The estimated amount of radioactive materials released into the air by Fukushima Daiichi NPS accident

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TEPCO
TOKYO ELECTRIC POWER COMPANY

Profile

- Name
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12.July.2013 at Fukushima Daiichi

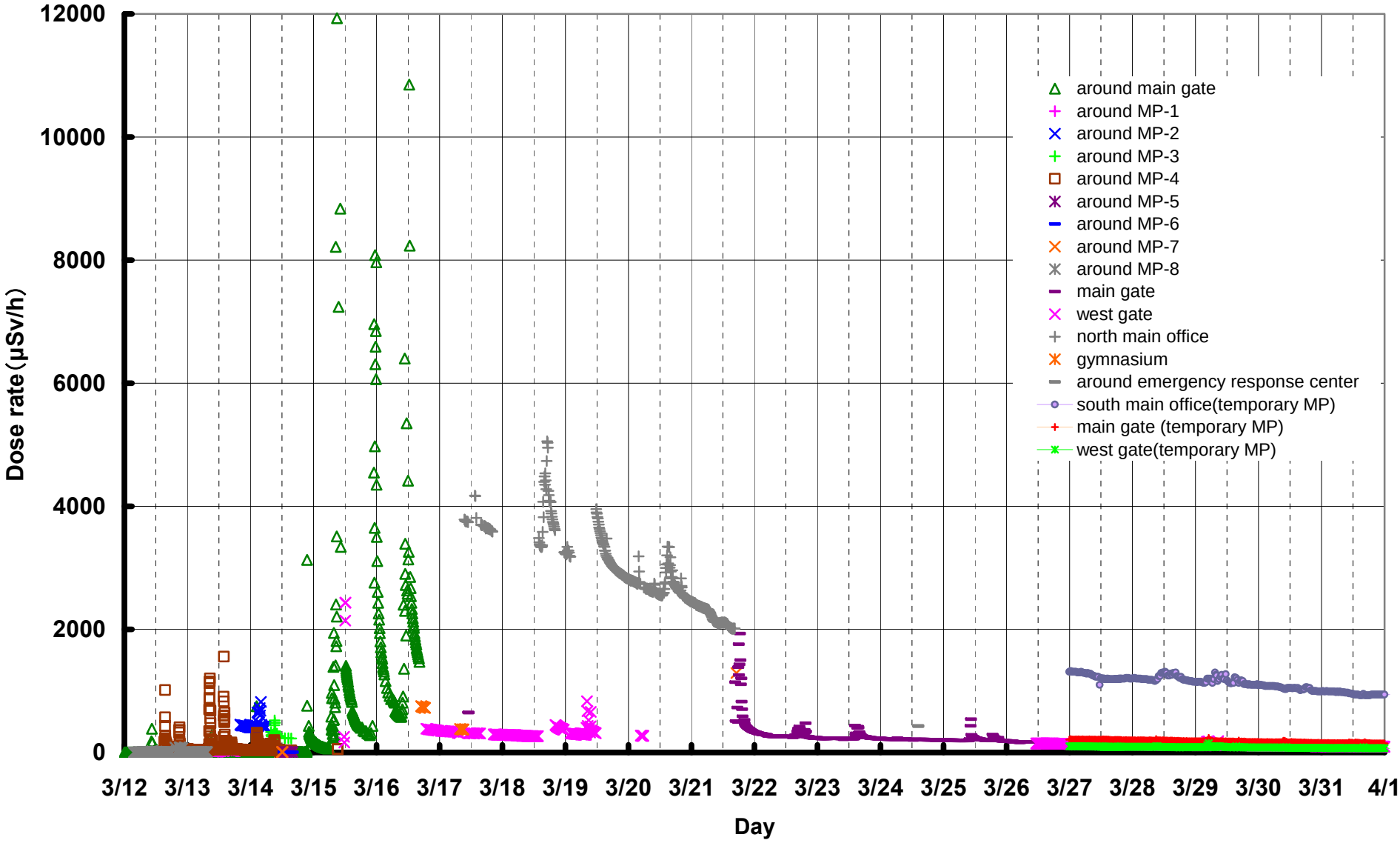
- Date of joining TEPCO
  4.1.2005～
- Work (After the accident)
  - Environmental assessment
    - monitoring plan
    - estimations of the release rate from reactor
  - Designing facilities to reduce the effect of additional release from reactor

Background

- After the accident, radioactive material was released from Units 1~3.
  - Venting and building explosions
  - Continuing releases of radioactive material to the atmosphere from buildings after the building explosions.
- The monitoring posts and stack monitors was lost due to the earthquake and tsunami.
- Monitoring cars were posted around the power station
  - To measure the air dose rate, meteorological data and other data in an effort to ascertain the status of radioactive material release.

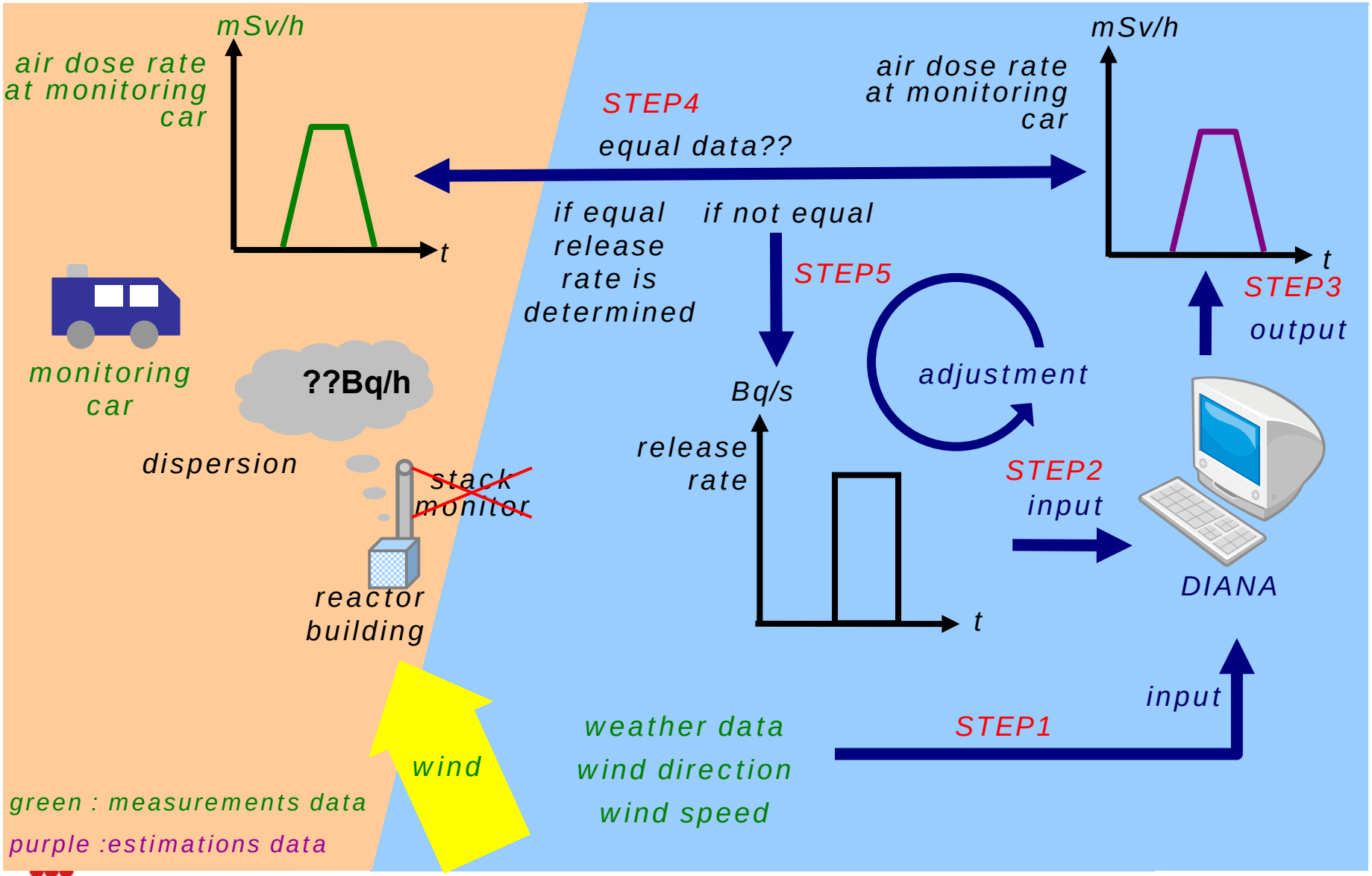
1. Fukushima-Daiichi site map

2 Measured air dose rate data



- Measured by monitoring car in power station

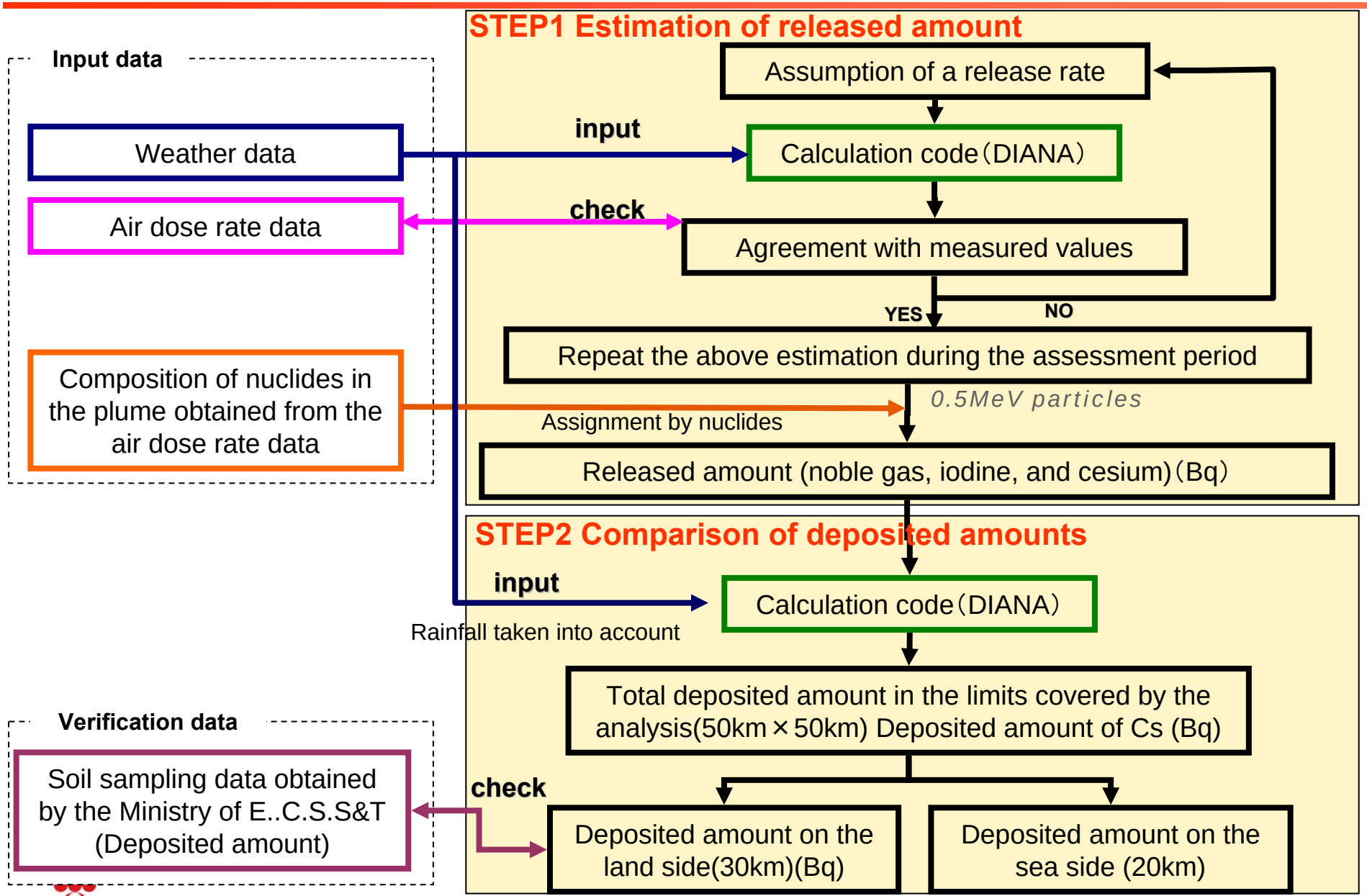
3.1 Image of estimation



3.2 weather data & DIANA

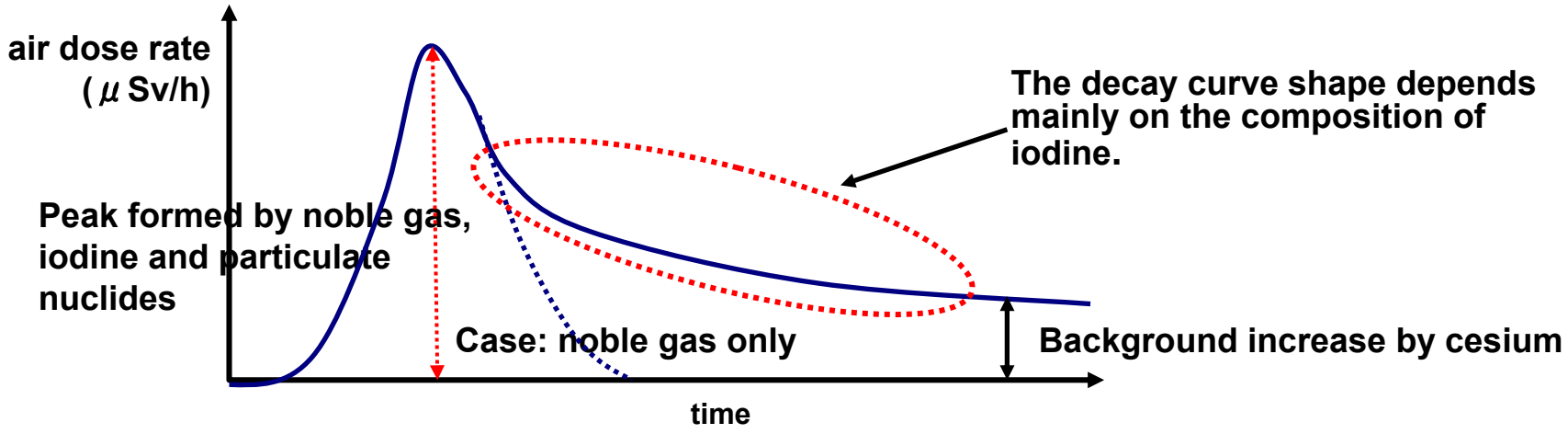
- **weather data**
  - the wind direction & wind speed (measured by monitoring car)
  - precipitation (by the Japan Meteorological Agency)
- **DIANA**
  - DIANA : Dose Information Analysis for Nuclear Accident
  - assessment domain :
    - 30km on the land side × 50km north-to-south line
    - 20km on the sea side × 50km north-to-south line
  - calculation step : 10-minutes intervals
  - release point : one point
  - Capable of assessing the air dose rate and the amount of deposition on soil at a specified location and time by inputting the release rate of 0.5 MeV-equivalent virtual particle and weather data.

3.3 Flowchart for Estimation



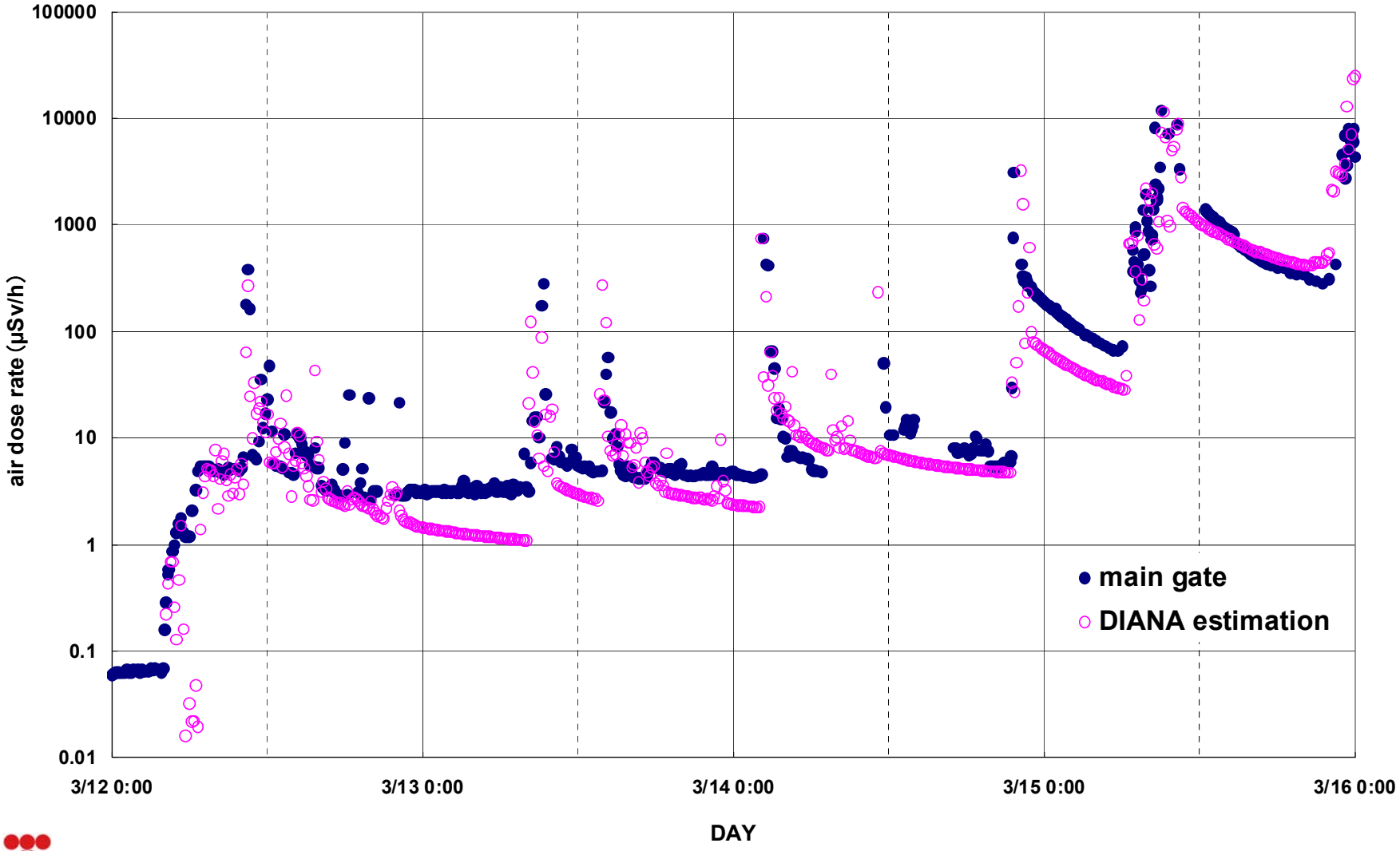
3.4 Estimation of release of each nuclide【1/3】

- Contamination of observation area are caused by deposition of iodine and cesium.
- Deposition of iodine and cesium increases the background dose rate around the observation area. (main contributor is cesium)
- The deposited iodine and particulate nuclides decay according to their half life period.
- To estimate the portion of noble gas, iodine and cesium in the plume, we varied the ratio and calculated by DIANA until we could reconstruct the curve of the measured dose rate.



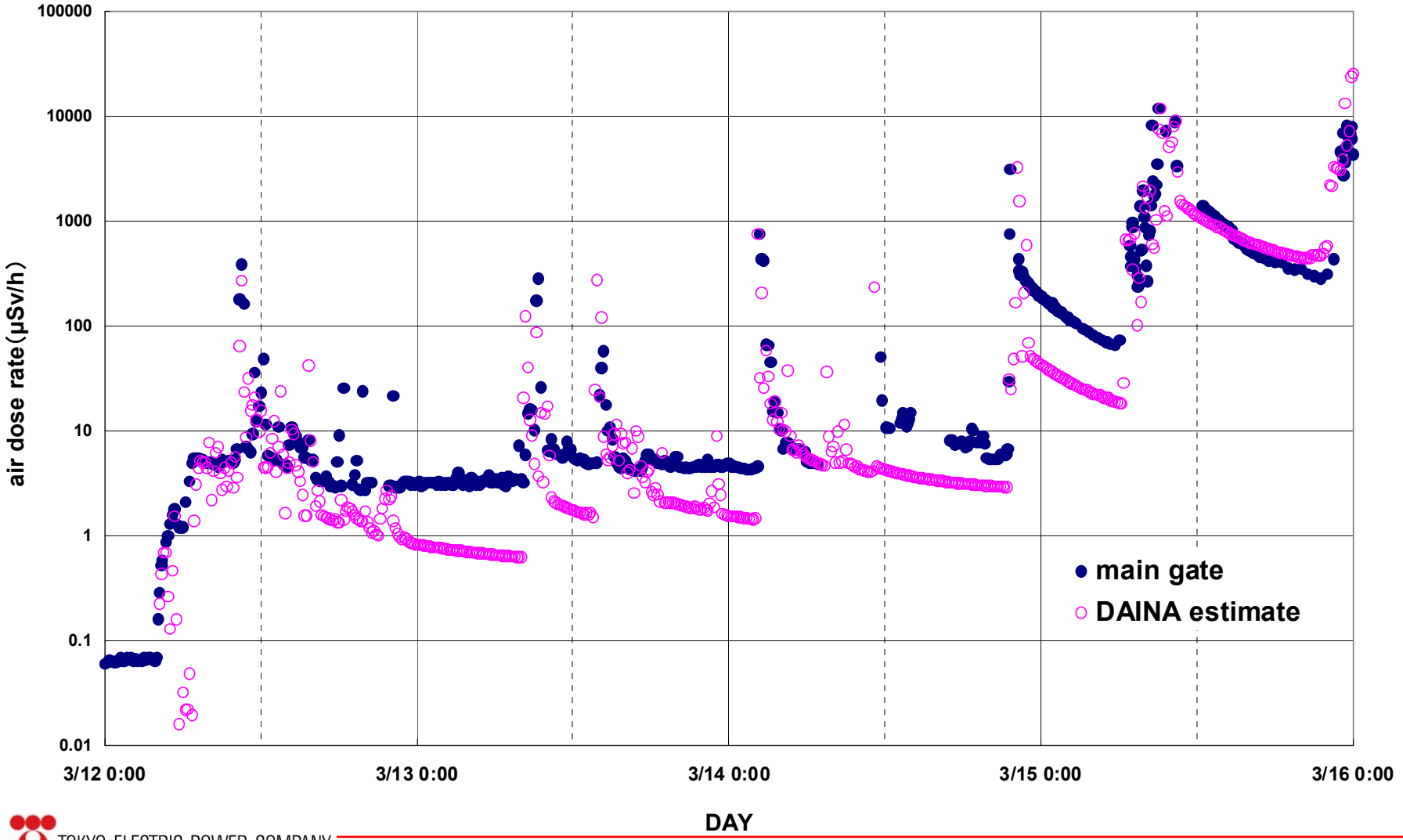
3.4 Estimation of release of each nuclide 【2/3】

- Ratio of Susceptibility of Radioactive Nuclides to Release
- noble gas : iodine : cesium = 100 : 2: 0.2



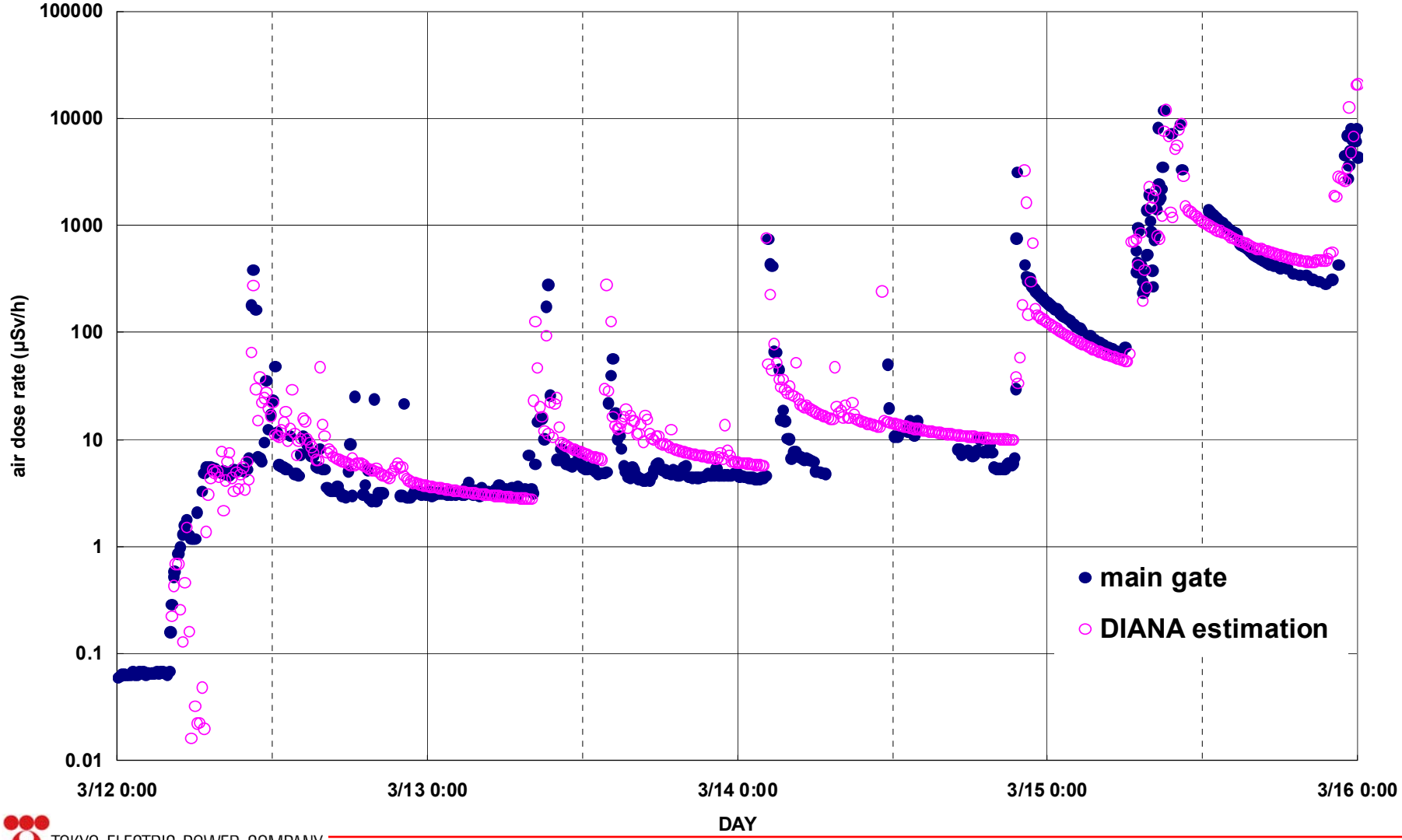
3.4 Estimation of release of each nuclide 【2/3】

- Ratio of Susceptibility of Radioactive Nuclides to Release
- noble gas : iodine : cesium = 100 : 1 : 0.1



3.4 Estimation of release of each nuclide 【2/3】

- Ratio of Susceptibility of Radioactive Nuclides to Release
- noble gas : iodine : cesium = 100 : 10 : 1



3.4 Estimation of release of each nuclide 【3/3】

■ $R(t) = Q'(t)\ (100C_1X(t) + 10C_2\,Y(t) + 1C_3\,Z(t)\ )$

- **R(t)** : **0.5MeV-equivalent virtual particle release rate (Bq/s)** calculated backwards using DIANA from the air dose rate
- **X(t)** : Noble gas inventory at time t (Bq)
- **Y(t)** : Iodine inventory at time t (Bq)
- **Z(t)** :Cesium inventory at time t (Bq)
- C_1 : Coefficient converting the **noble gas** inventory to 0.5MeV-equivalent value
- C_2 : Coefficient converting the **iodine** inventory to 0.5MeV-equivalent value
- C_3 : Coefficient converting the **cesium** inventory to 0.5MeV-equivalent value
- **Q'(t)** : Coefficient for converting a certain released amount (0.5MeV-equivalent value) to a release rate determined from the air dose rate. (1/s)

■ The values **except for Q'(t)** are determined for each time t.

→ **Q'(t) is determined.**

■ From the above equation, the release rate for each nuclide at time t is as given below.

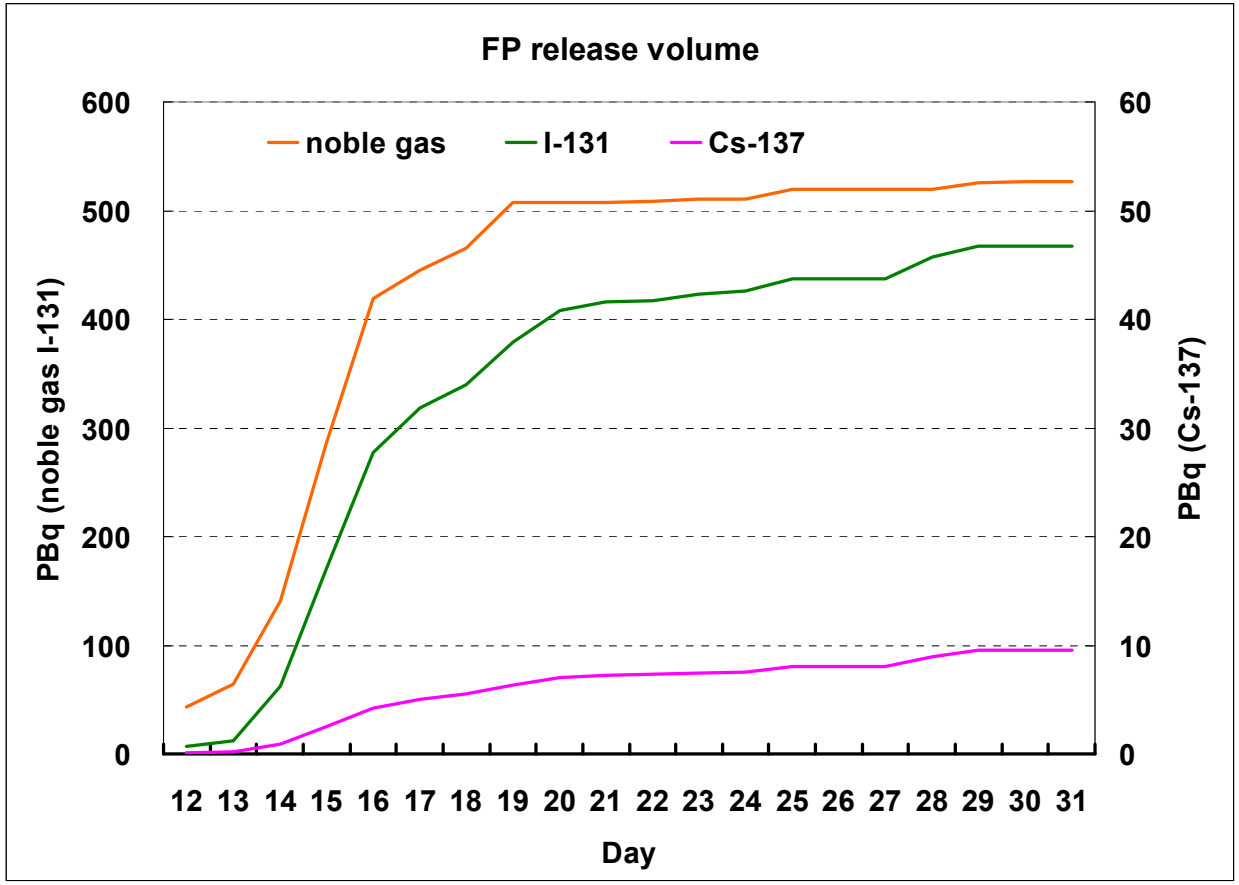
- **Noble gas** : $100C_1\,Q'(t)\,X(t)$ Bq/s
- **Iodine** : $10C_2\,Q'(t)\,Y(t)$ Bq/s
- **Cesium** : $C_3\,Q'(t)\,Z(t)$ Bq/s

4. Result of Investigations on FP release volume

noble gas（0.5MeV）	I-131	Cs-134	Cs-137
approx.500PBq	approx.500PBq	approx.10PBq	approx.10PBq

（PBq=10^{15}Bq）

The value estimated by our company is rounded off to one decimal place, being a figure in Bq at the time of being released.

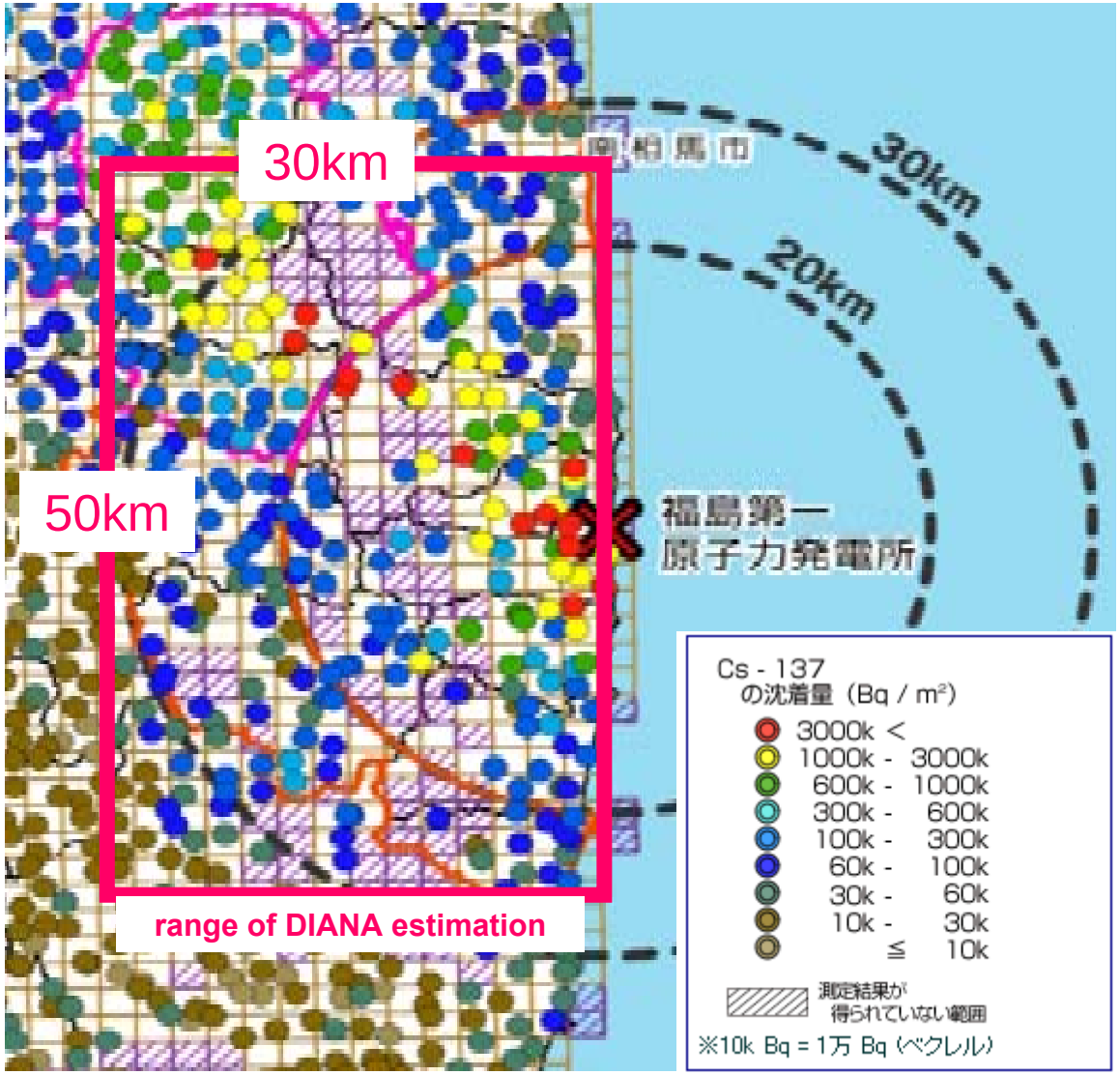


5. FP release volume 【vent & explosion】

unit	time	event	release volume (PBq)			
			noble gas	I-131	Cs-134	Cs-137
1	3.12 14:00～	vent	4	0.7	0.01	0.01
	3.12 15:36	explosion	10	3	0.05	0.04
3	3.13 09:00～	vent	1	0.3	0.005	0.003
	3.13 12:00～	vent	0～0.04	0～0.009	0～0.0002	0～0.0001
	3.13 20:00～	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.14 06:00～	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.15 16:00～	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.16 02:00	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.17 21:00	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.18 05:00～	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.20 11:00	vent	0～0.003	0～0.001	0～0.00002	0～0.00002
	3.14 11:01	explosion	1	0.7	0.01	0.009
total 【vent & explosion】			approx.20	approx.4	approx.0.09	approx.0.06
total 【between March 12 and March 31】			approx.500	approx.500	approx.10	approx.10

Majority of FP release is considered to be due to uncontrolled release from Reactor Buildings (not from venting or explosion.

6. Deposition Cs-137



Deposition Cs-137
PBq/(50km × 30km)

Survey Data	1PBq
DIANA estimation	1PBq

Soil sampling data & range of DIANA estimation

7.Estimation results of other Organization

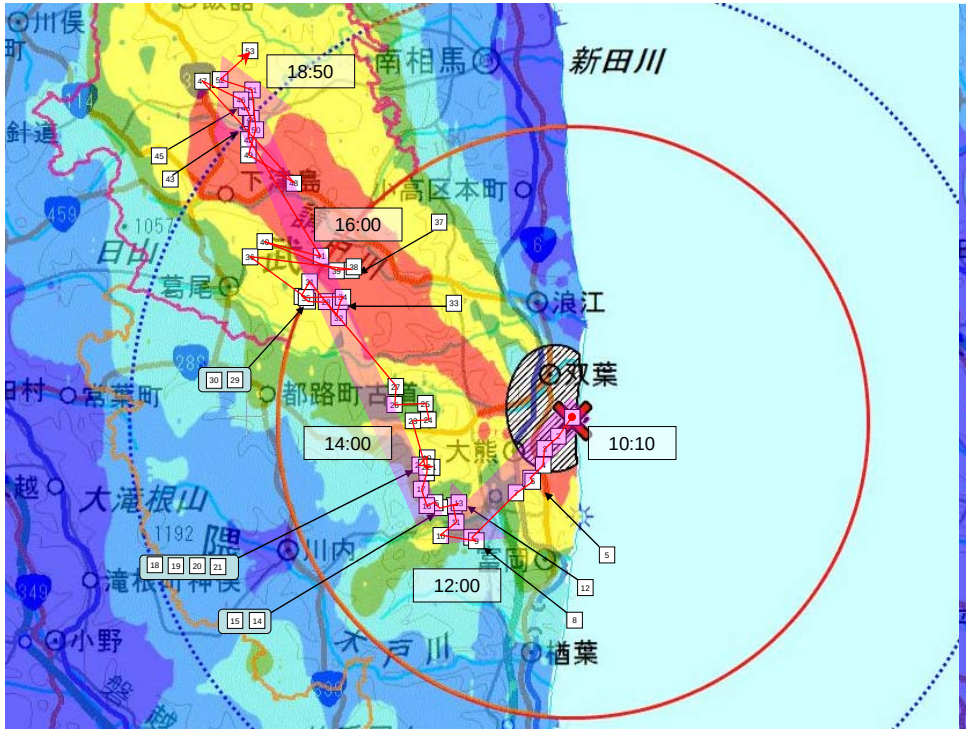
Organization	release volume unit : PBq			
	noble gas	I-131	Cs-134	Cs-137
TEPCO	approx.500	approx.500	approx.10	approx.10
JAEA 4.12.2011 & 5.12.2011	-	150	-	13
JAEA 8.22.2011	-	130	-	11
JAEA 3.6.2012	-	120	-	9
NISA 4.12.2011	-	130	-	6.1
NISA 6.6.2011	-	160	18	15
NISA 2.16.2012	-	150	-	8.2
IRSN	2000	200	30	

JAEA : Japan Atomic Energy Agency
NISA : Nuclear and Industrial Safety Agency
IRSN : Institut de Radioprotection et de Sûreté Nucléaire

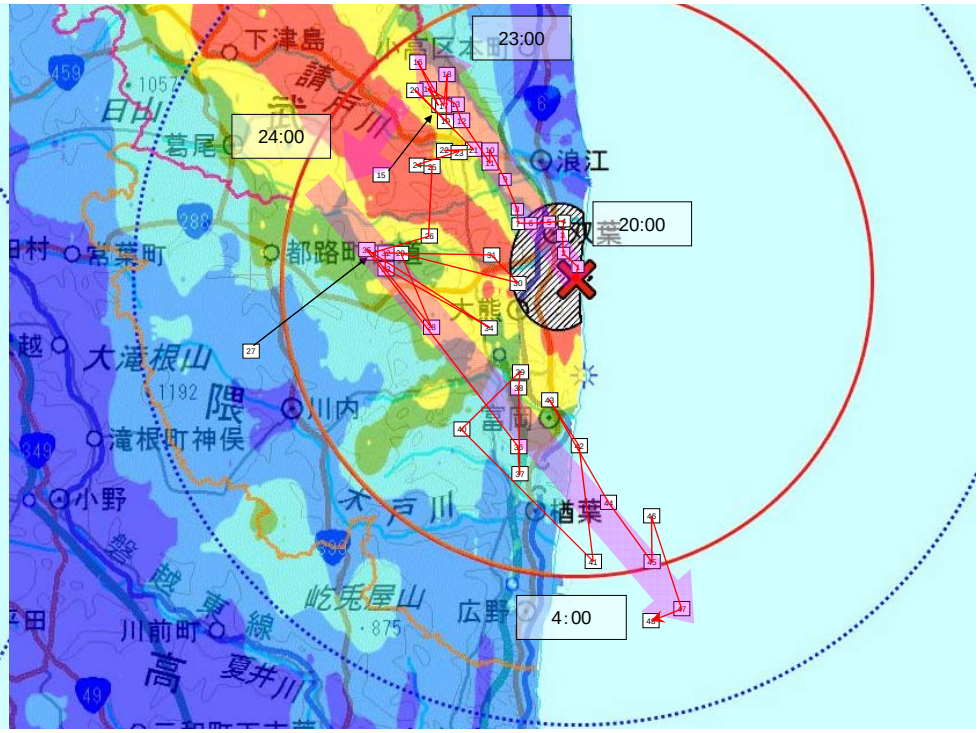
8. Cause of Contamination of NW region【1/3】

- Air dose rate showed rapid increase around 10:00 am on 3/15 but there were no plant operation like venting.
- This picture shows the steam release from Unit 2 around 10:00 am on 3/15.

8. Cause of Contamination of NW region【2/3】



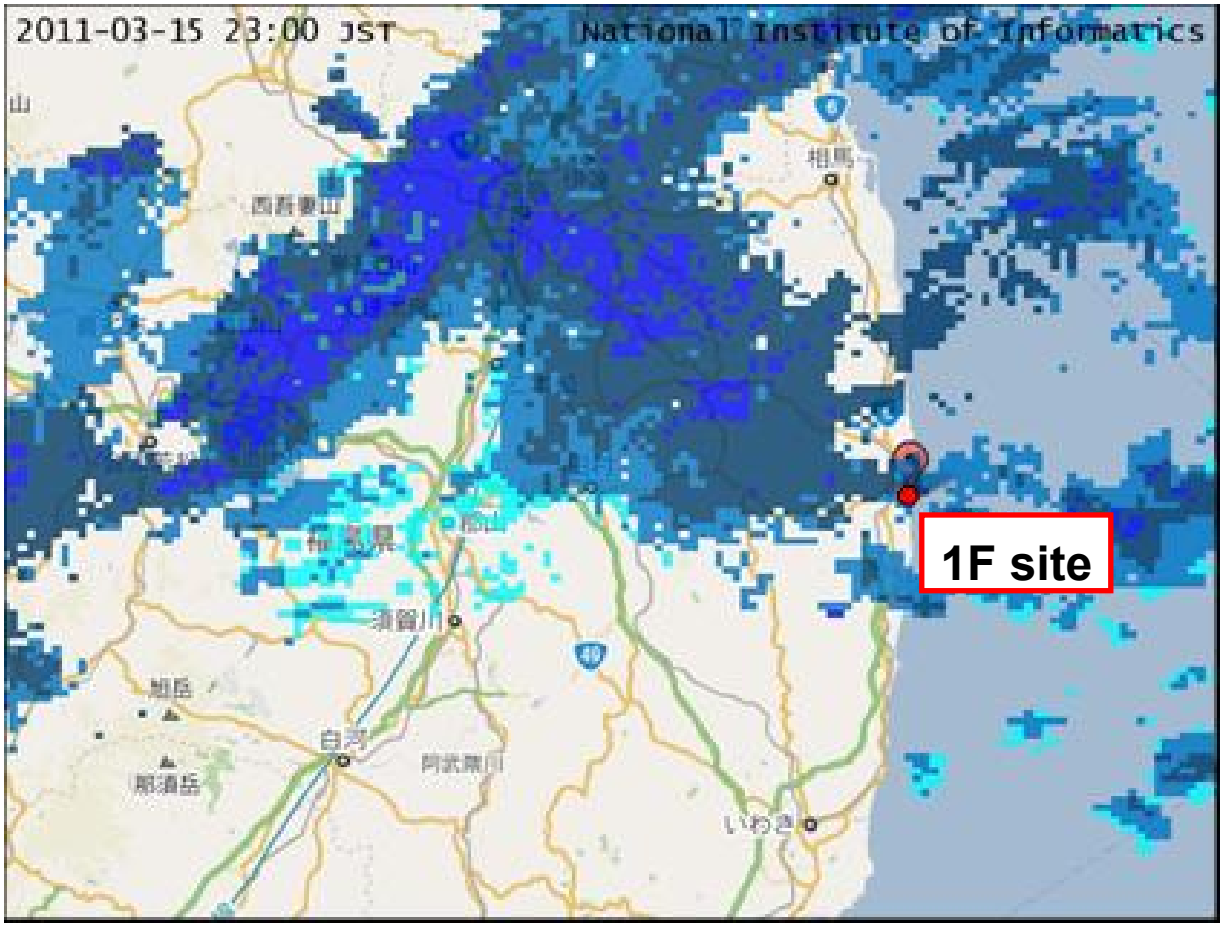
Trajectory of the plume released from Unit 2 at 10:00am 3/15.



Trajectory of the plume released from Unit 2 at 8:00pm 3/15.

- These pictures indicate that the plume released from Unit 2 on 3/15 located NW region from evening to midnight.

8. Cause of Contamination of NW region【3/3】



Weather radar around Fukushima Pref. at 11:00pm 3/15.

- According to the weather radar, around NW region it was raining from evening to midnight on 3/15.
- We concluded the main cause of the contamination of NW region was **the uncontrolled release from Unit 2.**

9. Conclusion

- Comparison with the estimation results of other organization, it can be said that **TEPCO's estimation about Cs is almost adequate.** But the amount of Iodine is too large. So, we think that **farther investigation is required**.
- The process of the main release is **uncontrolled release from Reactor Buildings.**
- **S/C venting is effective** to decrease the FP release to the air.
- Main Cause of the contamination of NW region is **uncontrolled release from Unit2 (potential impairment of torus).**

process of release	noble-gas	I-131	Cs-134	Cs-137
Venting	approx.5	approx.1	approx.0.02	approx.0.01
Hydrogen Explosion	approx.10	approx.3	approx.0.07	approx.0.05
uncontrolled release from Reactor Buildings	approx.500	approx.500	approx.10	approx.10
Total	approx.500	approx.500	approx.10	approx.10