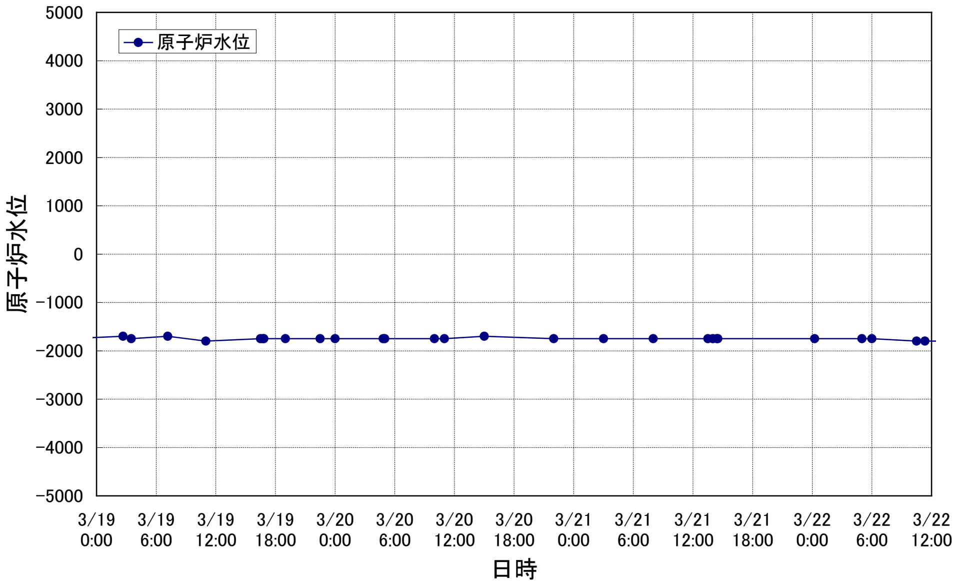


Figure 3　Reactor water level of Unit-1

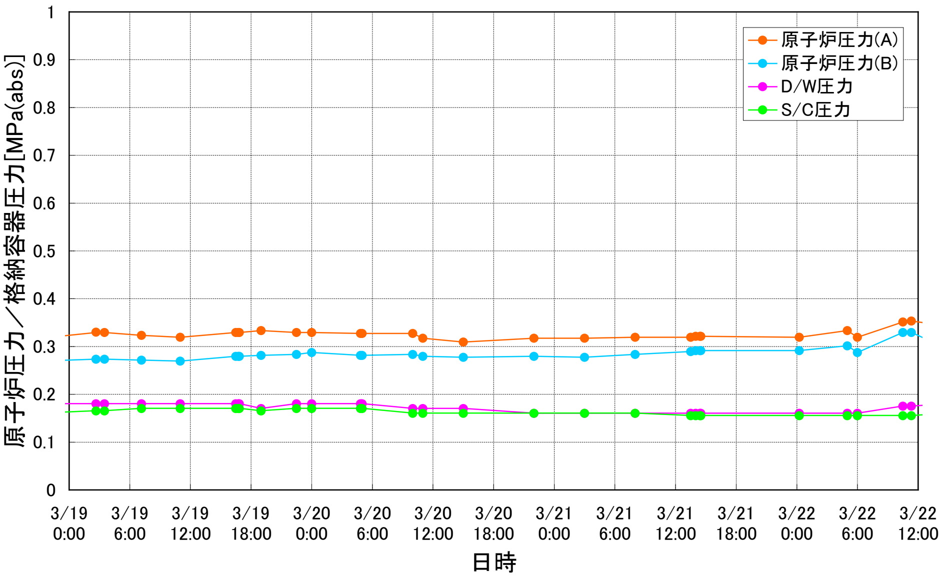


Figure 4　Reactor pressure and PCV pressure of Unit-1

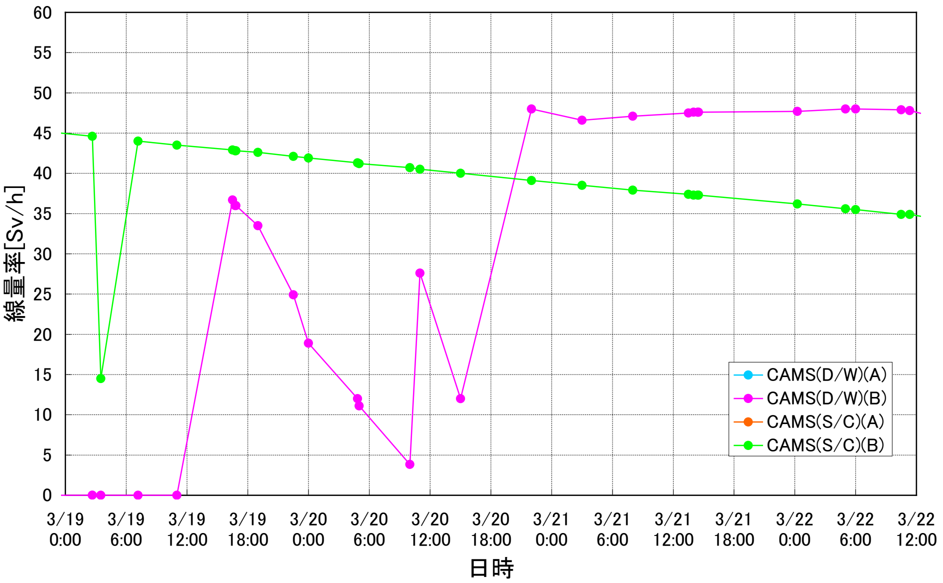


Figure 5　CAMS readings of Unit-1

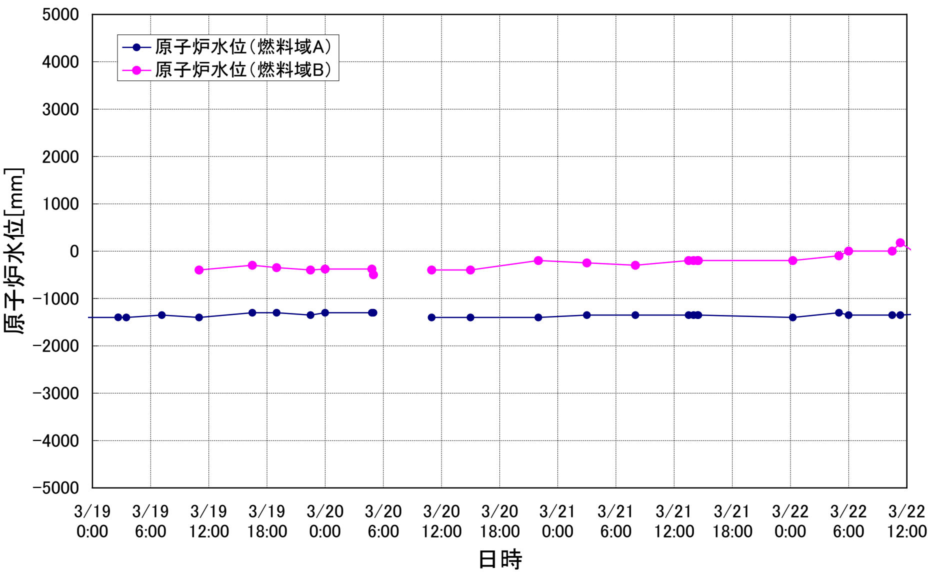


Figure 6　Reactor water level of Unit-2

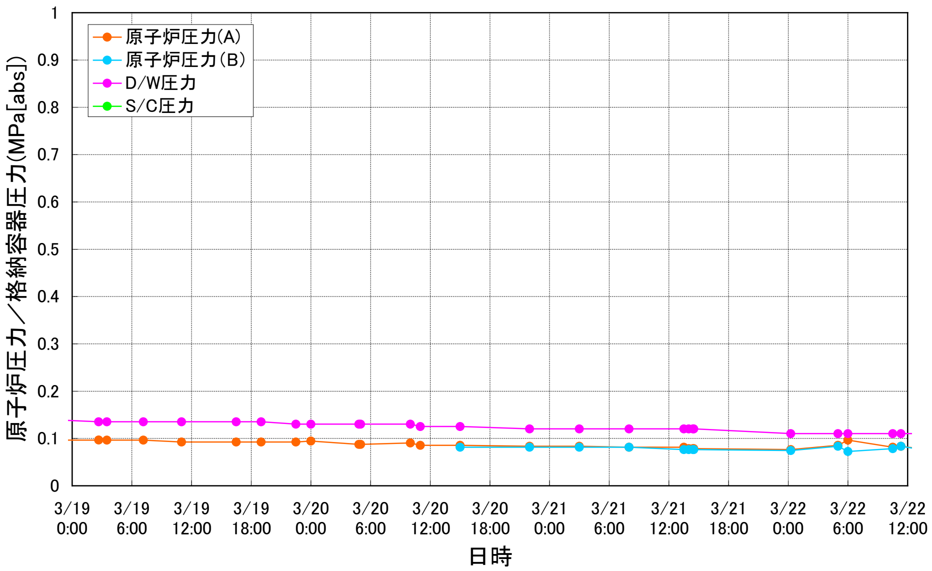


Figure 7　Reactor Pressure and PCV Pressure of Unit-2

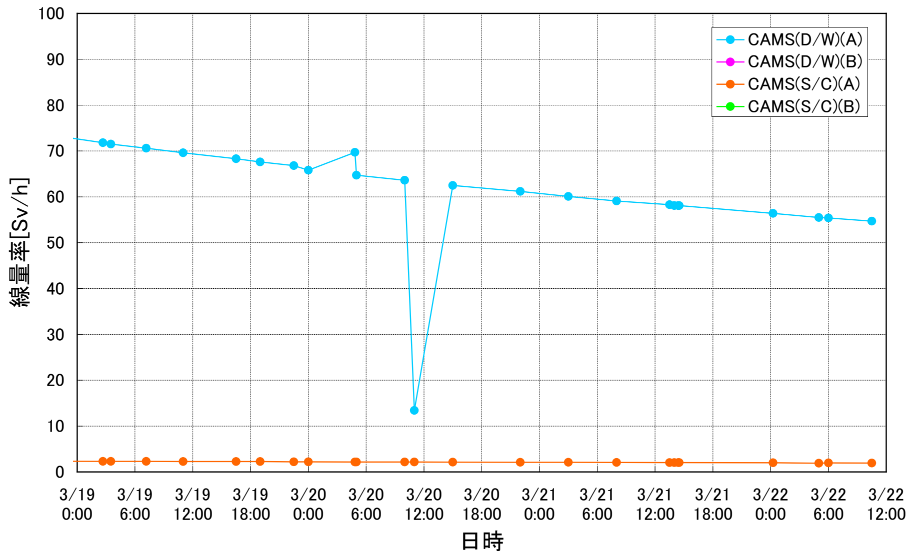


Figure 8　CAMS readings of Unit-2

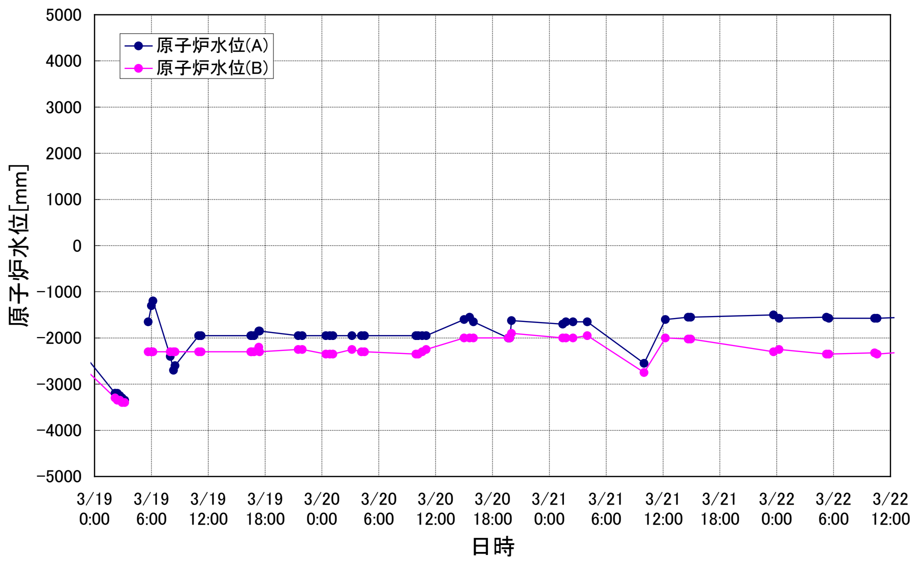


Figure 9　Reactor water level of Unit-3

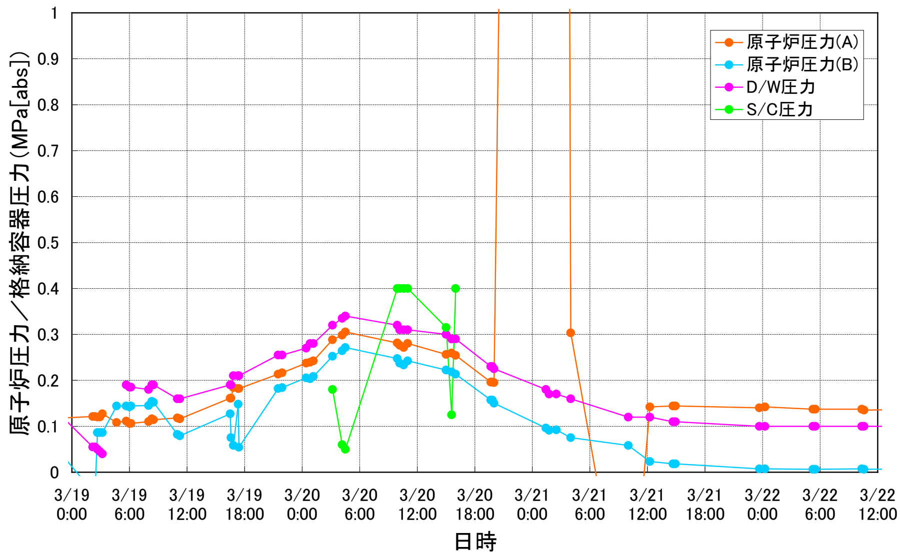


Figure 10　Reactor pressure and PCV pressure of Unit-3

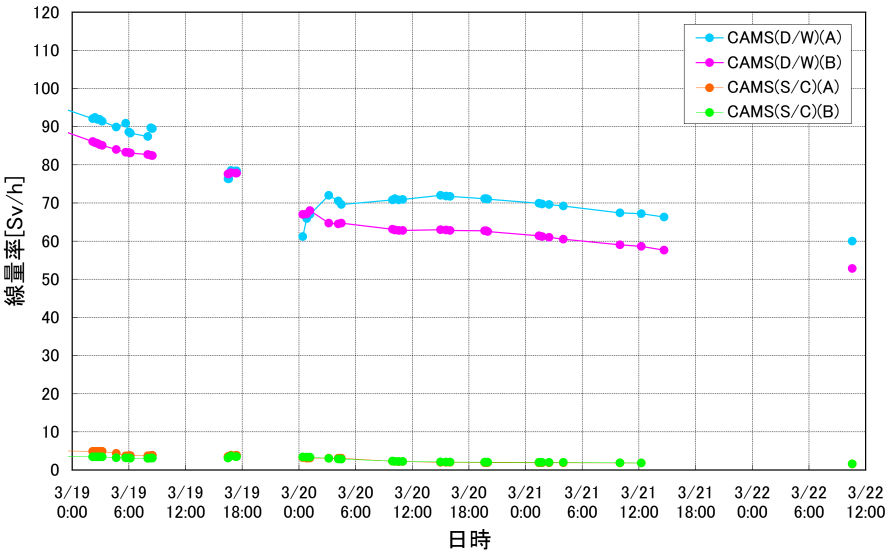


Figure 11　CAMS readings of Unit-3

Concerning Unit-1, Figure 3 and Figure 4 have no noticeable significant changes in the reactor water level, reactor pressure and PCV pressure during the time period when dose increase was observed, although the data points are limited. In Figure 5 CAMS (D/W) readings show a big drop after 12:00 on March 20th, which might indicate a possible release of radioactive materials from the containment vessel. But the PCV pressure shows no changes and the CAMS (S/C) data show no big changes during the period of interest. All in all, the change in the CAMS (D/W) readings is reasonably attributed to defective individual readings.

Concerning Unit-2, Figure 6 and Figure 7 have no noticeable significant changes in the reactor water level, reactor pressure and PCV pressure during the time period when the dose increase was observed, although the data points are limited. In Figure 8 CAMS (D/W) readings show a lower value at 11:00 on March 20th than those before and after. But again the change in the CAMS (D/W) readings is reasonably attributed to defective individual readings, because of a discontinuity in particular readings and the CAMS (S/C) data show no changes over the same time period.

Concerning Unit-3, Figure 9 and Figure 10 show a slight increase in the reactor water level and a slight decrease in the reactor pressure and D/W pressure during the time period when the dose increase was observed on March 20th. During this time period, the reactor temperature and PCV temperature showed a decreasing tendency [1]: the temperature of the feedwater nozzle (N4B) decreased from 210 deg C (at 11:00) to 140 deg C (at 15:00), that of reactor vessel bottom head from 244 deg C (at 11:00) to 220 deg C (at 15:00), and that of D/W HVH return line from 220 deg C (at 11:00) to 187 deg C (at 15:00). This leads to the understanding that the temperature decrease caused the pressure decrease of the reactor and PCV. In Figure 11 CAMS readings show no changes during the period of interest. From these considerations a new incident releasing radioactive materials during this time period of interest at Unit-3 seems unlikely to have occurred.

To sum up, the changes in relevant plant parameters have led to no possible scenario which can explain the occurrence of a new incident in the reactor vessel or PCV causing a release of radioactive materials at the timing when the dose increase was observed.

4.2. Examination based on the responses to the accident at that time

A possible interpretation of the dose increase was sought from the recorded TV conference between the head office and the Emergency Response Center at the Fukushima Daiichi NPS.

Dose increase on March 20th in the north area of the main administration building was mentioned in the TV conference, but no relevant information for its possible causes was reported.

On March 21st black smoke was noticed at about 16:00 coming from the southeast side of the Unit-3 reactor building. In order to grasp the impacts of this black smoke, a monitoring car was moved to a location where it could make downwind measurements. But the wind direction was changing all the time and the new location of the monitoring car was not always necessarily downwind (Table 1).

Table 1 Location changes of the monitoring car that measured the black smoke radioactivity

Moving	Date, time	Point of measurement	Wind direction	Positional relation to the Units-1 to 3
↓	March 21st, at 16:30	North of main administration building	Northeast	Upwind
↓	March 21st, at 16:42	Main gate	East	Downwind
↓	March 21st, at 16:50	Main gate	South	—
↓	March 21st, at 17:06	Near MP7	Southwest	Upwind
↓	March 21st, at 17:30	Main gate	East	Downwind

Emission of the black smoke slowed down once, but it is reported to have broken out again at around 16:00 on March 23rd.

It is recorded as having been reported that: There was a fluid coupling using oil on the 4th floor of the reactor building. The black smoke release probably occurred because this oil caught fire for some unknown reason. The oil quantity was finite and the fire would die down naturally when all the oil was consumed. As the Unit-3 reactor had been in operation on March 11th, the quantities of combustibles are thought to have been quite limited in the reactor building.

It should be noted that the monitoring car moved to the main gate from the north side of the main administration building after around 16:00 on March 21st. This was to check dose increase in the downwind position in connection with the black smoke.

From these considerations, the black smoke can be thought to have come from the oil fire of the fluid coupling in the existing MG set for some unknown reason. No correlation was confirmed between the black smoke and the release of radioactive materials.

5. A possibility of detecting dose increase caused by the change of wind directions

The following are the results from examination of Possibility (ii) mentioned in Item 3 above.

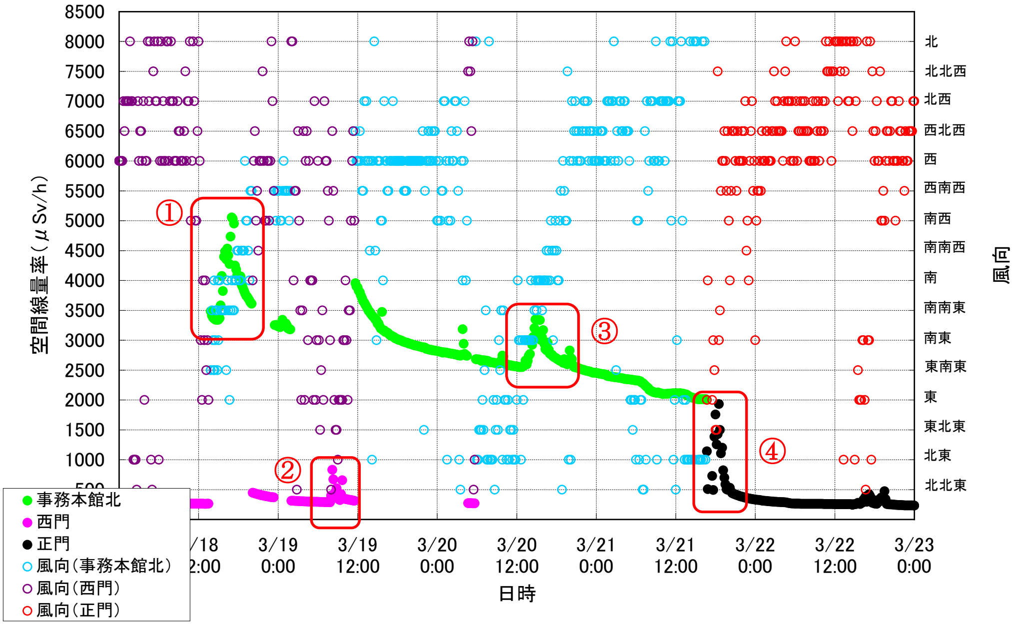
On around March 20th and 21st, certain amounts of radioactive materials are thought to have been more or less continuously released from the containment vessel of Units-1 to 3. For example, steam and other gases rose from the Unit-3 containment vessel as white smoke that passed from the upper side of the building after it had been damaged by the hydrogen explosion. This situation can be seen in an aerial photo taken on March 16th (Figure 12).

The monitoring car at around this time was positioned for measurements near the nuclear plant site, for example, at the north side of the main administration building or the main gate. It might have measured the dose increase depending on the wind direction.

To assess this possibility, the car position at the time of the dose increase was checked as to whether it was downwind. Figure 13 shows the correlation between wind direction and air dose during the period of March 18th to 23rd [2]. The relation between the monitoring car position and wind direction was reviewed, especially at the time points ① to ④ in Figure 13, when the air dose increase had been observed. The monitoring car was positioned at these times at the north side of the main administration building, the west gate or the main gate.

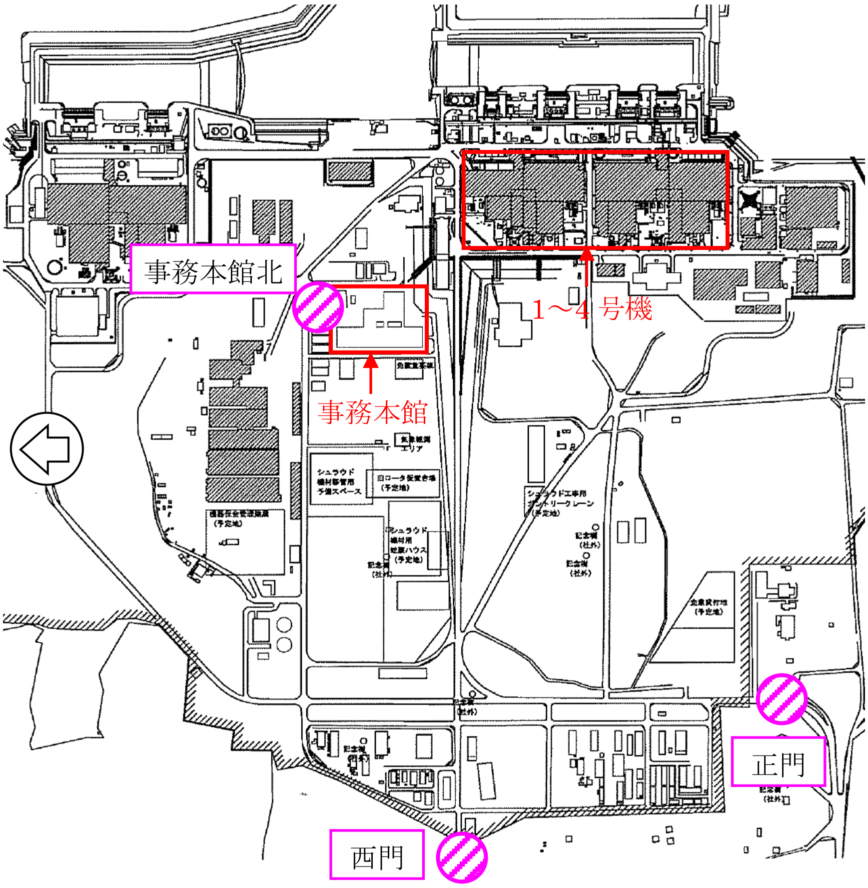
Figure 14 shows positional relations of the north side of the main administration building, the west gate and the main gate.

Figure 12 Aerial photo of Unit-3 (March 16th, 2011)



空間線量率	Air dose rate
事務本館北	North side of main administration building
西門	West gate
正門	Main gate
風向（事務本館北）	Wind direction (north side of main administration building)
風向（西門）	Wind direction (west gate)
風向（正門）	Wind direction (main gate)
風向	Wind direction
北	North
北北西	North-north-west
北西	North west
西北西	West-north-west
西	West
西南西	West-south-west
南西	South west
南南西	South-south-west
南	South
南南東	South-south-east
南東	South east
東南東	East-south-east
東	East
東北東	East-north-east
北東	North east
北北東	North-north-east

Figure 13　Air dose changes and wind direction



事務本館北	North side of main administration building
西門	West gate
正門	Main gate

Figure 14　Monitoring car positions for measurement

5.1 Correlation of dose increase and wind direction at the north side of the main administration building

The points of measurement at the north side of the main administration building are located in the north-north-west direction of the plant and just downwind when the wind direction is south-south-east. Table 2 shows the wind fractions in the south-east, south-south-east, and south directions over the time period of the dose increase and decrease.

Table 2 Correlation of dose increase and wind direction at the north side of the main administration building

	Time period	Wind fractions in the "south-east, south-south-east, and south" directions over each time period
1	15:10 - 17:20 on March 18th (Time period ① of dose increase in Fig. 13)	86%
2	17:30 - 20:00 on March 18th (Time period ① of dose decrease in Fig. 13)	31%
3	13:00 - 16:00 on March 20th (Time period ③ of dose increase in Fig. 13)	95%
4	16:10 - 19:40 on March 20th (Time period ③ of dose decrease in Fig. 13)	32%
5	Time periods other than above during March 18th to 20th	7%

5.2 Correlation of dose increase and wind direction at the west gate

The points of measurement at the west gate are located west of the plant and just downwind on the east side. Table 3 shows the wind fractions in the east-south-east, east, and east-north-east directions over the time period of dose increase and decrease.

Table 3 Correlation of dose increase and wind direction near the west gate

	Time period	Wind fractions in the "east-south-east, east, and east-north-east" directions over each time period
1	08:00 - 09:40 on March 19th (Time period ② of dose increase in Fig. 13)	64%
2	09:50 – 11:30 on March 19th (Time period ② of dose decrease in Fig. 13)	9%
3	Time periods other than above during March 18th to 22nd	8%

5.3 Correlation of dose increase and wind direction at the main gate

The points of measurement at the main gate are located approximately in the west-north-west direction of the plant and just downwind when the wind blows in the east-north-east direction. Table 4 shows the wind fractions in the east, east-north-east, and north-east directions over the time period of dose increase and decrease.

Table 4 Correlation of dose increase and wind direction near the main gate

	Time period	Wind fractions in the ”east, east-north-east, and north-east” directions over each time period
1	16:50 - 18:30 on March 21st (Time period ④ of dose increase in Fig. 13)	38%
2	18:40 – 19:40 on March 21st (Time period ④ of dose decrease in Fig. 13)	0%
3	Time periods other than above during March 18th to 22nd	4%

5.4 Deliberation on the dose increase and wind directions

As a general observation from Items 5.1 to 5.3 above, more measurement points seemed to have been downwind when the dose increase was observed, and on the contrary they seemed to have been in other wind directions when the dose decrease was observed. Consequently, the wind directions might have been relevant to the dose increase on March 20th and 21st.

On the other hand, it should be noted that radioactive materials may not disperse locally according to the overall wind direction because of swirling around buildings, for example. Further, the monitoring car measured the wind direction at about 2m above ground, which may not be the same as wind higher up in the sky which mainly controls dispersion in wide areas.

Therefore, the estimated correlation above between dose increase and wind directions indicates only one possibility.

6. Relationship to safety measures taken at the Kashiwazaki-Kariwa NPS

As mentioned in Item 5 above, radioactive materials are considered to have been more or less continuously leaking from the containment vessel of each unit around March 20th and 21st. This indicates the importance, therefore, of maintaining the integrity of the containment vessel regarding its confinement capability.

Under the severe conditions that existed during the Fukushima Daiichi NPS accident, high temperature steam might have deteriorated silicon gum seals used in the containment vessel top flange or hatches (gaskets) causing loss of the confinement function. From this concern, the following measure was taken at the Kashiwazaki-Kariwa NPS: additional backup seal material was coated on the flange outside of such gaskets in order to strengthen the resistance to steam at elevated temperatures. Also because the silicon-based seal material has a tendency to deteriorate upon exposure to high temperature steam, it is being replaced with a more temperature resistant seal material (improved ethylene-propylene rubber material (EPDM)).

The seal material for the containment air-lock equalizer valves, fluororesin, may experience deterioration in its seal performance when exposed to radiation under severe accident conditions. In order to ensure the integrity (of the confinement capability) under severe accident conditions, a measure was taken: a blind flange was newly mounted on the reactor building side opening of the piping which connected the equalizer valves across the outer side door of the air-lock. The blind flange was equipped with a seal with high tolerance to environmental conditions. An alternative seal material is also being used in equalizer valves, which is more resistant to radiation than fluororesin and to high temperatures.

7. Conclusion

The incidents of increased dose on March 20th and 21st, 2011, were investigated based on all available information at that time. No new incident hinting at any radioactive material releases was identified, but a possibility was found that the increased dose incidents might have been the result of detecting the effects of changing wind directions.

8. Related information

A dose increase was observed around March 20th and 21st, 2011, at the Fukushima Daiichi NPS. At about that time, a dose increase was also noticed in parts of the Kanto region. The recommendation of refraining from tap water intake was made by some local governments because of the increased radioiodine concentration. In connection with wide region dispersion of radioactive materials, Table 5 and Figures 15, 16 and 17 cite results (published on March 20th, 2011 [3]) calculated by WSPEEDI (Worldwide version of System for Prediction of Environmental Emergency Dose Information), a simulation code developed by JAEA.

Radioactive materials were dispersed over the Kanto region in the results, from which it can be reasoned that the impacts of the continuously released radioactive materials have also occurred in the Kanto region.

This indicates a possibility that the dose increase or increased radioiodine concentration in drinking water in the Kanto region, which led to the recommendation to refrain from tap water intake, might have been caused by not only an instantaneous release but also the continuous release of radioactive materials. Even if the dose increase observed around March 20th and 21st, 2011, at the Fukushima Daiichi NPS was due to changing wind directions, not an instantaneous release, the dose in the Kanto region could have increased.

Table 5　Calculation conditions

Item	Conditions
Time span for calculation	Starting at 09:00 on March 20th, the first one day was analyzed, and the following 2.5 days were predicted
Radionuclides released and release rates	I-131　5Bq/h Cs-137　1Bq/h
Point of release	Fukushima Daiichi Nuclear Power Station 141.0356 degrees east longitude, 37.4217 degrees north latitude
Height of release	Near the ground　(30m above ground)
Time of release	Continuous from 09:00, March 19th

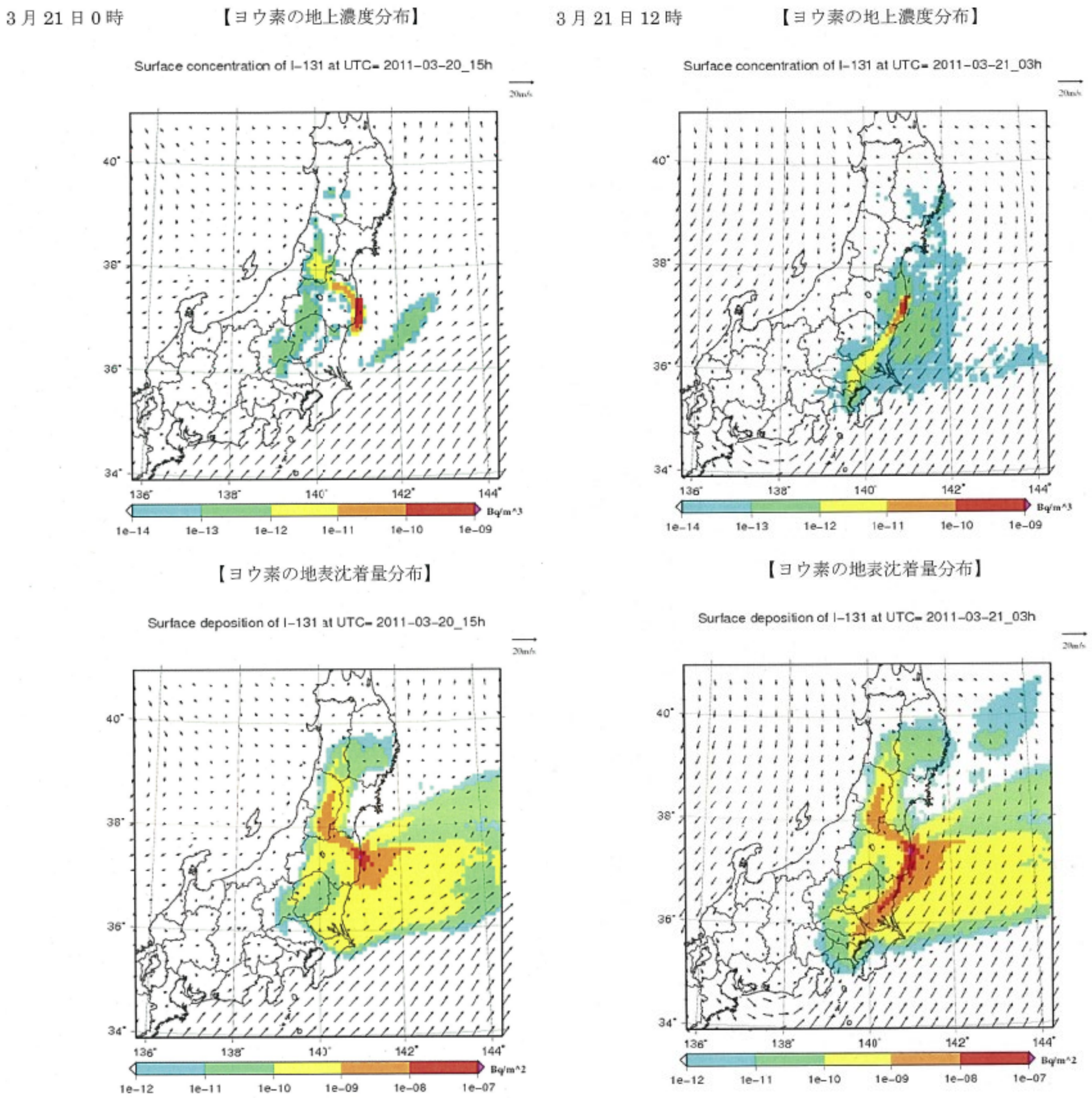


Figure 15 Dispersion state (calculated) as of 00:00 on March 21st and 12:00 on March 21st

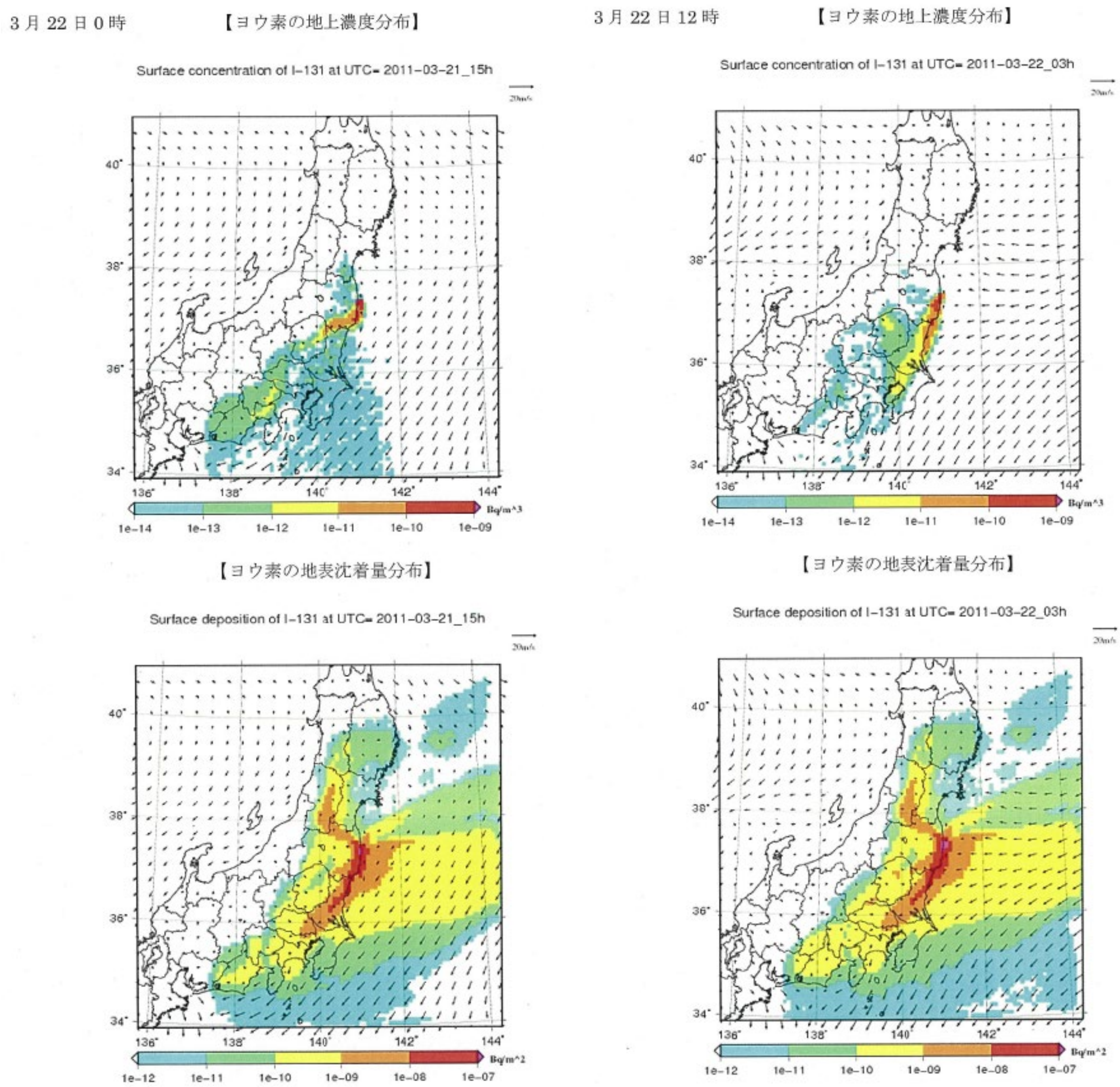


Figure 16 Dispersion state (calculated) as of 00:00 on March 22nd and 12:00 on March 22nd

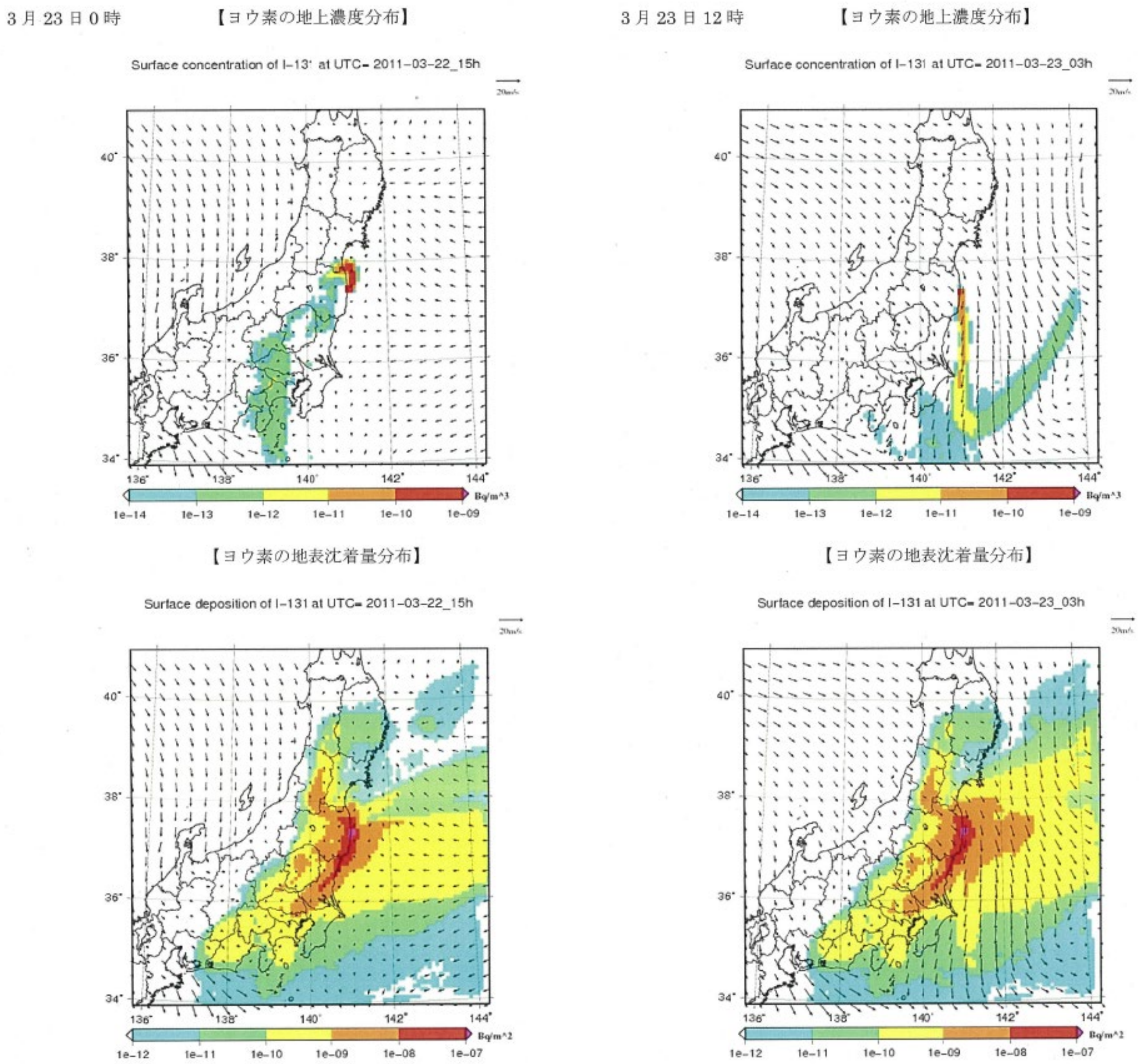


Figure 17 Dispersion state (calculated) as of 00:00 on March 23rd 12:00 on March 23rd

9. References

[1] Fukushima Daiichi Nuclear Power Plant Data Sheets at the time of Tohoku District Off-Pacific Ocean Earthquake, TEPCO, Revised on July 17th, 2013
http://www.tepco.co.jp/en/nu/fukushima-np/plant-data/f1_8_Parameter_data_20110717.pdf

[2] Estimation of the amount of radioactive materials released to the air and ocean due to the accident at Fukushima Daiichi Nuclear Power Station affected by the Tohoku District Off-Pacific Ocean Earthquake, TEPCO, May 24th, 2012
http://www.tepco.co.jp/en/press/corp-com/release/betu12_e/images/120524e0205.pdf

[3] WSPEEDI-II Prediction of dispersion of radioactive materials from the accident at Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (Report 2, March 20th, 2011), Japan Atomic Energy Agency, March 20th, 2011
http://www.jaea.go.jp/02/tei120706/20110320.pdf