Japan Atomic Energy Agency
Nuclear Science and Engineering Center
Environment and Radiation Sciences Unit
Research Group for Environmental Science

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Application of Atmospheric Dispersion Simulation System ***WSPEEDI*** for Analysis on the Environmental Impact due to the Fukushima Daiichi Nuclear Power Station Accident

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Development of simulation systems at JAEA

- System for Prediction of Environmental Emergency Dose Information: ***SPEEDI***
  - ***SPEEDI*** was developed after the TMI accident (1980～1985), and has been operated as the emergency response system by Nuclear Safety Technology Center.

- Worldwide version of ***SPEEDI:*** ***WSPEEDI***
  - ***WSPEEDI*** has been developed after the Chernobyl accident (1987～) .
  - Completion of ***WSPEEDI-Ⅰ***（1997）, ***WSPEEDI-Ⅱ***（2009）
  - ***WSPEEDI*** has been used for research purpose and analysis in case of nuclear accidents and nuclear test. It will also provide prediction results to IAEA Response and Assistance Network: RANET（2010～）.

- Coupling simulation of atmospheric, terrestrial, and oceanic models: ***SPEEDI-MP***
  - ***SPEEDI-MP*** has been developed after1999.
  - Long term simulation for the transport in the terrestrial and oceanic environments
  - Consideration of complicated transport processes for some radionuclides (^{3}H, ^{14}C)

- Application to the Fukushima Daiichi nuclear power station accident (2011～)
  - Source term estimation
  - Analysis on the atmospheric dispersion, oceanic dispersion, etc.

Operational model description: ***SPEEDI***

Items	Description
Code name	***SPEEDI***; System for Prediction of Environmental Emergency Dose Information
Development organization	Japan Atomic Energy Research Institute
Operational organization	Nuclear Safety Technology Center (SPEEDI Ver.1: since 1986, Ver.2: since 2005)
Air flow model	Hydrostatic mesoscale model and diagnostic mass-consistent local model
Gas dispersion model	Lagrangian particle model
Dry deposition model Wet deposition model	Simple formula: deposition velocity Simple parameterizations: scavenging rate
Precipitation data	Observed data (in situ, if available) or weather forecast data (GPV) by JMA
Calculation spatial domain	100 km rectangle area with 1 km grid, max depth 4 km for regional calculation 25 km rectangle area with 250 m grid, max depth 2 km for local calculation
Output period, interval	Up to 84 hours from initial time, 1 hour interval
Output data	Wind velocity, air concentration, deposition and radiation doses
Terrain effect	Import terrain grid, land use to meteorological field calculation
Source term estimation	Simulations of the progression of the accident (ERSS)

Evacuation decision process (at Fukushima)

Decision process based on the Guideline by Nuclear Safety Commission (NSC)

■Basis for protective action (based on ICRP, etc.)

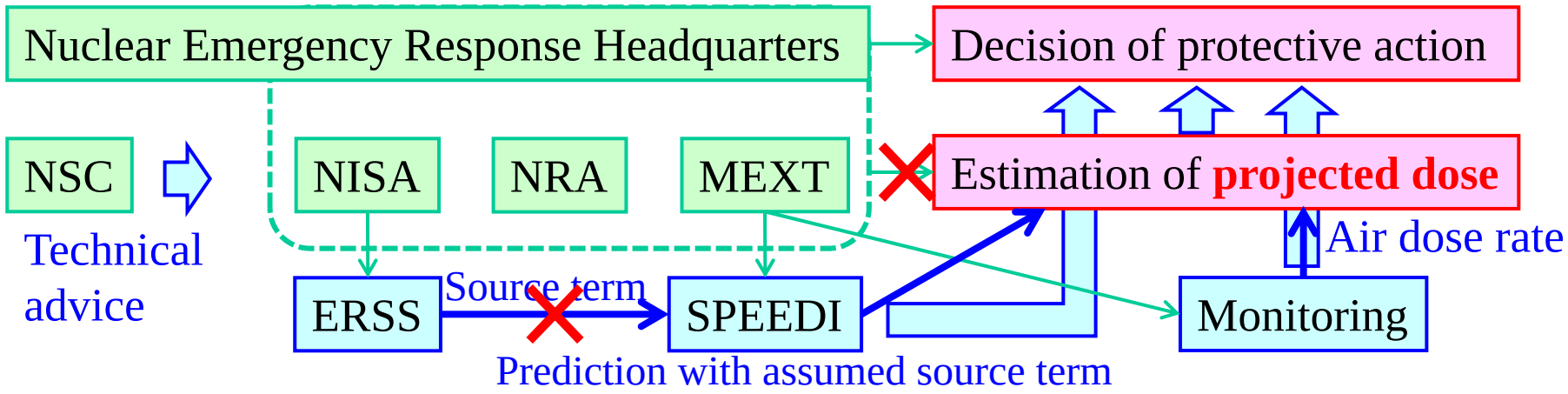
•Indicator for protective action: **projected dose*** **”予測線量”≠predicted dose**

* The dose that would be expected to be incurred if a specified countermeasure was to be taken.

•The **projected dose** is estimated by considering the state of NPS, source term, environmental monitoring data, meteorological data, SPEEDI prediction, etc.

Projected dose (mSv)		**Protective action**
Effective dose (external)	Equivalent doses (internal)	
10～50	100～500	Sheltering indoors
＞50	＞500	Evacuation

■Decision process (Organizational structure, responsibilities and authorities)



Model description: ***WSPEEDI***

Items	Description (in red; essential difference from *SPEEDI*)
Code name	***WSPEEDI***; Worldwide version of ***SPEEDI***
Development organization	Japan Atomic Energy Agency (JAEA)
Operational organization	Not operational, used by JAEA
Air flow model	Mesoscale model; MM5
Gas dispersion model	Lagrangian particle model
Dry deposition model Wet deposition model	Simple formula: deposition velocity Simple parameterizations: scavenging rate
Precipitation data	Calculated data by MM5
Calculation spatial domain	Variable; several hundred km rectangle area with several km grid, max depth 10 km Fukushima case; 190x190 km with 1 km grid, 690x 960 km with 3 km grid, etc.
Output period, interval	Up to 84 hours from initial time in real time calculation, 1 hour interval (variable)
Output data	Wind velocity, air concentration, deposition and radiation doses
Terrain effect	Import terrain grid, land use to meteorological field calculation
Source term estimation	“reverse” modelling using measurements of levels of radiation or radioactive material in the environment (UNSCEAR 2013 report)

Activities during the Fukushima accident

【Source term estimation】 Collaboration with the NSC of Japan

- Estimation by coupling monitoring data with atmospheric dispersion simulations
  ⇒ M. Chino, et al., 2011: J. Nucl. Sci. Technol., 48,1129–1134
- Re-estimation of release rate from 12 to 15 March (Report to NSC on 22 Aug.)
  ⇒ G. Katata, et al., 2012: J. Environ. Radioactiv., 109, 103-113
- Detailed estimation of release rate by using new deposition model and new data
  ⇒ G. Katata, et al., 2015: Atmos. Chem. Phys., 15, 1029–1070, 2015

【Analysis of atmospheric dispersion】

- Analysis on the formation process of high dose rate zone around NW of the plant
  ⇒ JAEA News Release (http://www.jaea.go.jp/english/jishin/press/press110613.pdf)
  G. Katata, et al., 2012: J. Environ. Radioactiv., 111, 2-12
- Preliminary estimation of 2-month accumulated radiological doses over Japan
  ⇒ JAEA Technical Report (http://www.jaea.go.jp/english/jishin/kaisetsu03.pdf)
- Validation of estimated source term and analysis on deposition process of ^{137}Cs
  ⇒ H. Terada, et al., 2012: J. Environ. Radioactiv., 112, 141-154
- Improvement of the wet deposition process of ^{137}Cs
  ⇒ H. Nagai, et al., 2012: Proceedings of the 1st NIRS Symposium, 137-149

Method and data for source term estimation

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

[Re-estimation]
Release rate from 12 to 15 March by using newly released data: G. Katata, et al., 2012: J. Environ. Radioactiv., 109, 103-113 (Report to NSC on 22 Aug.)

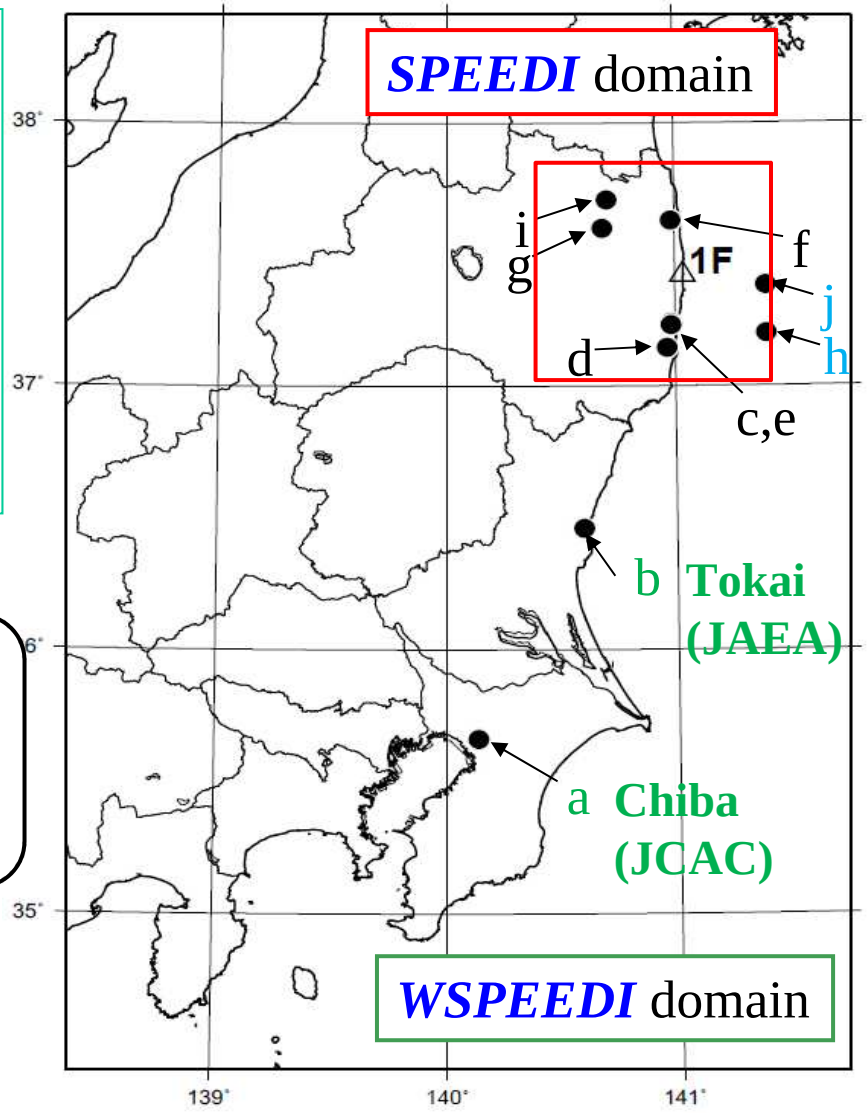
Simple source estimation method

Calculation
Unit release (1 Bq/h)
↓
Dilution factor

Monitoring
Concentration
and
Air dose rate

Comparison

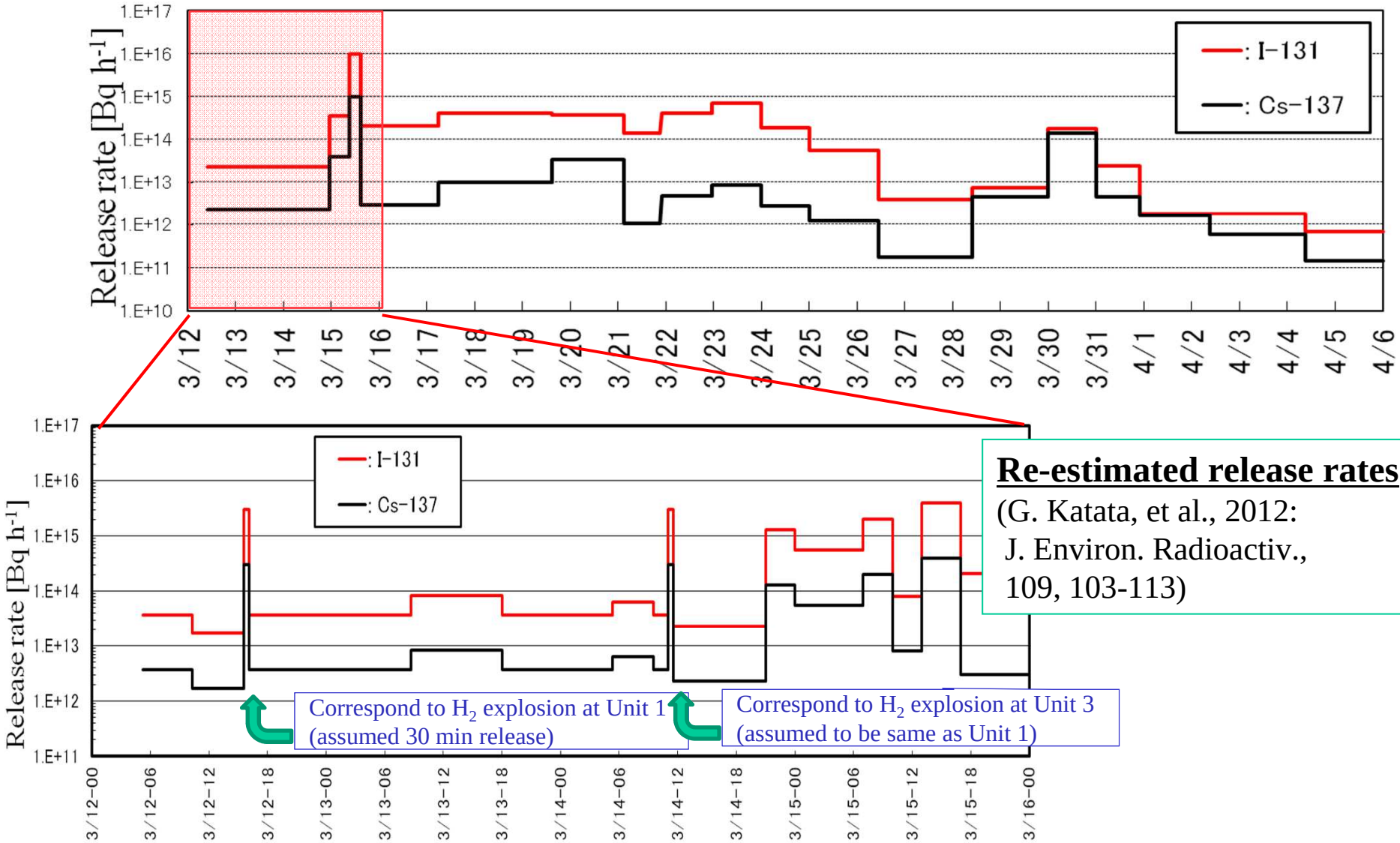
$$\textbf{Release rate} = \frac{\textbf{Monitoring}}{\textbf{Calculation}}$$



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

Source term estimation

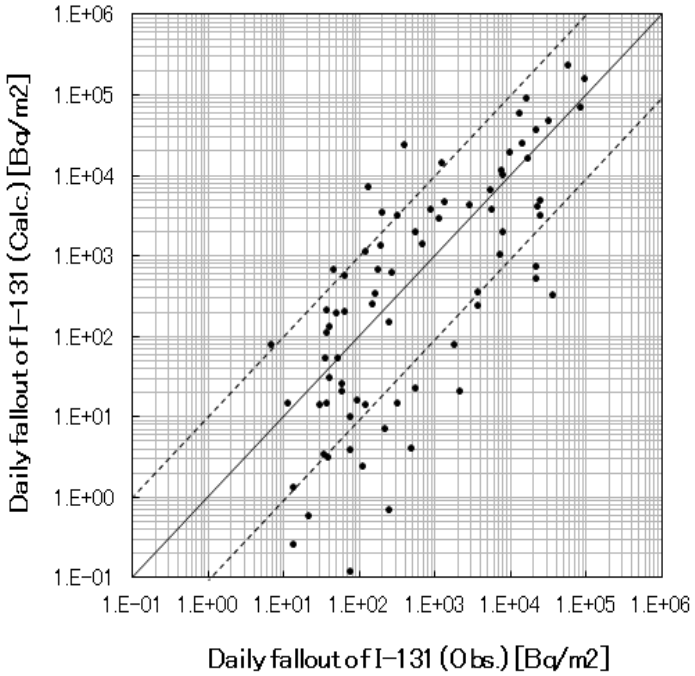
Preliminary estimated release rates of ^{131}I & ^{137}Cs (M. Chino, et al., 2011: JNST, 48,1129–1134)
- Total release amount from 11 March to 5 April $^{131}I: 1.5 \times 10^{17}$ Bq $^{137}Cs: 1.2 \times 10^{16}$ Bq



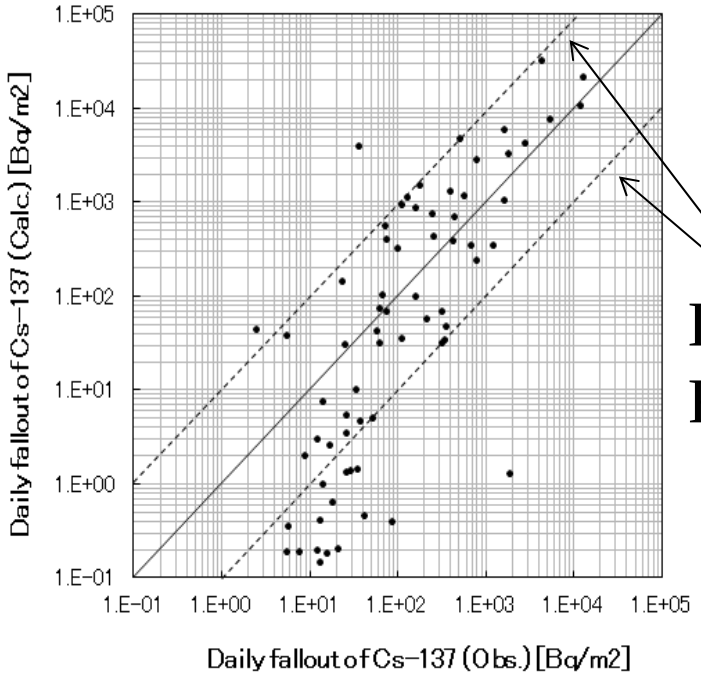
Re-estimated release rates
(G. Katata, et al., 2012:
J. Environ. Radioactiv.,
109, 103-113)

Comparison with measured daily deposition

^{131}I daily deposition



^{137}Cs daily deposition

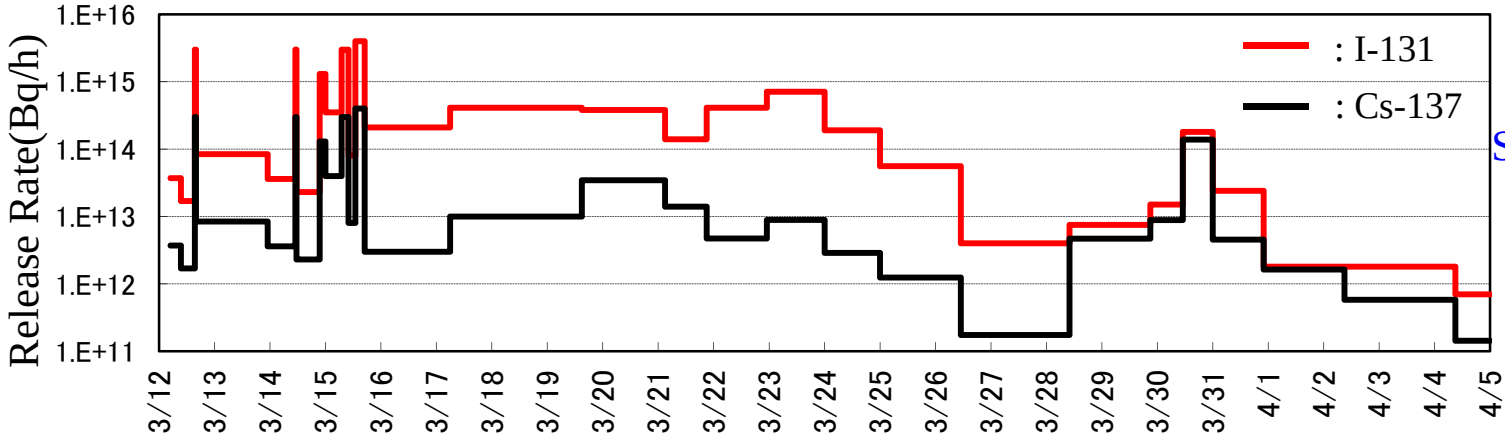


Lines of FA10

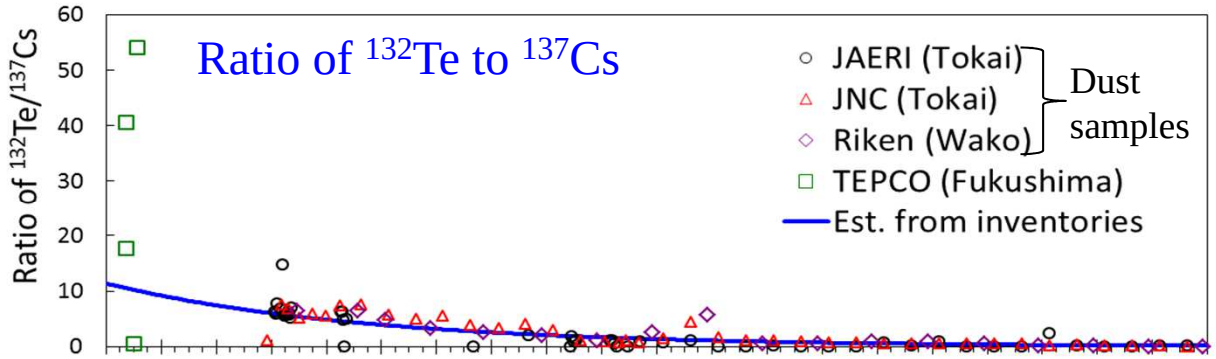
Radionuclides	FA2 (%)	FA5 (%)	FA10 (%)	Correlation coefficients
^{131}I	22.4	48.7	65.8	0.75
^{137}Cs	26.5	48.5	70.6	0.72

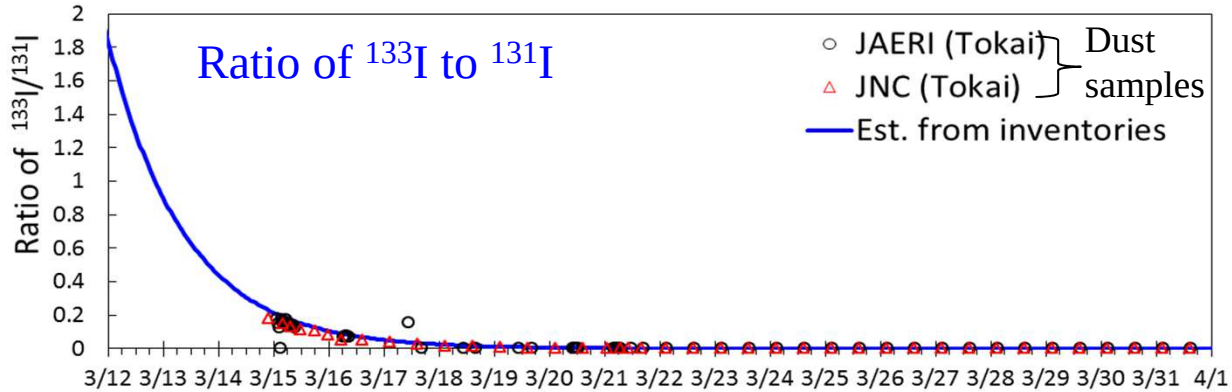
This result indicates the validity of the estimated source term.

Source term used in UNSCEAR 2013 report



Source term by JAEA for ^{131}I and ^{137}Cs (Terada et al. 2012)





Temporal changes in radioactivity ratios ($^{132}Te/^{137}Cs$ and $^{133}I/^{131}I$) of dust samples are approximated by those of the reactor core inventory.

Source term used in UNSCEAR 2013 report

Re-estimation of source term

Background and Purpose

- From the initial stage of the Fukushima Daiichi Nuclear Power Station (FNPS1) accident, we have been carrying out reverse estimations of source term by the combination of atmospheric dispersion model and environmental monitoring data.

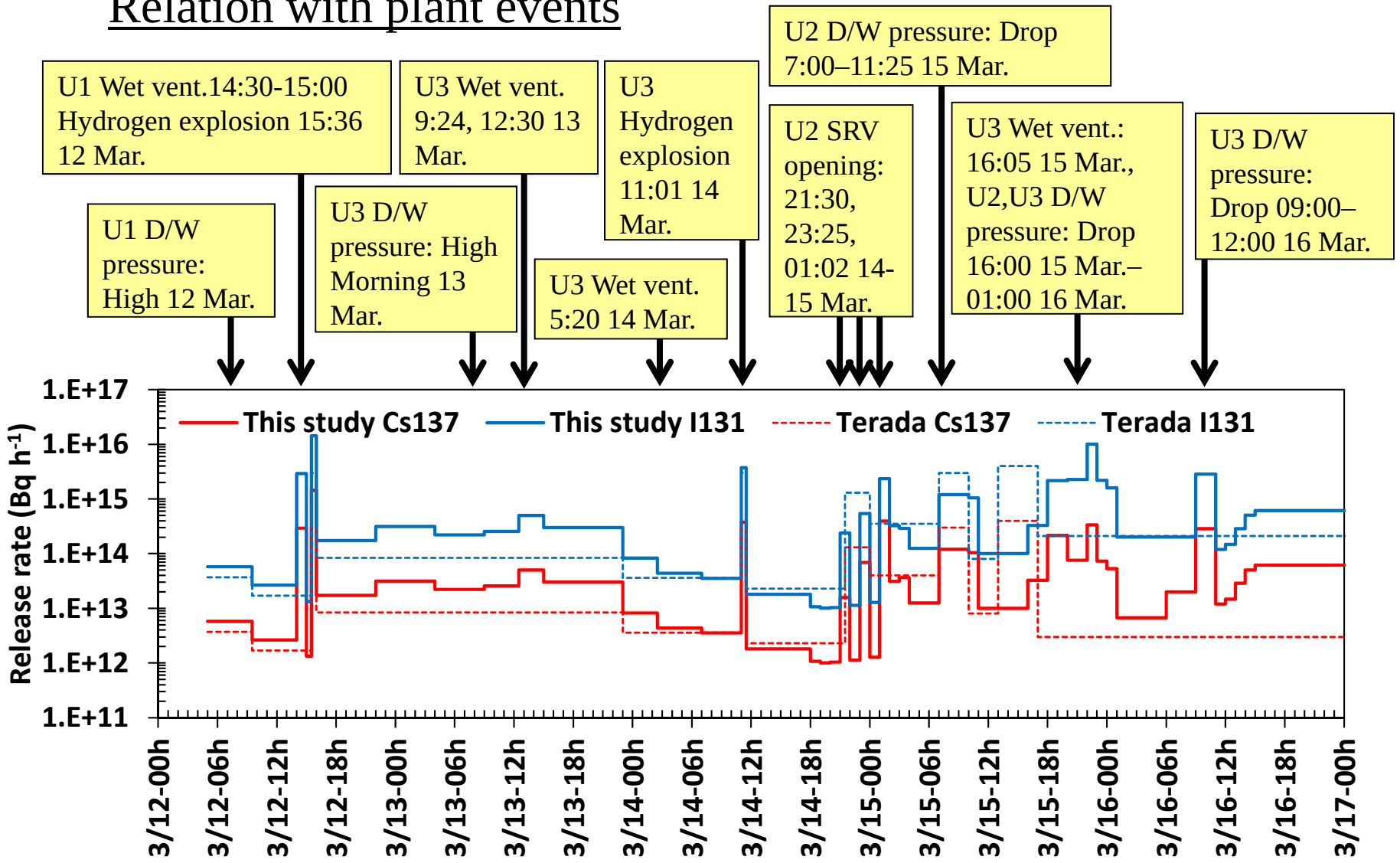
  (Chino et al., 2011; Katata et al. 2012a, b; Terada et al. 2012; Kobayashi et al. 2013)

- New monitoring information available after the above work:
  - Air dose rates from automatic monitoring posts of Fukushima Pref. during the period from Mar. 12 -16 2011.
  - Deposition distributions of I-131 and Cs-137 at Apr. 3 2011 derived from the US-DOE & MEXT airborne survey . (Torii et al. 2013)
  - Concentrations of Cs-134 and Cs-137 in marine surface over the Pacific Ocean observed during the period from Apr. 2 to May 17 2011.

Source term is re-estimated by coupling new monitoring data and ***WSPEEDI*** including new deposition scheme

Estimated Source Term (1st half of March)

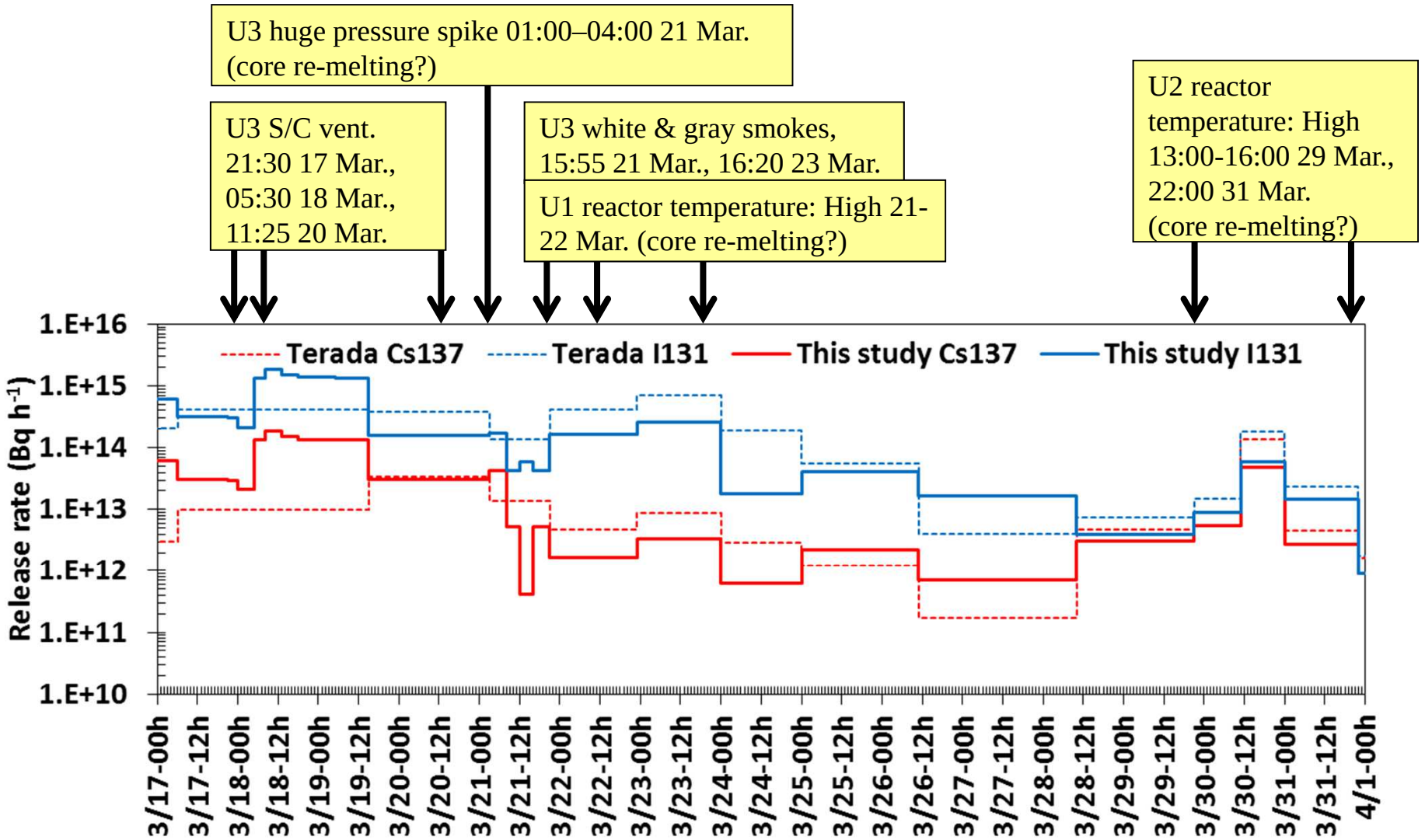
Relation with plant events



G. Katata, et al., 2015: Atmos. Chem. Phys., 15, 1029–1070, 2015

Estimated Source Term (2nd half of March)

Relation with plant events



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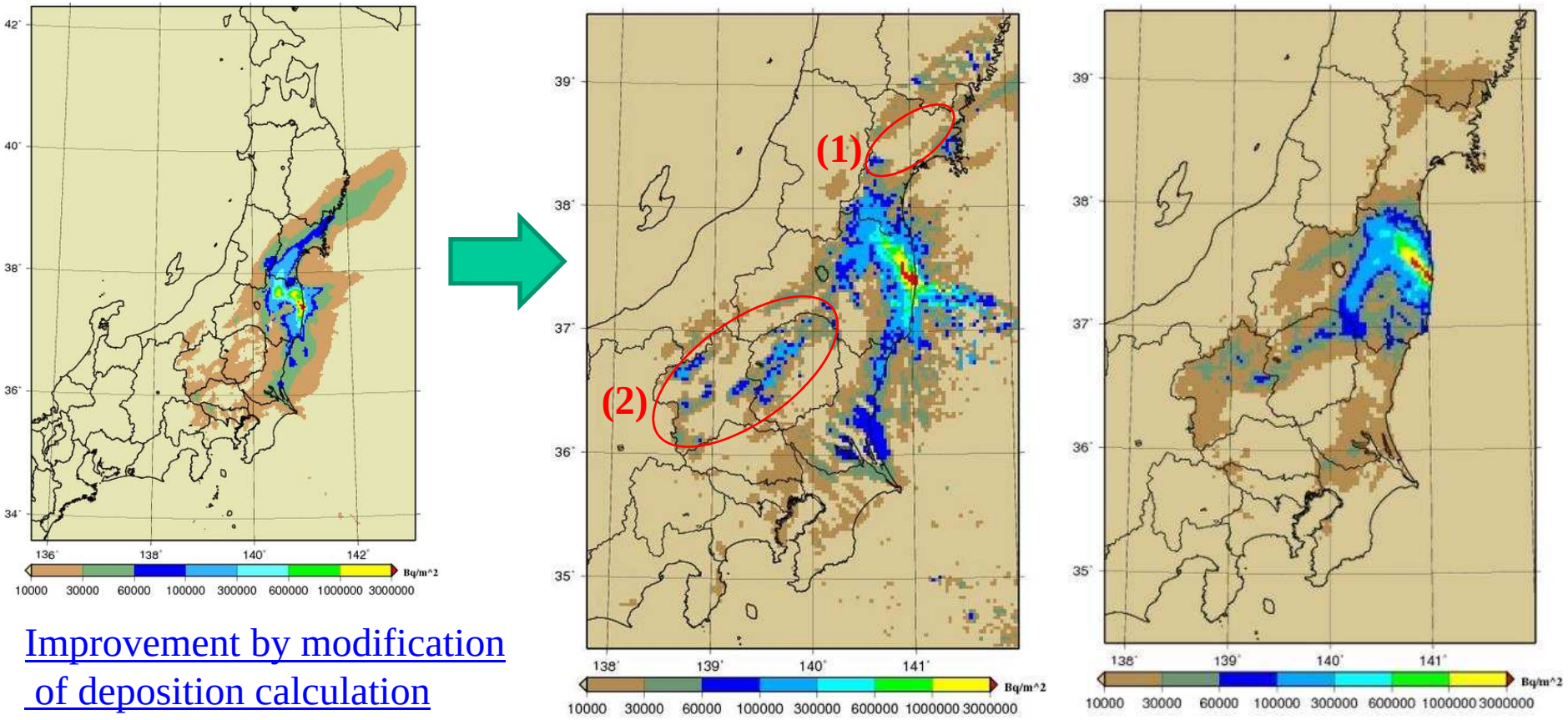
Improvement in deposition calculation (1)

【Changes in dispersion simulation】

- Modification of deposition calculation
- New source term

WSPEEDI simulation (1 April 2011)

Airborne survey by MEXT (31 May 2012)



Improvement by modification of deposition calculation

(1) Overestimation in Miyagi Pre.

(2) Underestimation in Tochigi and Gunma Pre.

G. Katata, et al., 2015:
Atmos. Chem. Phys., 15, 1029–1070, 2015

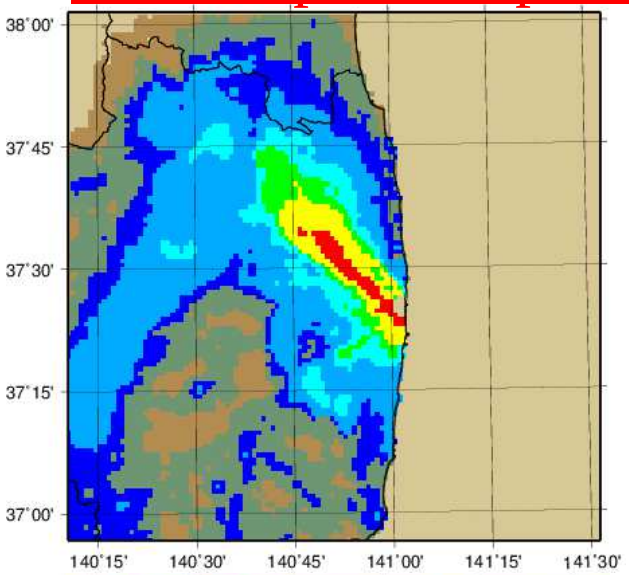
Improvement in deposition calculation (2)

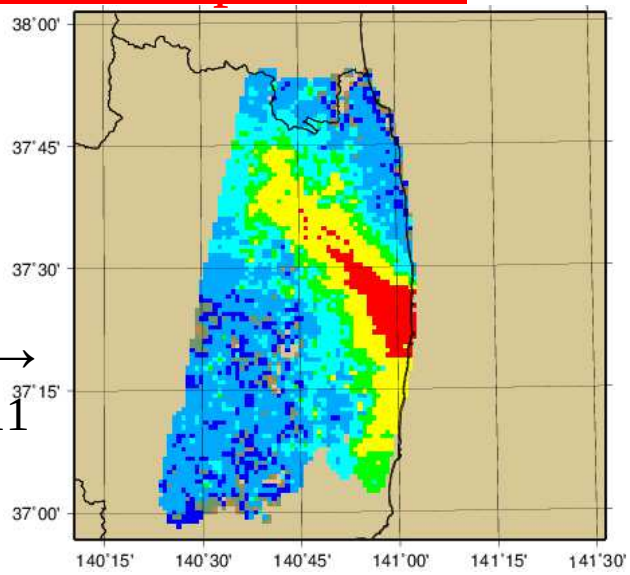
Local deposition patterns of I-131 and Cs-137 are reproduced.

Airborne survey

← ^{137}Cs deposition observed on 31 May 2012

Total ^{131}I deposition → observed on 1 April 2011 (Torii et al., 2013)

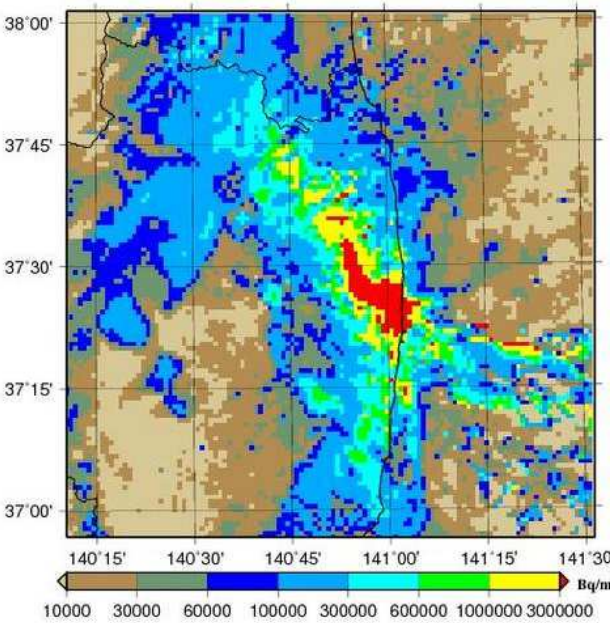


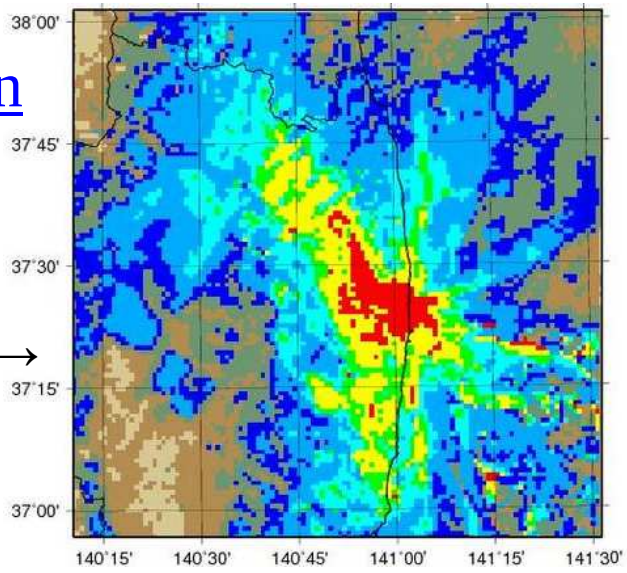


WSPEEDI simulation

← ^{137}Cs deposition at 0:00 on 1 April

Total ^{131}I deposition → at 0:00 on 1 April





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Summary

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, UNSCEAR, etc.
- Improvement of deposition processes of *WSPEEDI*
- Refinement of the source term by using modified *WSPEEDI*

- Reconstruction of atmospheric dispersion and surface deposition
- Coupling of atmospheric, oceanic and terrestrial transport models

- Detailed evaluation of public dose
- Prediction of long term migration