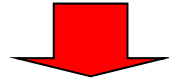SPEEDI-MP

International Workshop, Feb. 22-23, 2012

Source term estimation and atmospheric dispersion simulations of radioactive materials discharged from the Fukushima Daiichi Nuclear Power Plant due to Accident

Haruyasu NAGAI, Masamichi CHINO, Hiroaki TERADA,
Genki KATATA, Hiromasa NAKAYAMA, and Masakazu OTA
Japan Atomic Energy Agency

SPEEDI-MP

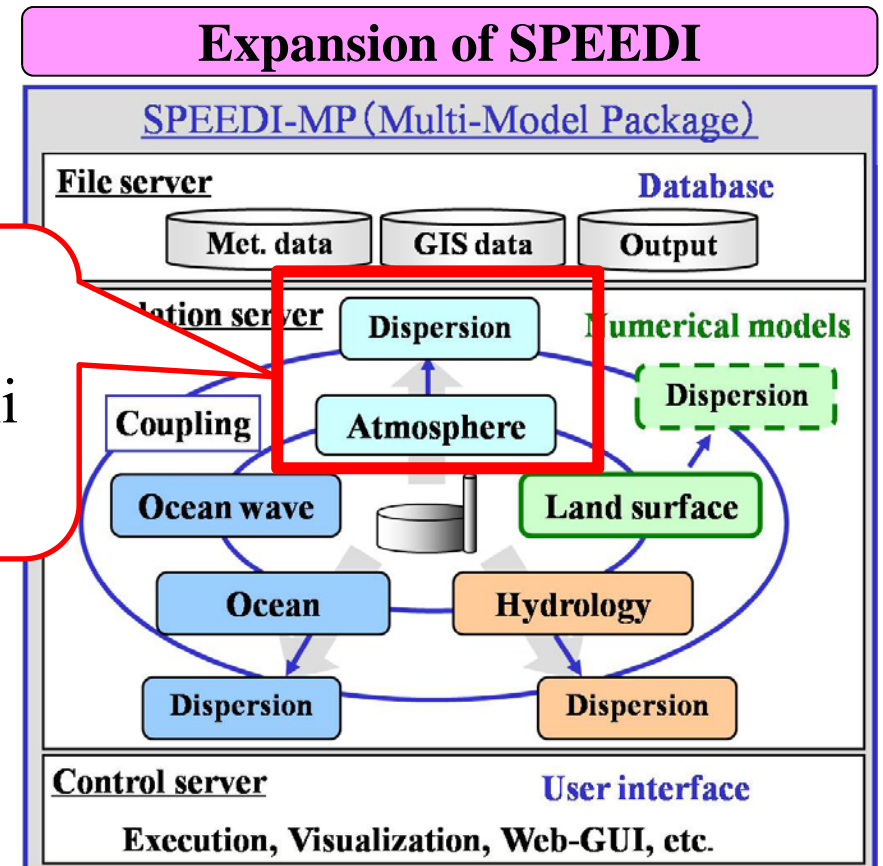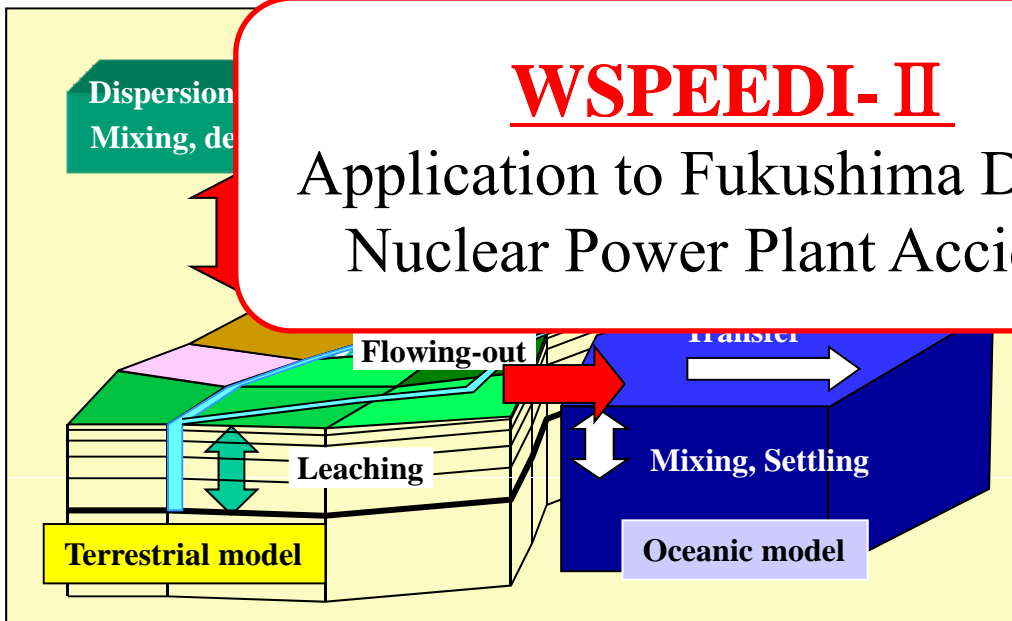## Changes and needs of the society

- Advance in nuclear fuel cycle, increase of nuclear facilities in East Asia, and so on
  → Diversification of nuclear activities and complication of release conditions
- General environmental problems: global warming, water cycle problems, and so on
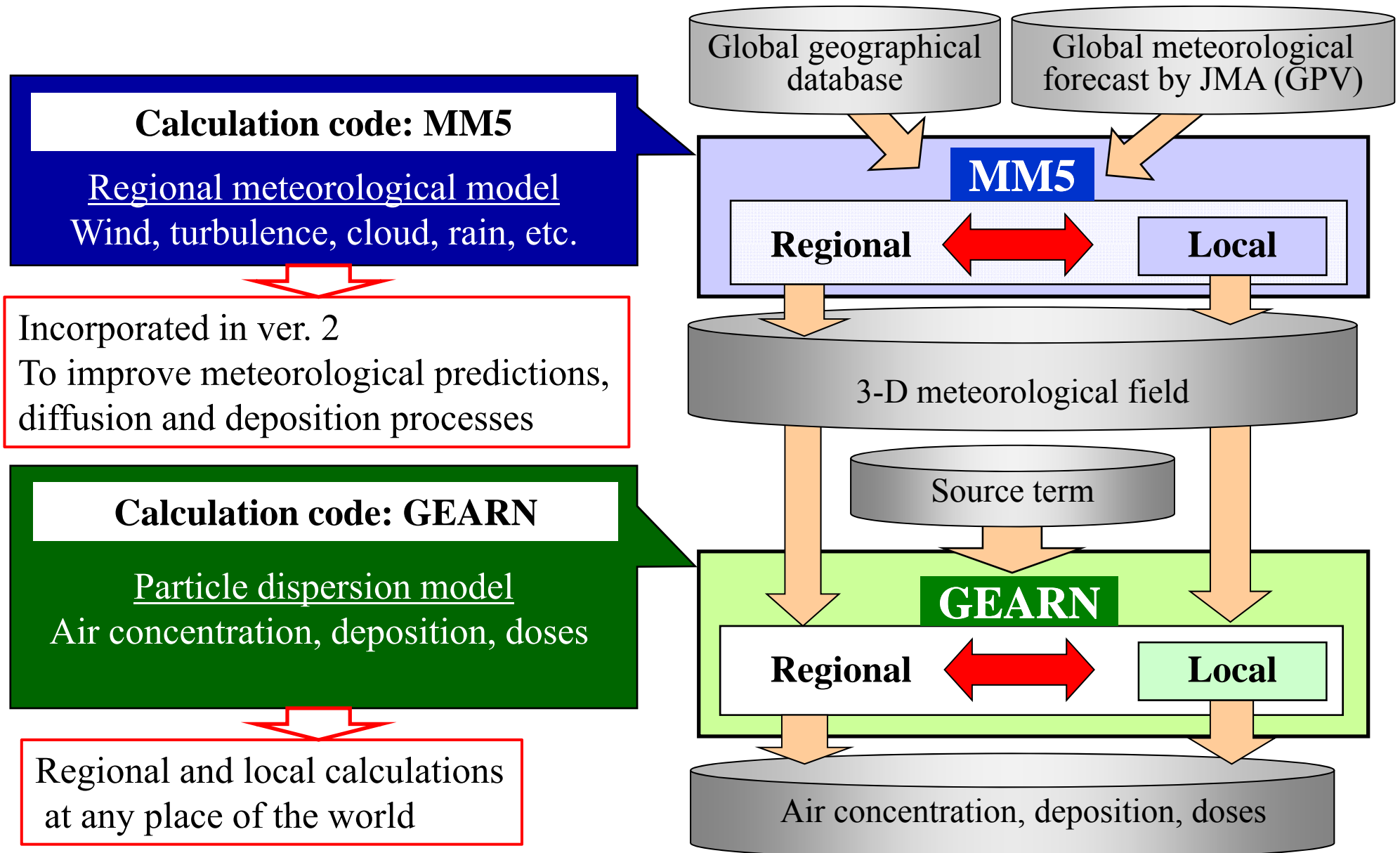 → To be solved by applying any kind of science and technology

Simulation for elucidation of the behavior of materials in the multiple environments

Expansion of SPEEDI

WSPEEDI-II

Application to Fukushima Daiichi Nuclear Power Plant Accident

Dispersion
Mixing, de

Flowing-out

Transfer

Leaching

Mixing, Settling

Terrestrial model

Oceanic model

SPEEDI-MP (Multi-Model Package)

File server   Database

Met. data   GIS data   Output

lation server   Numerical models

Coupling   Dispersion   Dispersion

Atmosphere

Ocean wave   Land surface

Ocean   Hydrology

Dispersion   Dispersion

Control server   User interface

Execution, Visualization, Web-GUI, etc.

SPEEDI-MP

WSPEEDI-Ⅱ
Model structure of WSPEEDI-Ⅱ

Calculation code: MM5

Regional meteorological model
Wind, turbulence, cloud, rain, etc.

Incorporated in ver. 2
To improve meteorological predictions, diffusion and deposition processes

Calculation code: GEARN

Particle dispersion model
Air concentration, deposition, doses

Regional and local calculations at any place of the world

Global geographical database

Global meteorological forecast by JMA (GPV)

MM5

Regional ⬌ Local

3-D meteorological field

Source term

GEARN

Regional ⬌ Local

Air concentration, deposition, doses

WSPEEDI-Ⅱ
Nesting calculations

MM5 domain

【MM5】
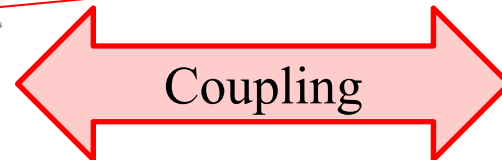2-way nesting up to 5 domains: select arbitrary 2 domains
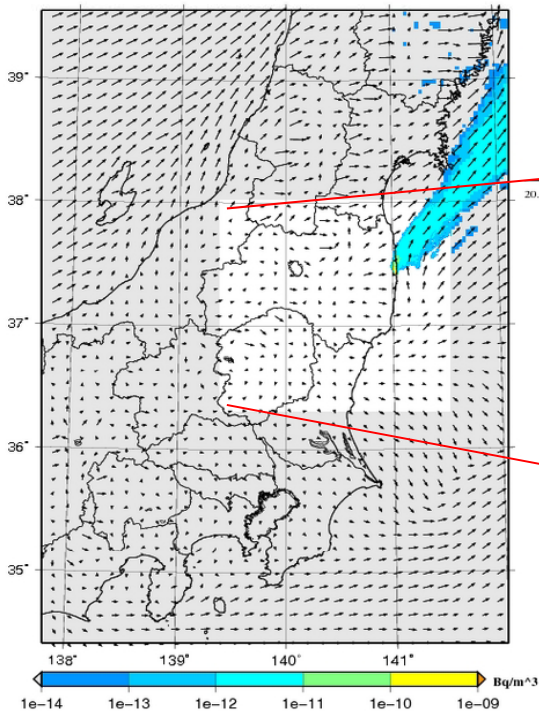
Off-line or on-line coupling

【GEARN】
2-way nesting for 2 domains: exchange input/output data via MPI between 2 model domains separately executed as parallel tasks
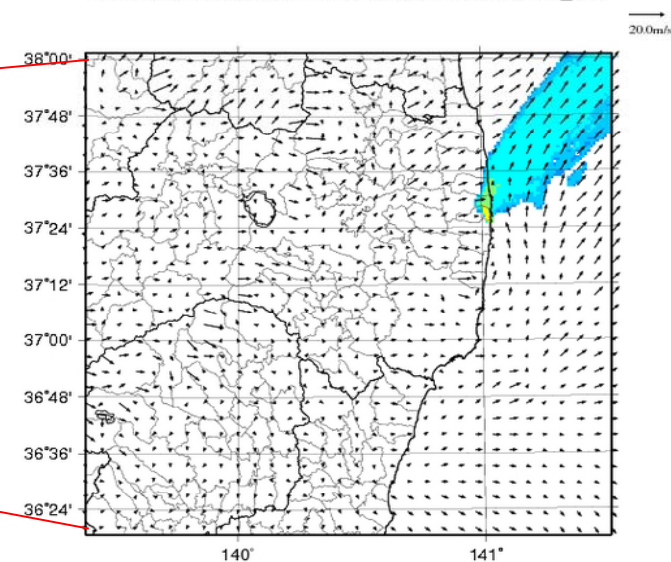
GEARN domains

Surface concentration of I-131 at UTC= 2011-03-13_00h

Coupling

Flow in/out between local and wide domains

Bq/m^3
1e-14   1e-13   1e-12   1e-11   1e-10   1e-09

SPEEDI-MP
WSPEEDI-Ⅱ
Application to Fukushima NPP accident
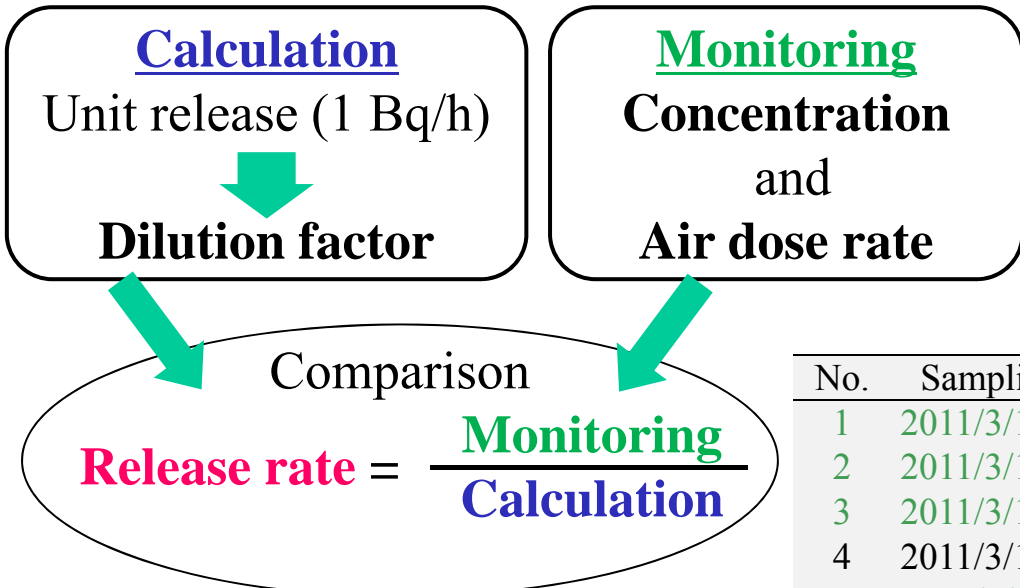
【Source term estimation】
- Collaboration with the Nuclear Safety Commission (NSC) of Japan
- Estimation by coupling monitoring data with atmospheric dispersion simulations
  ⇒ M. Chino, et al., 2011: J. Nucl. Sci. Technol., 48,1129–1134
      Available from (http://www.jstage.jst.go.jp/article/jnst/48/7/1129/_pdf)

- Re-estimation of release rate from 12 to 15 March (Report to NSC on 22 Aug.)
      (http://www.nsc.go.jp/anzen/shidai/genan2011/genan063/siryo5.pdf, in Japanese)

【Analysis of atmospheric dispersion】
- Analysis on the local dispersion during significant release (15 to 16 March)
  - Formation process of high dose rate zone around the northwest region of the plant
  ⇒ JAEA News Release (http://www.jaea.go.jp/english/jishin/press/press110613.pdf)
      G. Katata, et al., 2012: J. Environ. Radioactiv., (in press)
      Available from (http://www.sciencedirect.com/science/article/pii/S0265931X11002335)

- Preliminary estimation of 2-month accumulated radiological doses over Japan
  ⇒ JAEA Technical Report (http://www.jaea.go.jp/english/jishin/kaisetsu03.pdf)

- Analysis on the deposition process of ^{137}Cs over Eastern Japan area
  ⇒ JAEA Technical Report (http://nsed.jaea.go.jp/fukushima/data/20110906.pdf, in Japanese)

Method and data for source term estimation

Simple source estimation method

Calculation
Unit release (1 Bq/h)

⬇

Dilution factor

Monitoring
Concentration
and
Air dose rate

Comparison

$$\text{Release rate} = \frac{\text{Monitoring}}{\text{Calculation}}$$

[Preliminary estimation]
(M. Chino, et al., 2011:
JNST, 48,1129–1134)

No.	Sampling date and time	Point
1	2011/3/15 06:00-07:00	a
2	2011/3/15 06:55-07:15	b
3	2011/3/16 06:05-06:25	b
4	2011/3/18 10:50-11:18	c
5	2011/3/21 04:45-05:05	b
6	2011/3/21 10:50-11:08	d
7	2011/3/22 14:17-14:31	c
8	2011/3/23 13:15-15:10	e
9	2011/3/24 14:55-15:15	f
10	2011/3/25 15:05-15:22	g
11	2011/3/27 11:45-	h
12	2011/3/29 11:17-12:15	f
13	2011/3/30 15:11-15:32	g
14	2011/3/31 12:22-13:12	e
15	2011/4/1 12:00-12:20	i
16	2011/4/3 11:04-	j
17	2011/4/5 13:07-13:27	f

(M. Chino, et al., 2011: JNST, 48,1129–1134)

SPEEDI-MP

[Re-estimation]
Release rate from 12 to 15 March
by using newly released data
(Report to NSC on 22 Aug.)

Environmental monitoring points used for
the estimation of release rates on March 13

Kawazoe, Namie-machi
(12:00-12:10)
Concentration of ^{131}I :
165 Bq m^{-3}

Odaka-ku,
Minamisoma
(13:20-13:35)
Concentration of ^{131}I :
63 Bq m^{-3}

Takase, Namie-machi
(8:39-8:49)
Concentration of ^{131}I :
37 Bq m^{-3}

1F

Ottozawa, Okuma-machi
(8:37-8:47)
Concentration of ^{131}I :
12 Bq m^{-3}

37°30'
37°12'
140°42'   141°00'

Hirusone, Namie-machi
(16:22-16:32)
Concentration of ^{131}I :
100 Bq m^{-3}

Otabashi,
Minamisoma
(15:08-15:18)
Concentration of
^{131}I : 84 Bq m^{-3}

Environmental
Radioactivity
Monitoring Center
(18:00-18:10)
Concentration of ^{131}I :
60 Bq m^{-3}

> 30 μSv h^{-1}
4.98   4.0
11.9   3.59
6.99
1.66
3.09
8.2
1.9
5.25   5.0
19.3
2.82
2.45
3.19
4.88
2.28   2.21
9.59   2.51
2.3
15.7
18.2
0.42
0.13   0.08
0.07

●1F

37°39'
37°36'
37°33'
37°30'
37°27'
37°24'
140°51'   140°54'   140°57'   141°00'   141°03'

Air dose rate
observations at 06:00-
15:00 on March 13
✓Unit: micro Sv/h
✓●: over 30 micro Sv/h

Environmental monitoring points used for
the estimation of release rates on March 12

Preliminary estimated release rates of ^{131}I & ^{137}Cs (M. Chino, et al., 2011: JNST, 48,1129–1134)

- Total release amount from 11 March to 5 April ^{131}I: 1.5×10^{17} Bq ^{137}Cs: 1.2×10^{16} Bq

Re-estimated release rates (http://www.nsc.go.jp/anzen/shidai/genan2011/genan063/siryo5.pdf)
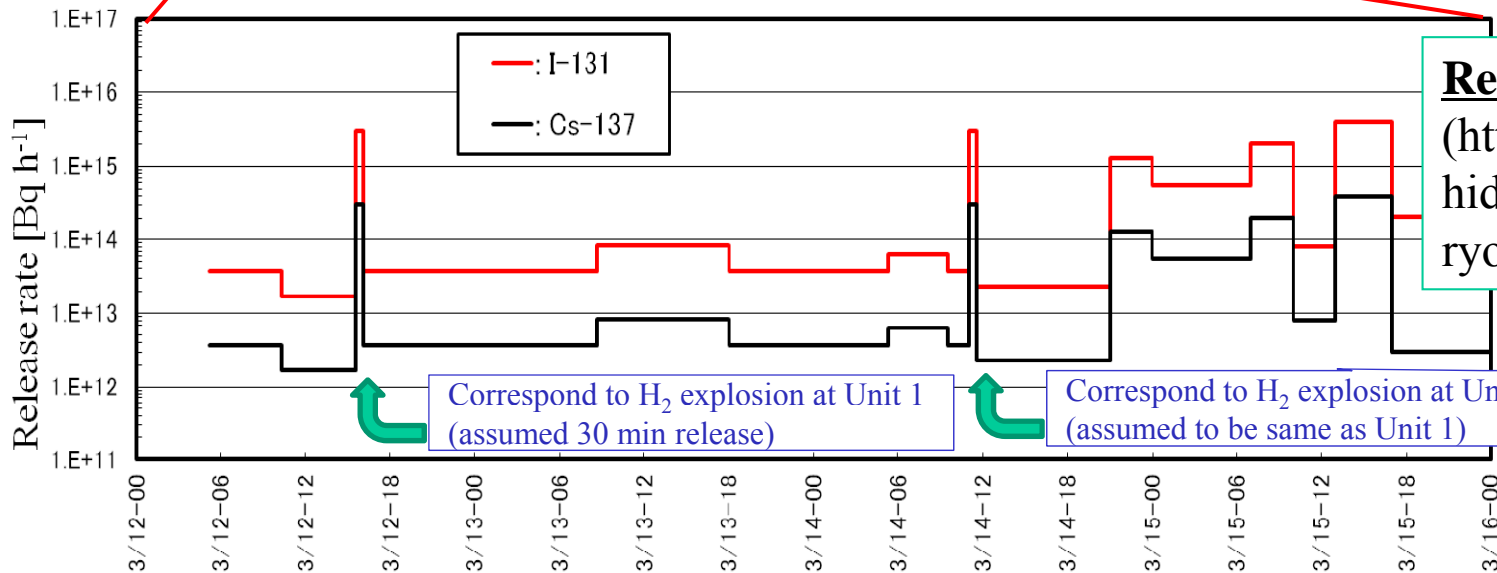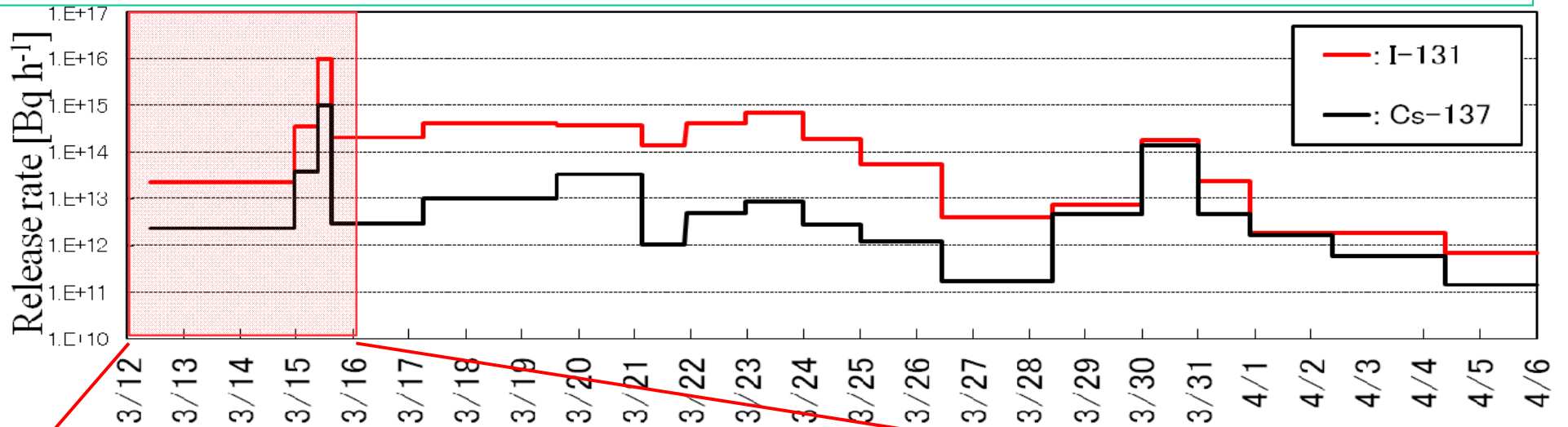
Correspond to H_2 explosion at Unit 1 (assumed 30 min release)

Correspond to H_2 explosion at Unit 3 (assumed to be same as Unit 1)

SPEEDI-MP

Formation process of high dose rate zone

□ Analysis on the formation process of high dose rate zone in the northwest direction of the plant and the middle part of Fukushima Prefecture

□ Numerical simulations of the atmospheric dispersion of radioactive materials discharged from the plant during the period from 15 to 16 March
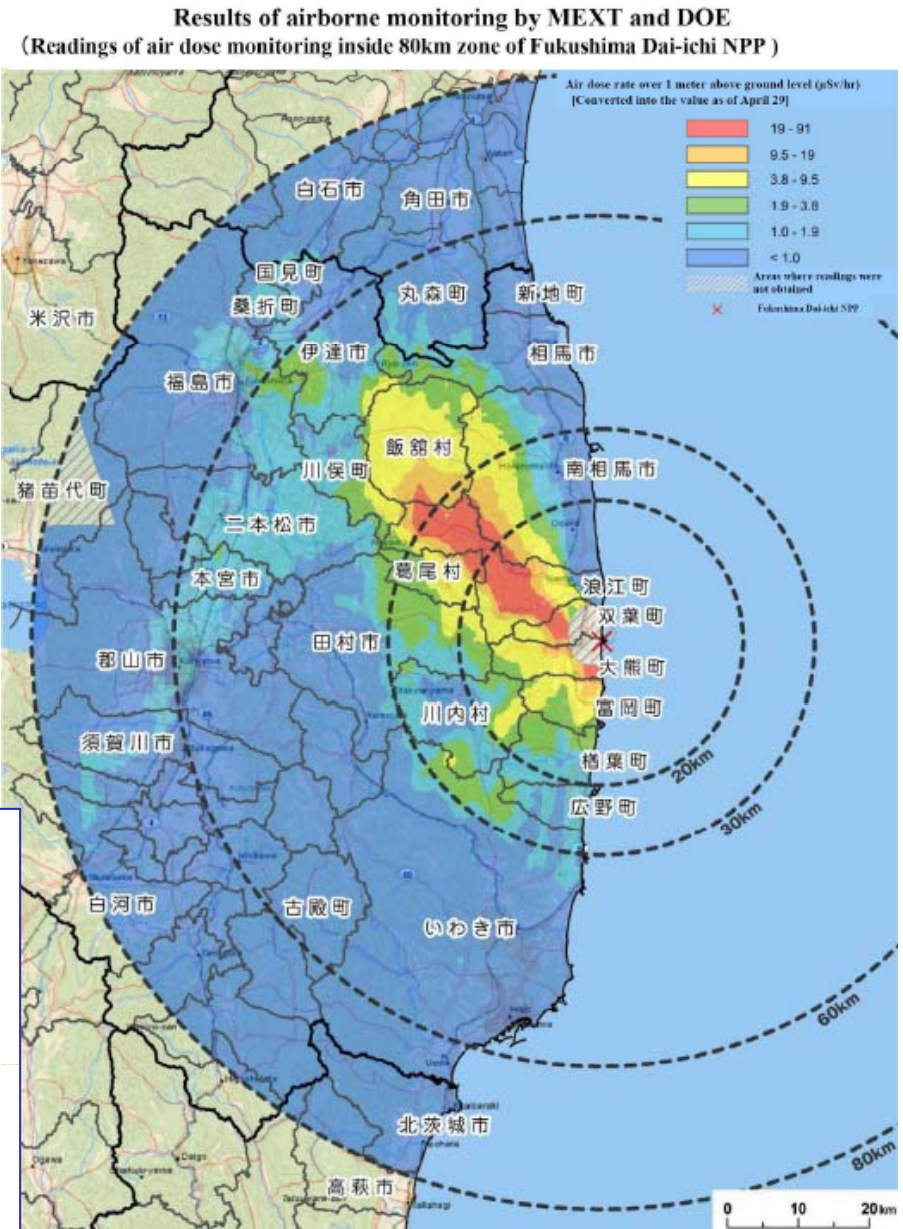
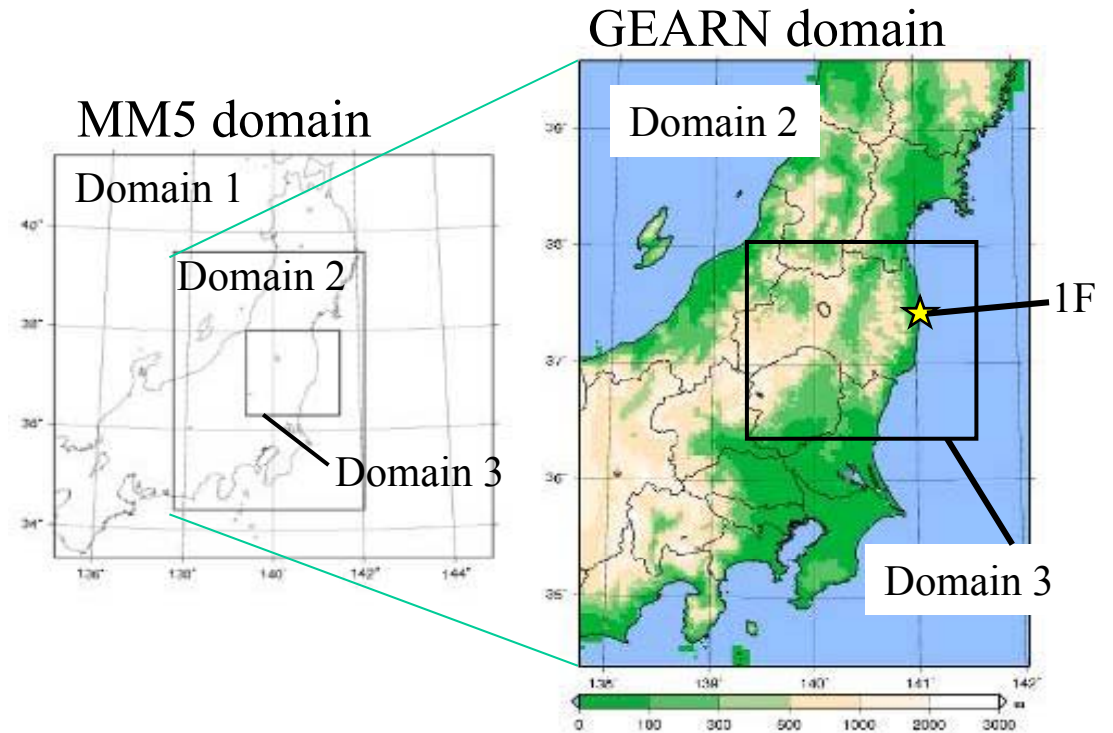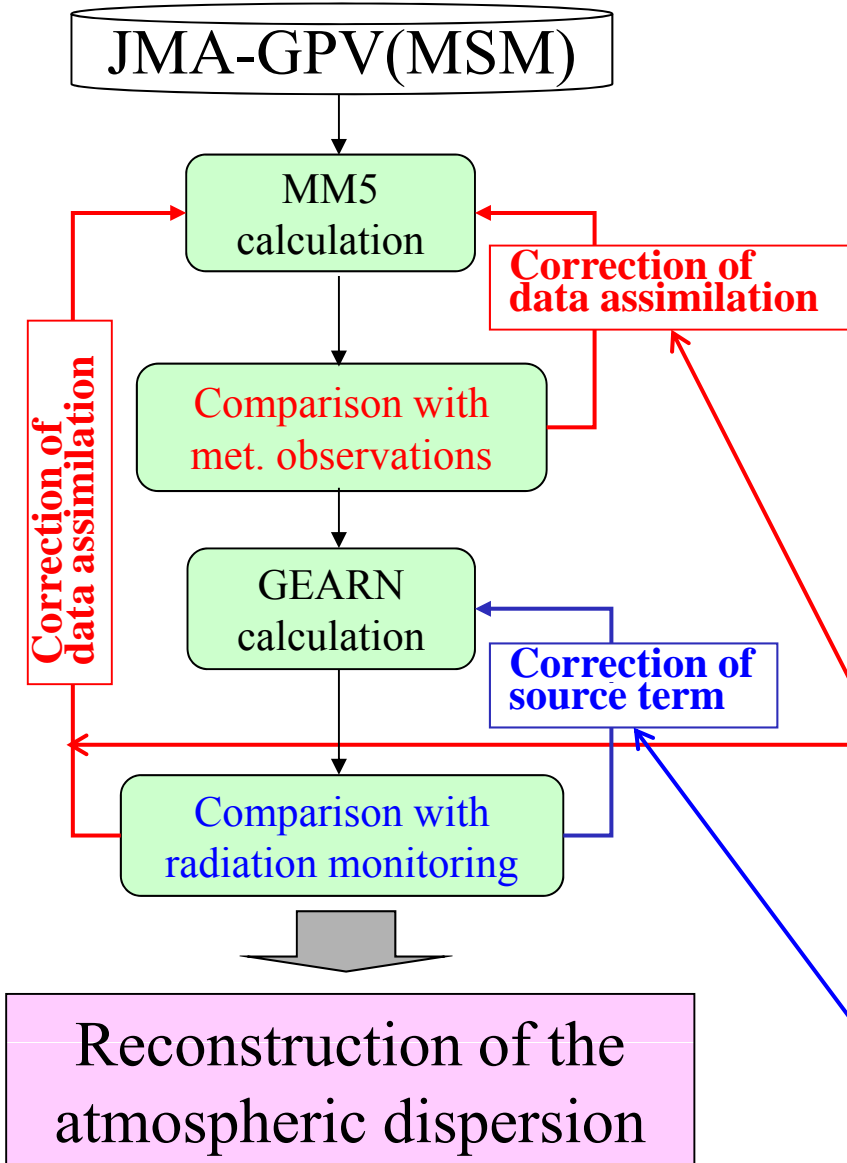**Results of airborne monitoring by MEXT and DOE**
Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety
- The Accident at TEPCO's Fukushima Nuclear Power Stations –
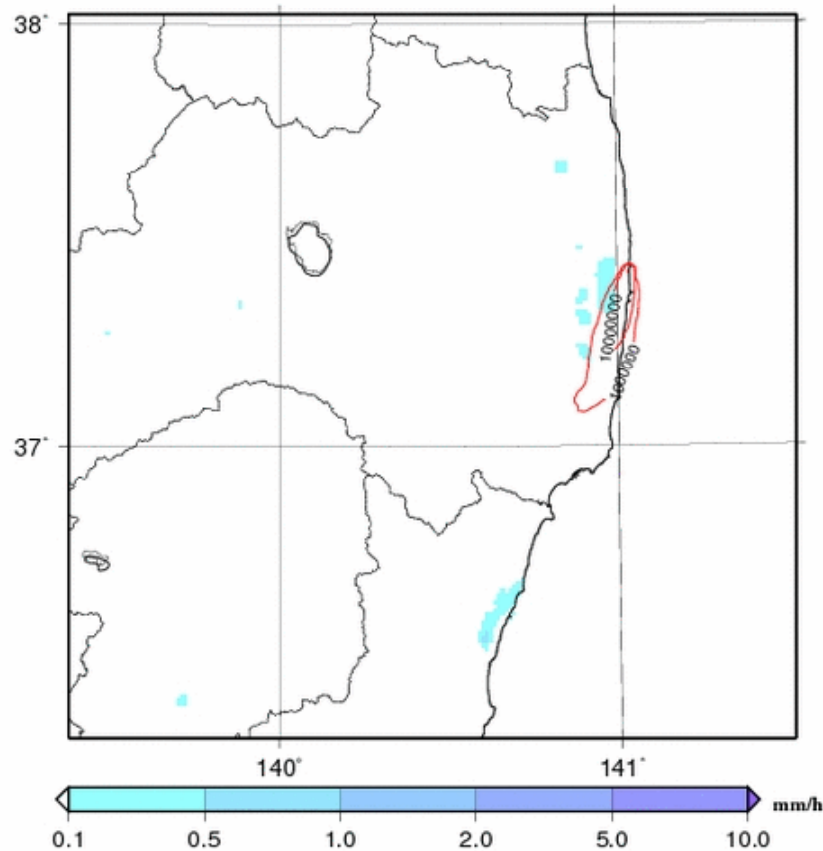(http://www.kantei.go.jp/foreign/kan/topics/201106/iaea_houkokusho_e.html)

Results of airborne monitoring by MEXT and DOE
(Readings of air dose monitoring inside 80km zone of Fukushima Dai-ichi NPP)

JAEA SPEEDI-MP

JMA-GPV(MSM)

MM5 calculation

Comparison with met. observations

Correction of data assimilation

GEARN calculation

Correction of source term

Comparison with radiation monitoring

Correction of data assimilation

Reconstruction of the atmospheric dispersion

GEARN domain

MM5 domain

Domain 1

Domain 2

Domain 3

Domain 2

1F

Domain 3

● Analysis and observational nudging: AMeDAS data, Wind data at 1F and 2F

● 3 domain nest: 9 km (D1), 3 km (D2), 1 km (D3)

● Period: 17JST on 14 to 00JST on 17 March 2011

● Radionuclide: ^{131}I, ^{132}Te ($+^{132}$I), ^{134}Cs, ^{137}Cs

● Release rate: Correct the initial condition based on Chino et al. (2011) to fit monitoring data

SPEEDI-MP

Calculated concentration and rain

Rain intensity: shaded area

Vertical accumulated conc.: red contours

Air dose rate

Calculation: shaded area

Monitoring: plot with values

Air concentration of I-131 and rain at UTC= 2011-03-15_00h

Air dose rate at UTC= 2011-03-15_00h

SPEEDI-MP
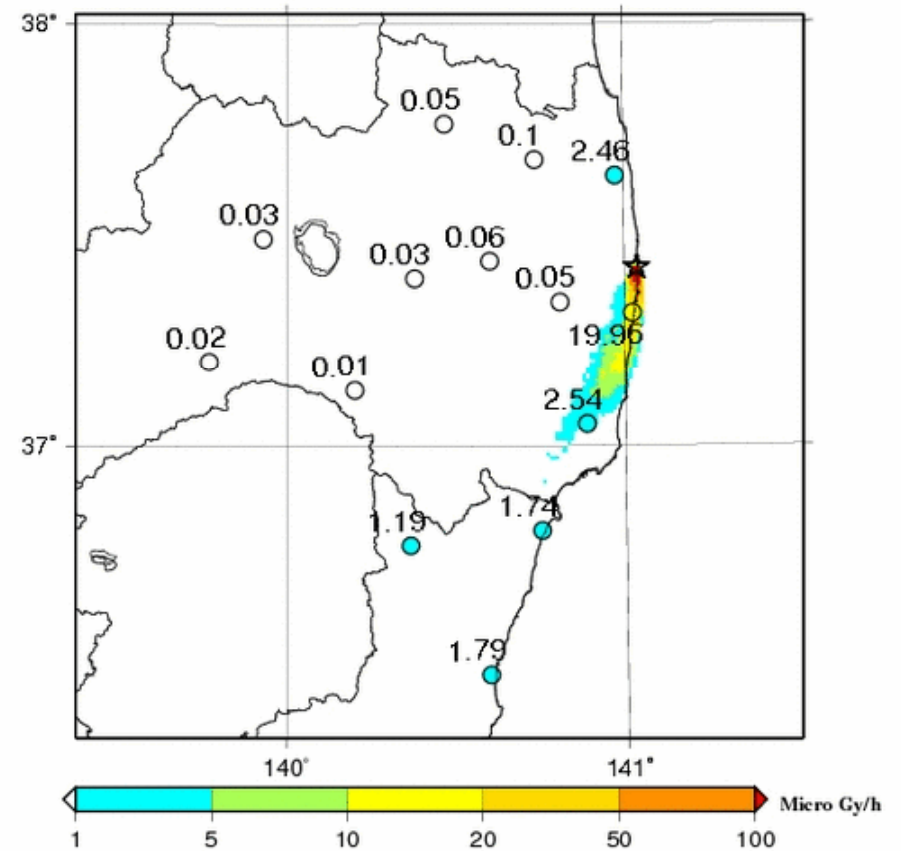
Formation process of high dose rate zone

Air dose rate (21JST on 16 March)

Fukushima
- ○ Obs.
- — Calc.

Koriyama
- ○ Obs.
- — Calc.

Tamura
- ○ Obs.
- — Calc.

15 Mar PM

15 Mar AM

14.96

0.4

2.76   0.21

0.08

3.1

1.61

1.34

1.49

0.13

1.37

0.12

0.31

0.08
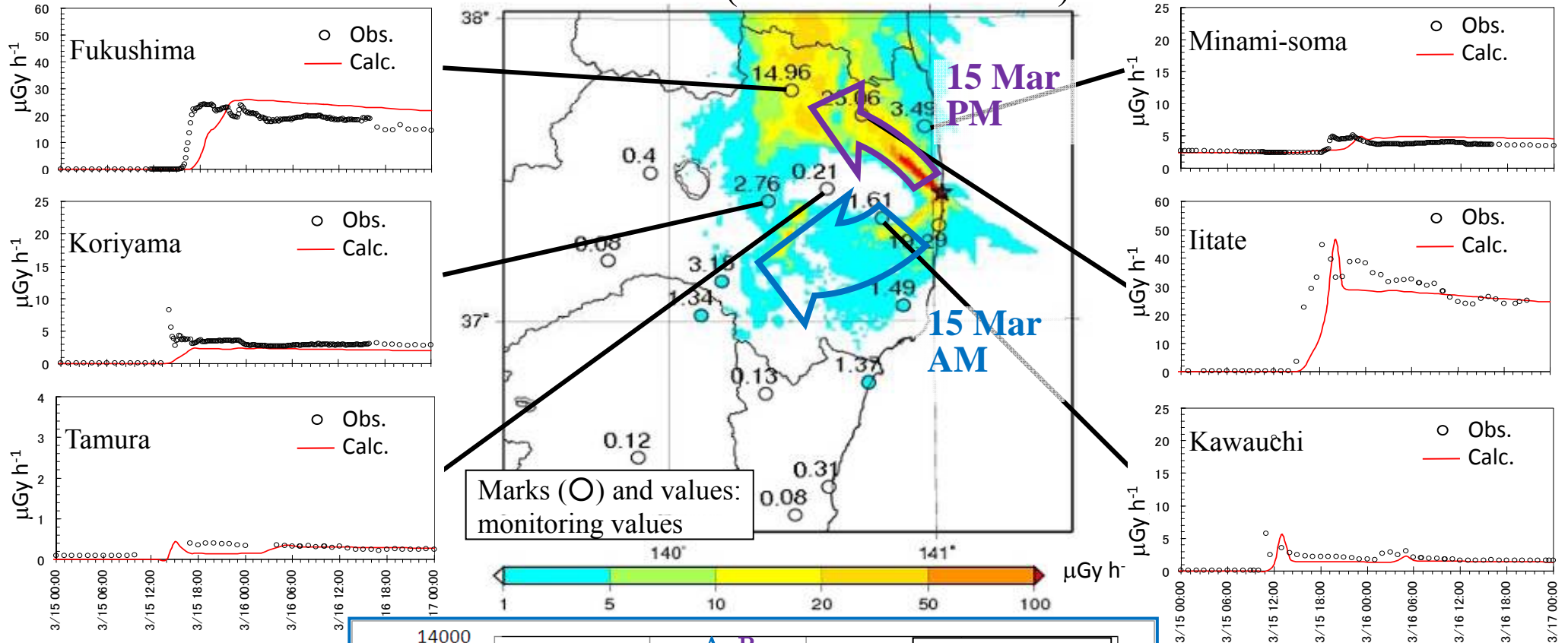
Marks (○) and values: monitoring values

140°   141°   μGy h⁻

Minami-soma
- ○ Obs.
- — Calc.

Iitate
- ○ Obs.
- — Calc.

Kawauchi
- ○ Obs.
- — Calc.

Air dose rate at the Fukushima Daiichi NPP

- ◆ : near main gate
- ■ : near west gate
- ▲ : near gym.

A   B
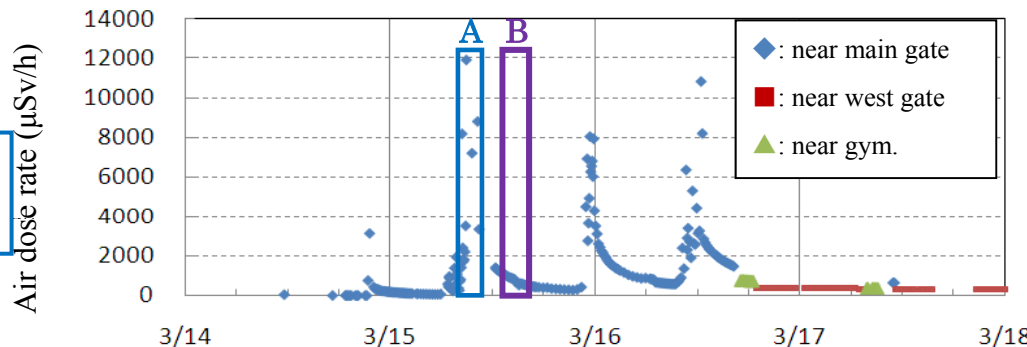
Rapid pressure decrease in Unit 2
Period A: 7 to 11 JST on 15 Mar.
Period B: 13 to 15 JST on 15 Mar.

SPEEDI-MP

Deposition of ^{137}Cs over eastern Japan

■ <u>Domain</u>: (Horizontal) 690 km × 960 km
      (vertical) 10 km

■ <u>Resolution</u>: 3 km grid

■ <u>Period</u>: 05JST on 12 March to 24JST on 30 April 2011

■ <u>Input meteorological data</u>
・JMA-GPV(MSM): 3 h interval
・AMeDAS data, Wind data at 1F and 2F

■ <u>Release rate</u>
・Chino et al.(2011) + re-estimated source term
・Assume that the release rate on 5 April continue until the end of calculation period

Local Domain 3

1F

Validation of the estimated source term
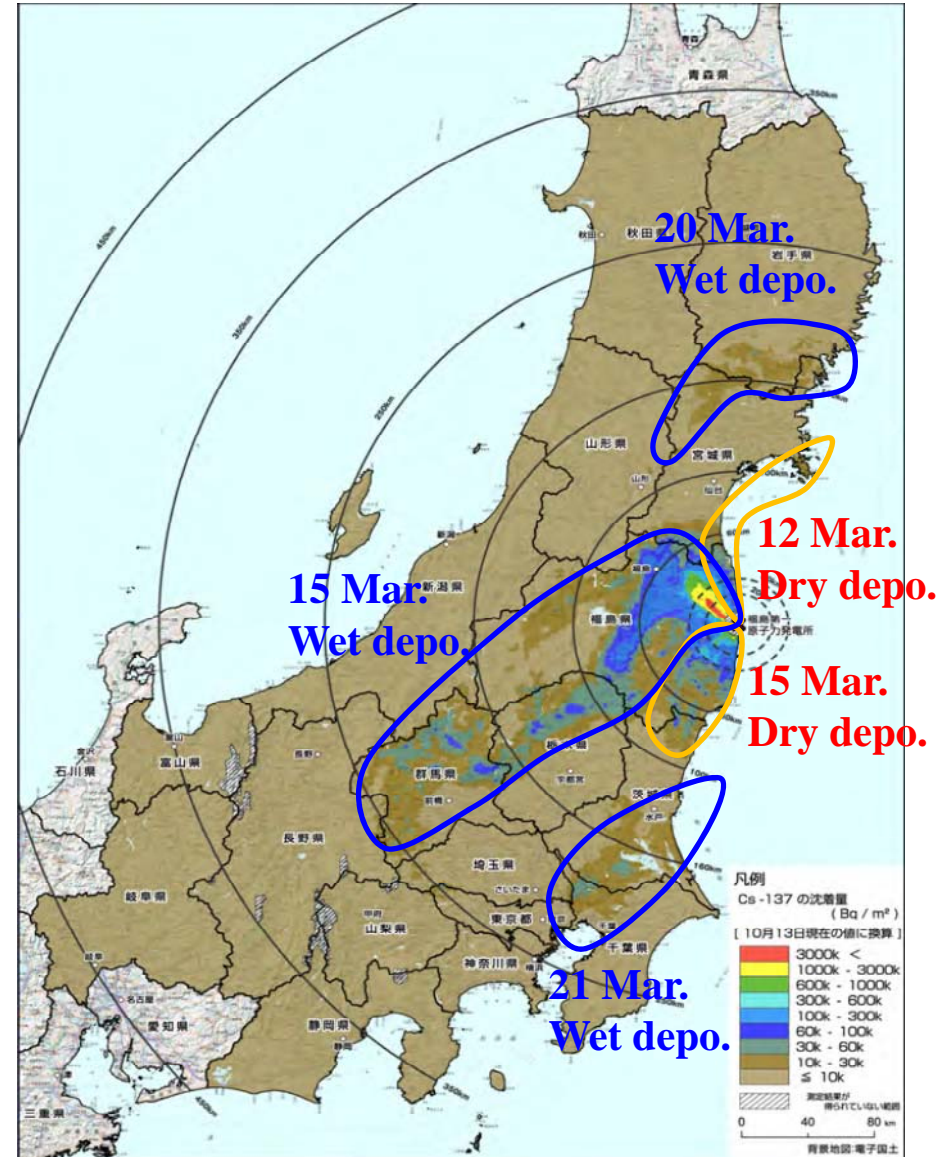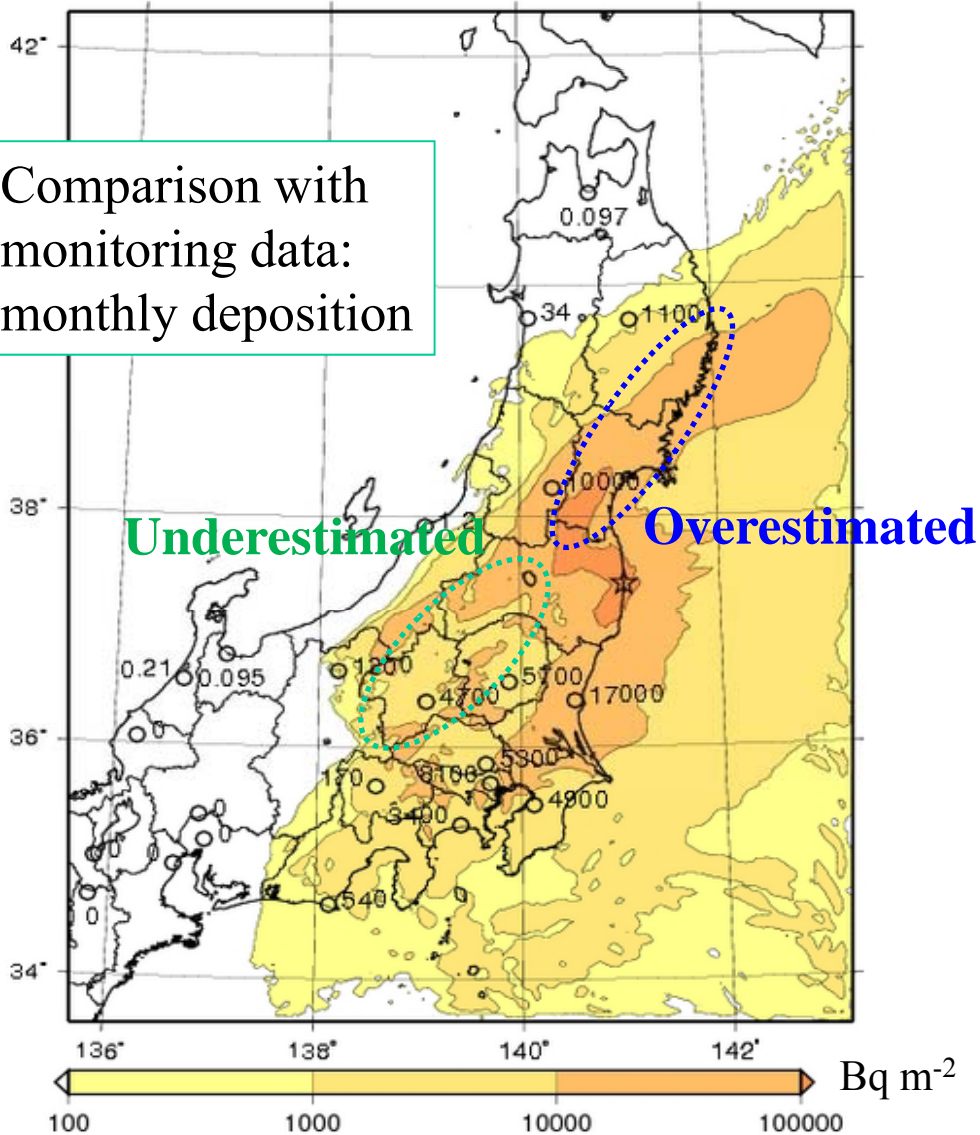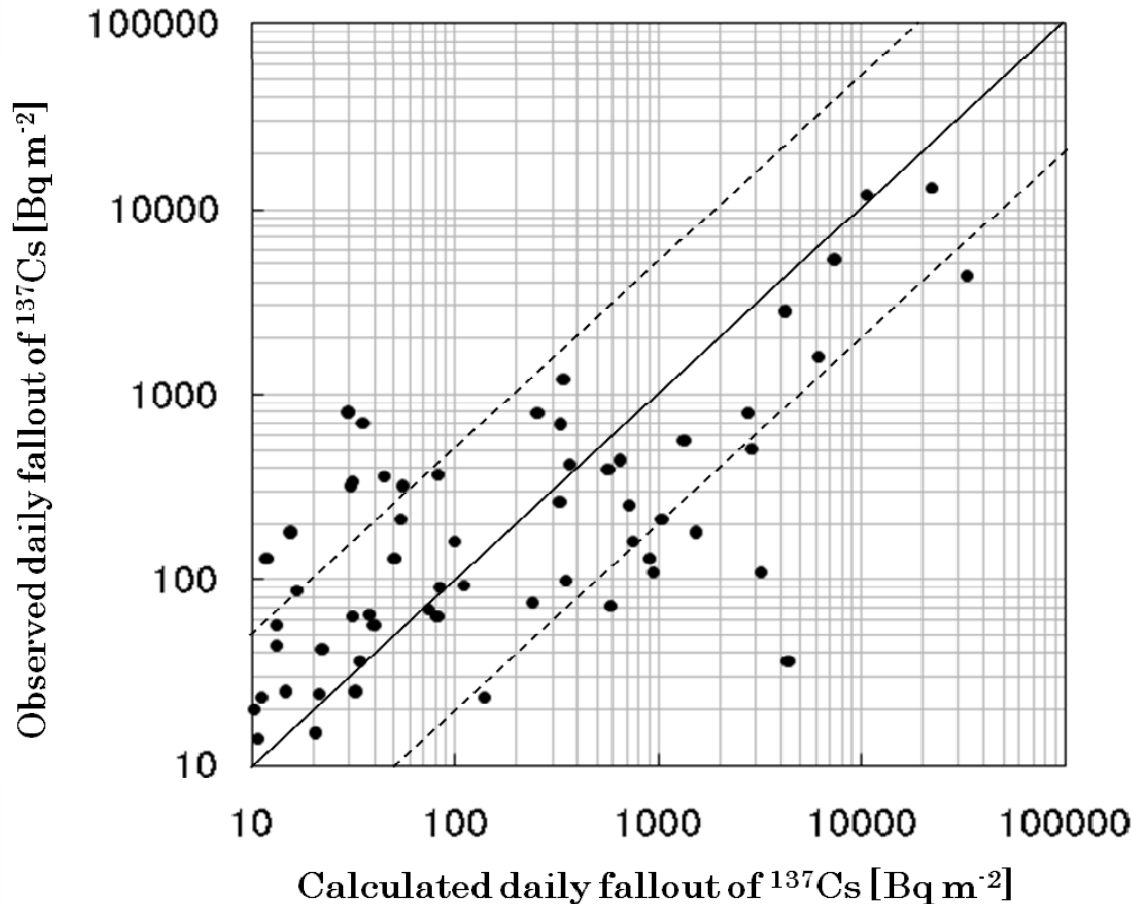
SPEEDI-MP
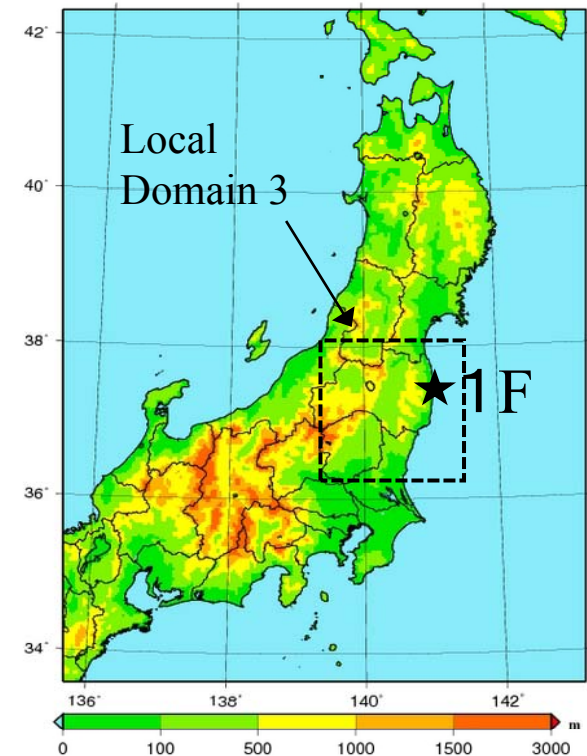
Formation process of ^{137}Cs deposition

Deposition until the end of March

Airborne monitoring of ^{137}Cs deposition by MEXT

Comparison with monitoring data: monthly deposition

Underestimated

Overestimated

Bq m^{-2}

20 Mar. Wet depo.

12 Mar. Dry depo.

15 Mar. Wet depo.

15 Mar. Dry depo.

21 Mar. Wet depo.

SPEEDI-MP

Comparison with measured ^{137}Cs deposition

^{137}Cs daily deposition

Factor 2	39.0 %
Factor 5	69.5 %
Factor 10	86.4 %
Correlation coefficient	0.72

This result indicates the validity of estimated source term.

JAEA *SPEEDI-MP*

Activities during the Fukushima Daiichi nuclear accident

- **Source term estimation** by coupling environmental monitoring data with atmospheric dispersion simulations by *SPEEDI/ WSPEEDI*
- **Prediction of air concentration, deposition and radiological doses** by *WSPEEDI*
  ➡ **provided to the Japanese government, local authorities, etc.**
- In present, **prediction of oceanic dispersion** by coupling oceanic dispersion model with *WSPEEDI* to consider the fallout to sea surface
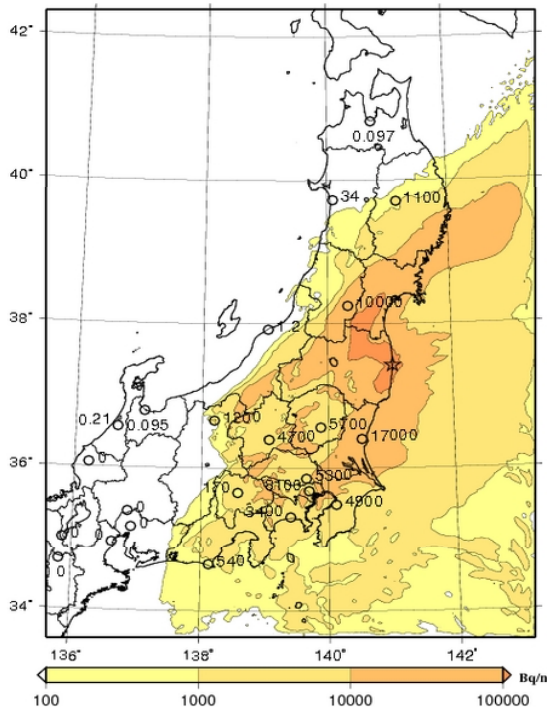
(Left) Predicted deposition of ^{137}Cs until 31 March

(Below) Example of predicted oceanic dispersion

nwpacific_20110401120000_xy_d0.00_k001.dat

Concentration[Bq/L]

Bq/n
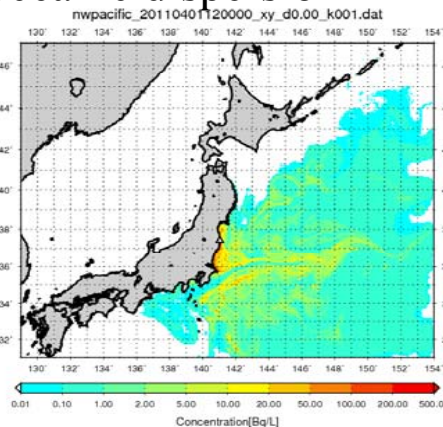
Future work

- **Coupling of atmospheric, oceanic and terrestrial transport models**
- **Dose evaluation modeling in contaminated circumstances**