Intercomparison of Regional Chemical Transport Models for the Fukushima Daiichi Nuclear Power Plant Accident

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ISET-R Interdisciplinary Study on Environmental Transfer of Radionuclides from the Fukushima Daiichi NPP Accident
福島原発事故により放出された放射性核種の環境動態に関する学際的研究
Science Council of Japan 日本学術会議
JAMSTEC

Masayuki Takigawa

2000 : earned a PhD. in geophysics. at the University of Tokyo. Title of my thesis is "Climatological impact of Pinatsubo eruption"

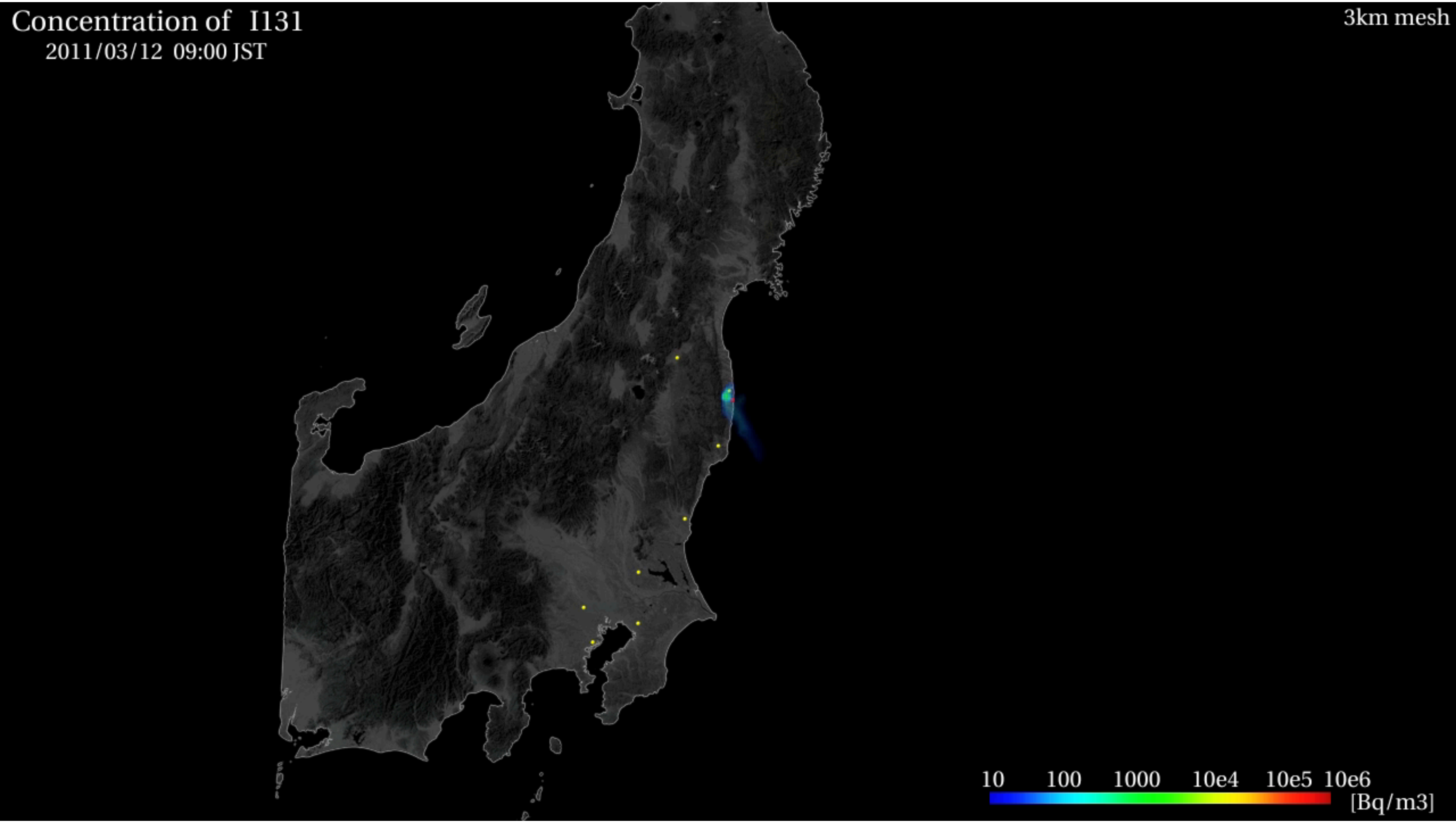
since 2000 : entered Japan Agency for Marine-Earth Science and Technology. Main target is the transport and transformation of <u>pollutants</u> (not radionuclides) in the troposphere.

March 11, 2011 :

I have attended a workshop for the inventory for pollutants at Tsukuba, and spent one night at Tsukuba.

As I have an experience of pollutants modeling, some researchers requested me to include radionuclides in our model, because there is very few information about the transport of radionuclides.

Concentration of iodine-131 emitted from the accident in March 2011
(made by a Japanese TV company (NHK) based on my model results.)

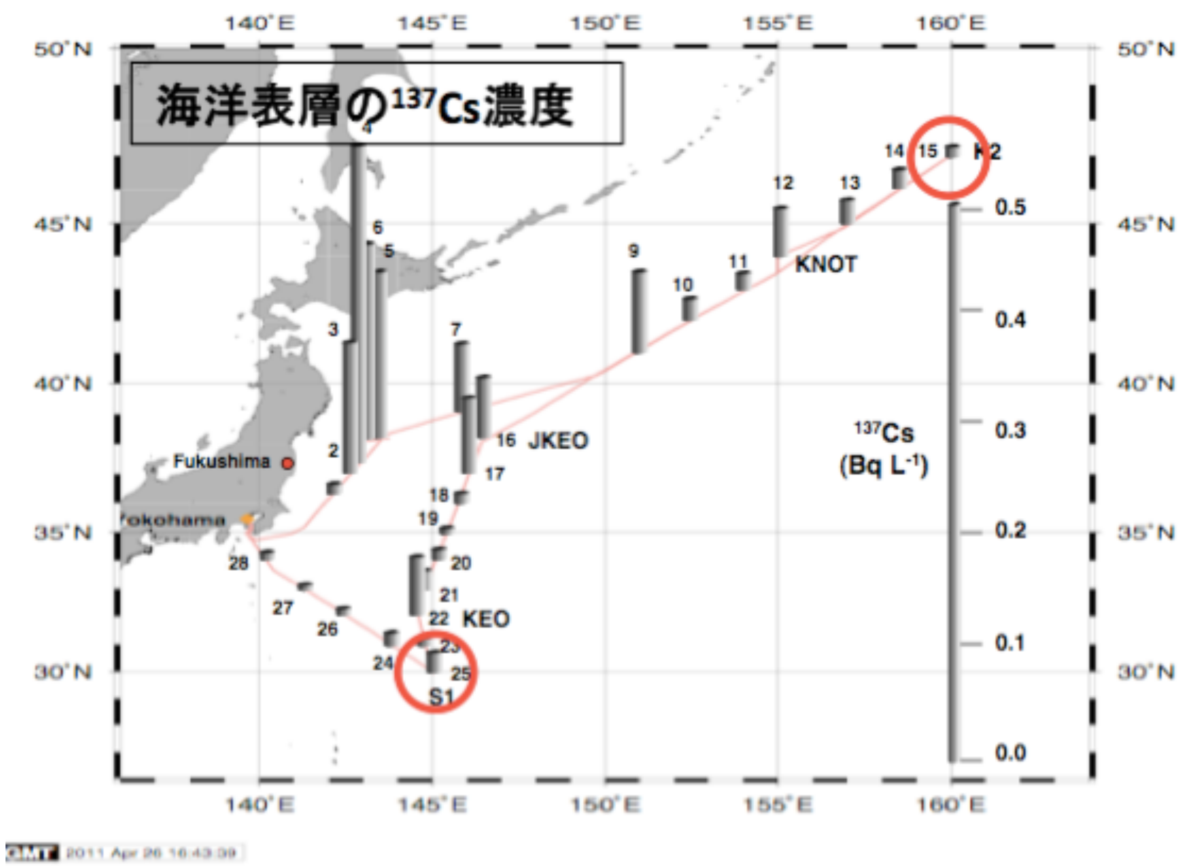


Iodine-131 might affect the human health via inhalation. The total amount of released iodine-131 is quite huge (it is estimated 2 times larger than that from Chernobyl), but the half-life period of iodine-131 is about 8 day.

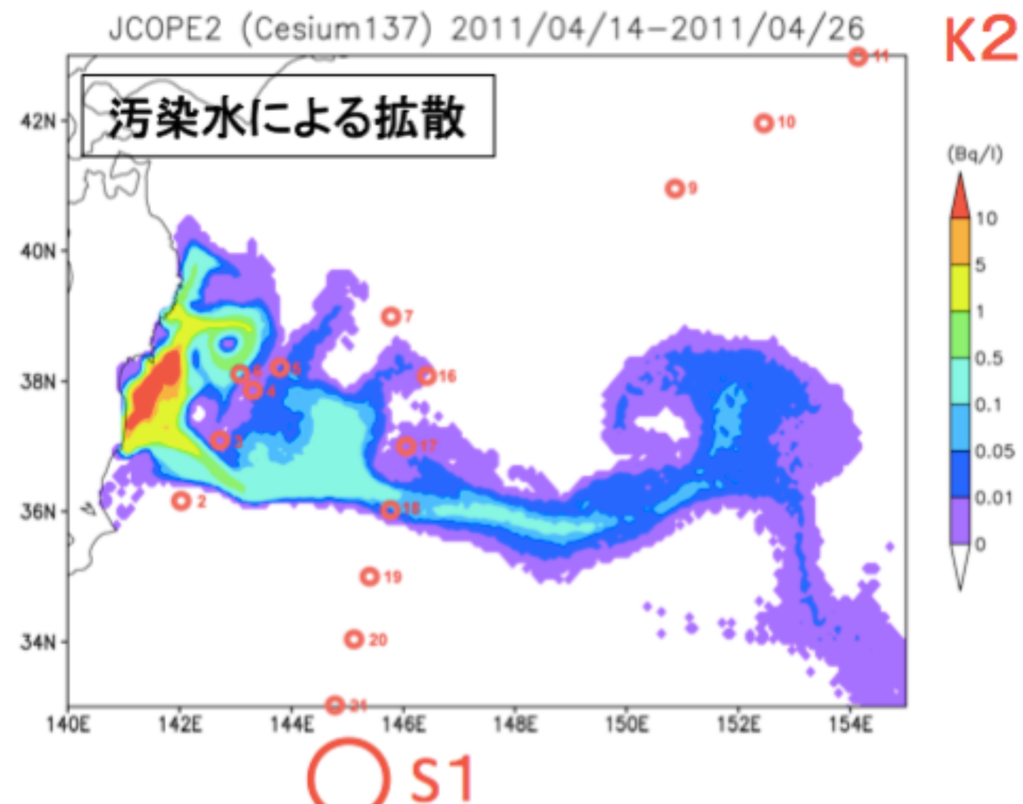
effect of atmospheric transport

JAMSTEC has conducted a cruise in April-May 2011 to estimated the distribution of radionuclides in the ocean, and our results showed the importance of atmospheric transport.

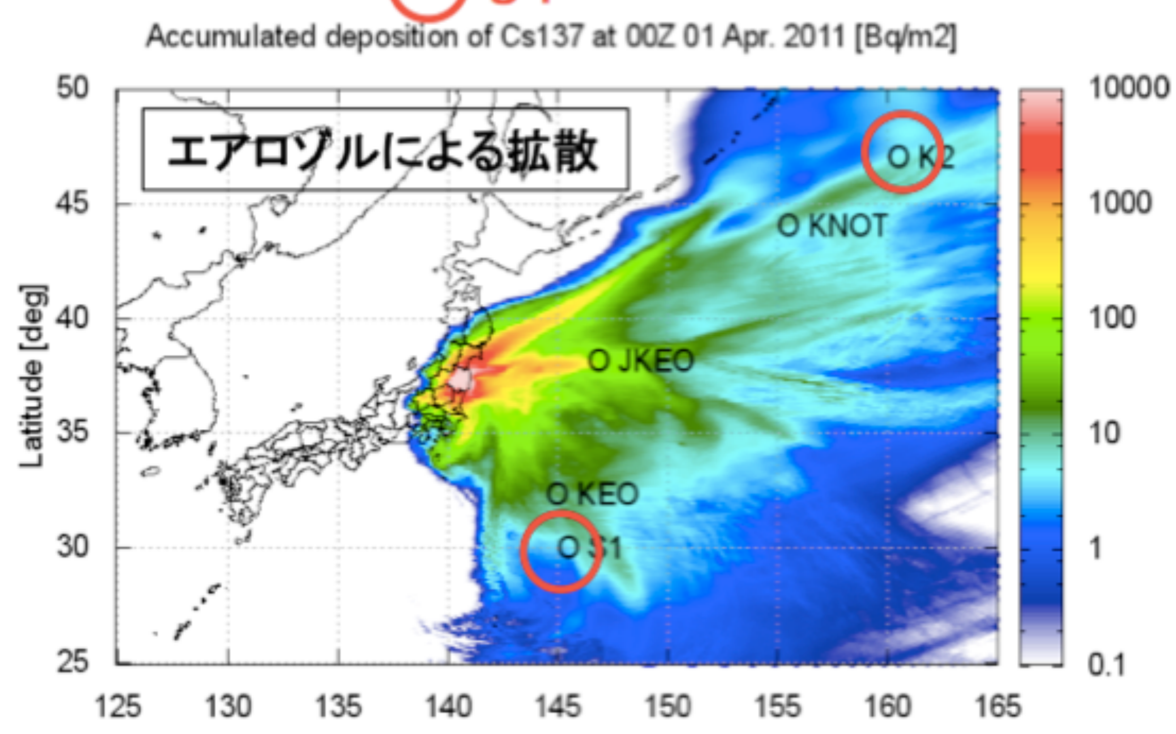
observed concentration in sea water



ocean model



atmospheric model



Honda et al. (2012)

About this work (1)

A Working Group for Model Intercomparison was formed in July 2012 under the Subcommittee of Investigation on the Environmental Contamination Caused by the Nuclear Accident in the Sectional Committee on Nuclear Accident (chair: Dr. Shibata), the Committee Comprehensive Synthetic Engineering, Science Council of Japan (SCJ).

The purpose of this working group (SCJ WG) is to compare **existing model results** and **to assess the uncertainties in the simulation results**. The emerging knowledge will be invaluable for various applications designed to mitigate environmental contamination in wide areas. The working group solicited international colleagues and groups to provide their model simulation results for the intercomparison.

About this work (2)

admin.

co-chairs:
Drs. Shibata and Nakajima

global atm. models

chair: Dr. Tanaka (MRI)
participants: 3 Japanese models and 2 foreign models

regional atm. models

chair: Dr. Takigawa (JAMSTEC)
participants: 6 Japanese models and 3 foreign models

ocean models

chair: Prof. Masumoto (Tokyo Univ.)
participants : 5 Japanese models and 2 foreign models

日本学術会議
Science Council of Japan
7-22-34 Roppongi, Minato-ku, Tokyo 106-8555

September 11, 2012

Dear Colleagues:

It is our pleasure to inform you that the Science Council of Japan (SCJ) has started to review the modeling capability of the transportation of radioactive materials released to the environment as a result of the Fukushima Daiichi Nuclear Power Plant accident. The purpose of this initiative is to compare existing model results in order to assess the uncertainties in the results, as this will be an important consideration when evaluating the various applications to the mitigation measures. In this regard, we would like to request that you and your colleagues contribute to the comparison of the models by collecting and comparing the relevant results. We will send details of the design of the intercomparison, as well as the format and data policy for data sharing, to those persons/groups who express an interest in participating. The final report will be issued in March 2013 by the SCJ committee along with a list of participants.

We express our gratitude in advance for your kind help and for contributing to this initiative. Please feel free to forward this letter to your colleagues.

Sincerely yours,

Tokushi Shibata

Tokushi Shibata, Chair, Subcommittee to Review the Investigation on Environmental Contamination Caused by the Nuclear Accident, Committee on Comprehensive Synthetic Engineering, SCJ

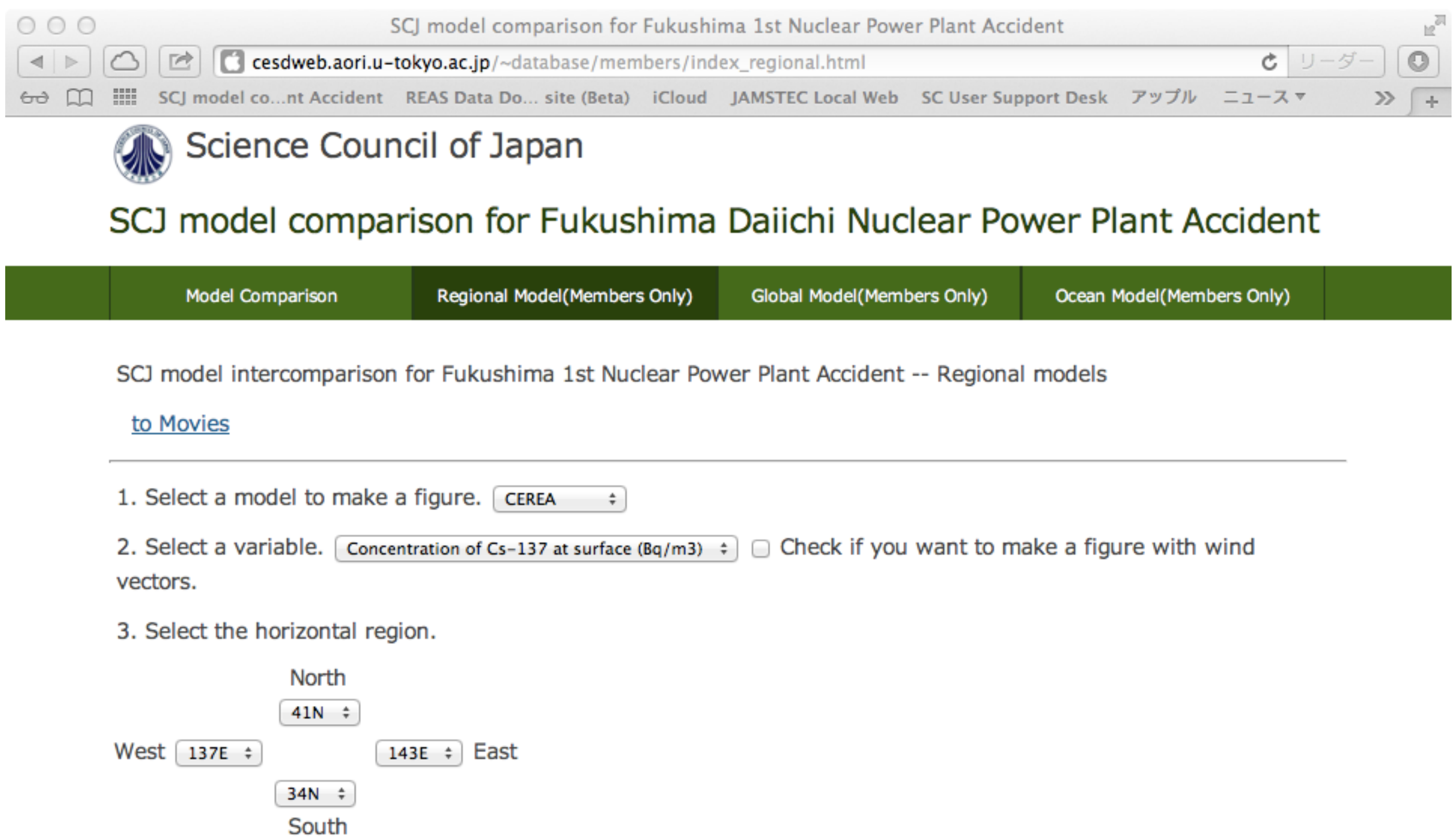
T. Nakajima

Teruyuki Nakajima, Chair, Working group for model intercomparison*

About this work (3)

A report has been published from the Science Council of Japan in September 2014 as:
http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-22-h140902-e1.pdf

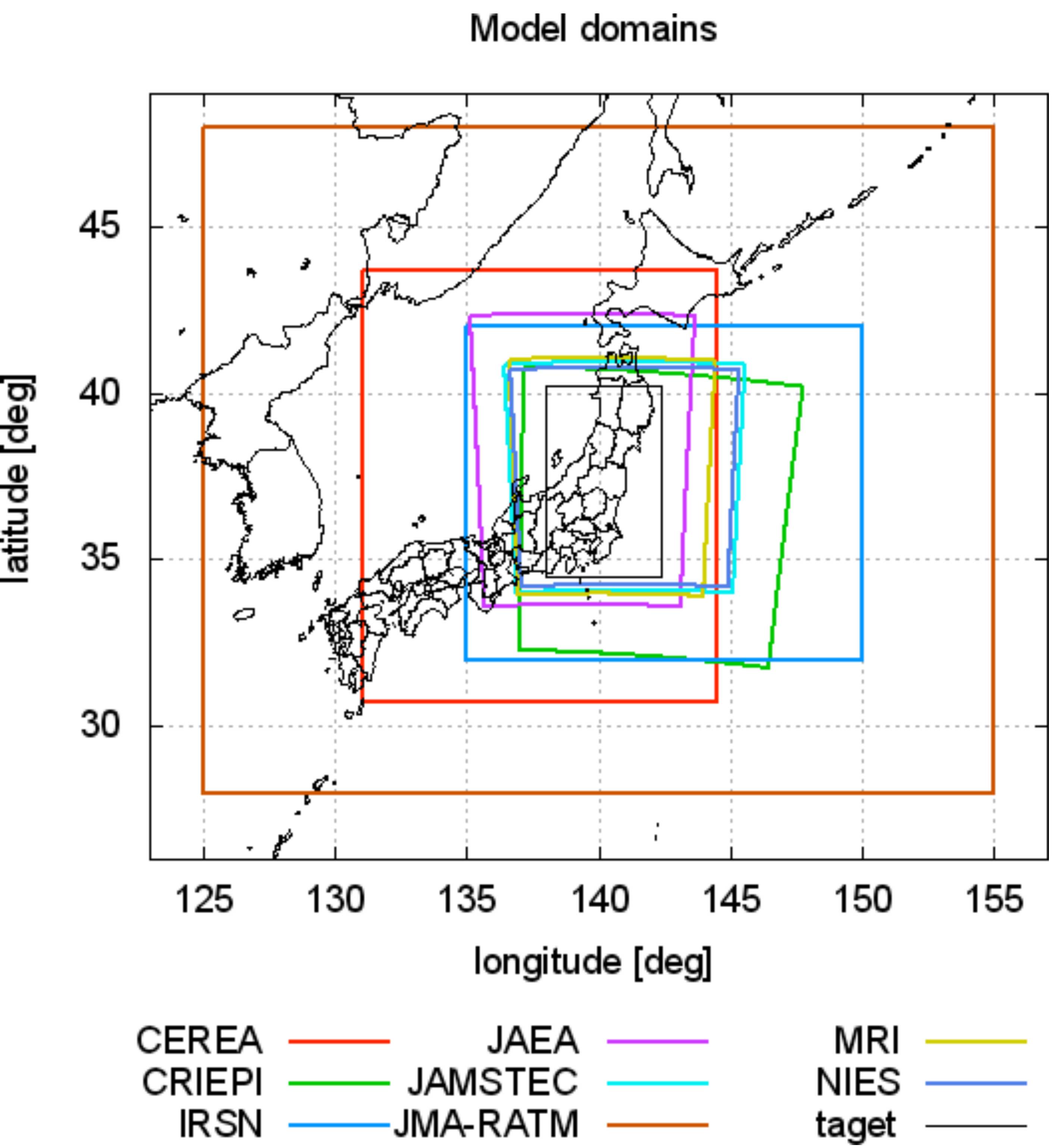
and the model output are also available at:
http://cesd.aori.u-tokyo.ac.jp/cesddb/scj_fukushima/index_j.html



summary of participated regional models

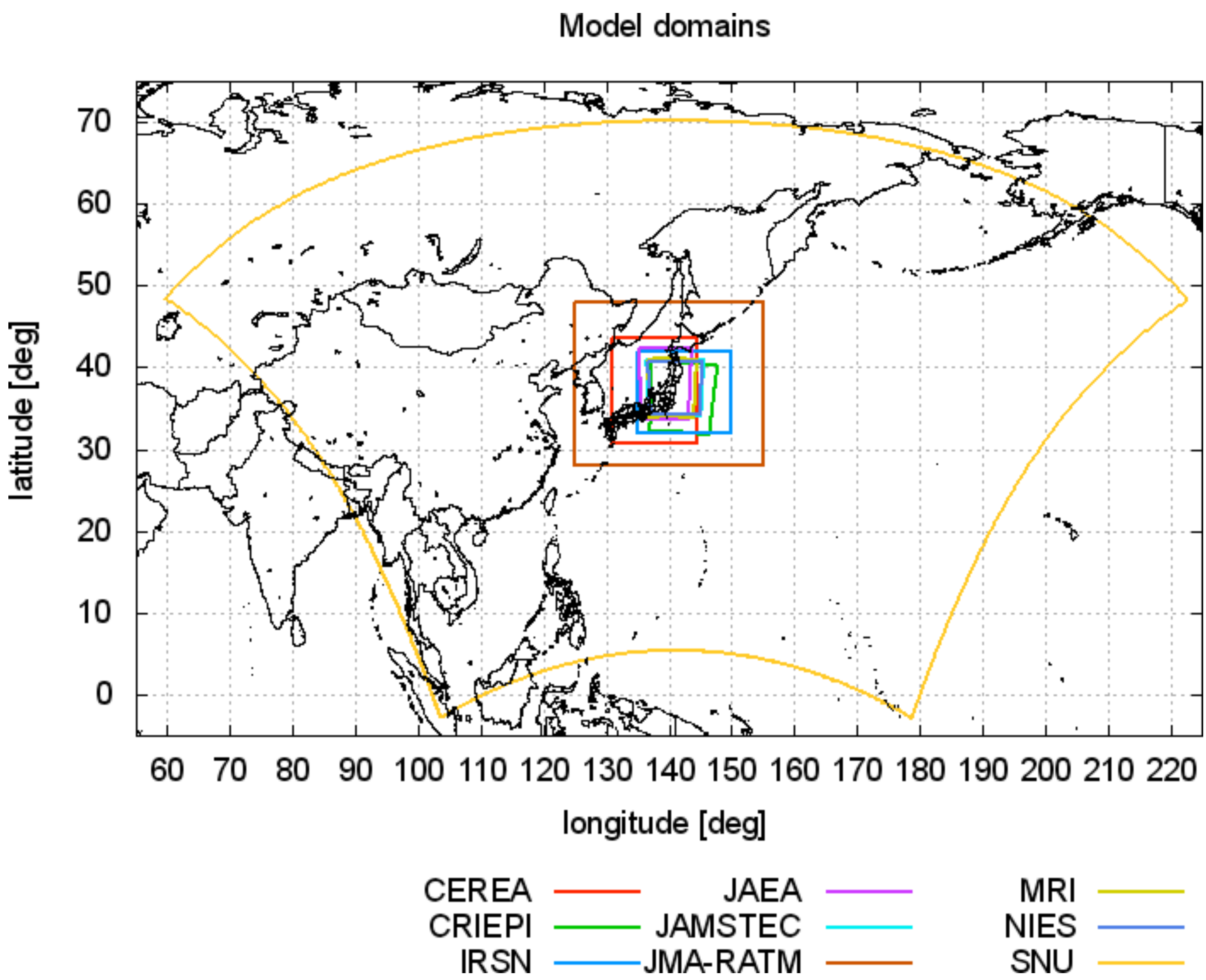
Organization	resolution	model type	Emission	base met.	dry dep.	wet dep.
CEREA	3min.(4km)	Euler	original		fixed velocity	Brandt et al (2002)
IRSN	3min.(4km)	Euler	original	JMA MSM	fixed velocity	$L=L_0P$
CRIEPI	5km	Euler	JAEA	GPV MSM	Zhang et al. (2001, 2003)	Seinfeld and Pandis (1998)
JAEA	3km	Lagrangian	JAEA	GPV MSM	Sehmel (1980)	Brenk and Vogt, (1981)
JAMSTEC	3km	Euler	JAEA	GPV MSM	Wesely (1989) with fixed velocity	Maryon et al. (1996)
MRI	3km	Euler	JAEA	assimilate using same dataset for MSM	Zhang et al. (2001, 2003), and Katata et al.	Pleim and Chang, 1992
JMA	3min (4km)	Lagrangian	JAEA (Kobayashi et al. 2013)	JMA MSM	Iwasaki et al., (1998)	Kitada (1994)
NIES	3km	Euler	JAEA	GPV MSM	Wesely (1989)	Byun and Schere (2006)
SNU	27km	Euler	JAEA(?)			Park [1998]

target area of regional models



For the intercomparison of regional models, we set a region between 138.0E-142.5E, 34.5N-40.5N (black lines in the left figure), and the model outputs were interpolated into 0.1 degree x 0.1 degree grids.

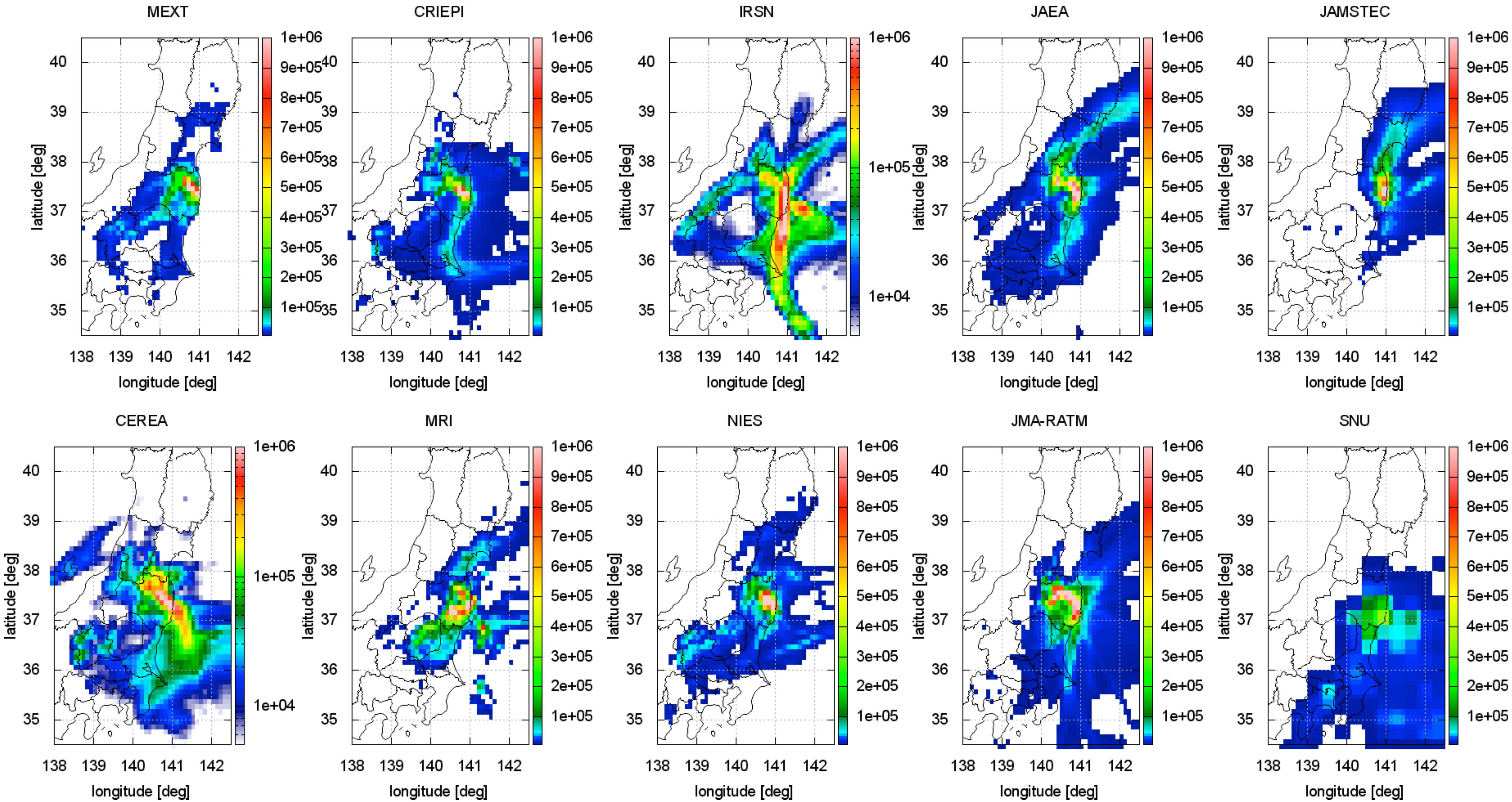
The calculation period is different in each models, and we have calculated the accumulated values from 2011/03/12 00Z to 2011/04/01 00Z.



Model domains
70
60
50
40
30
20
10
0
latitude [deg]
60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220
longitude [deg]
CEREA
CRIEPI
IRSN
JAEA
JAMSTEC
JMA-RATM
MRI
NIES
SNU

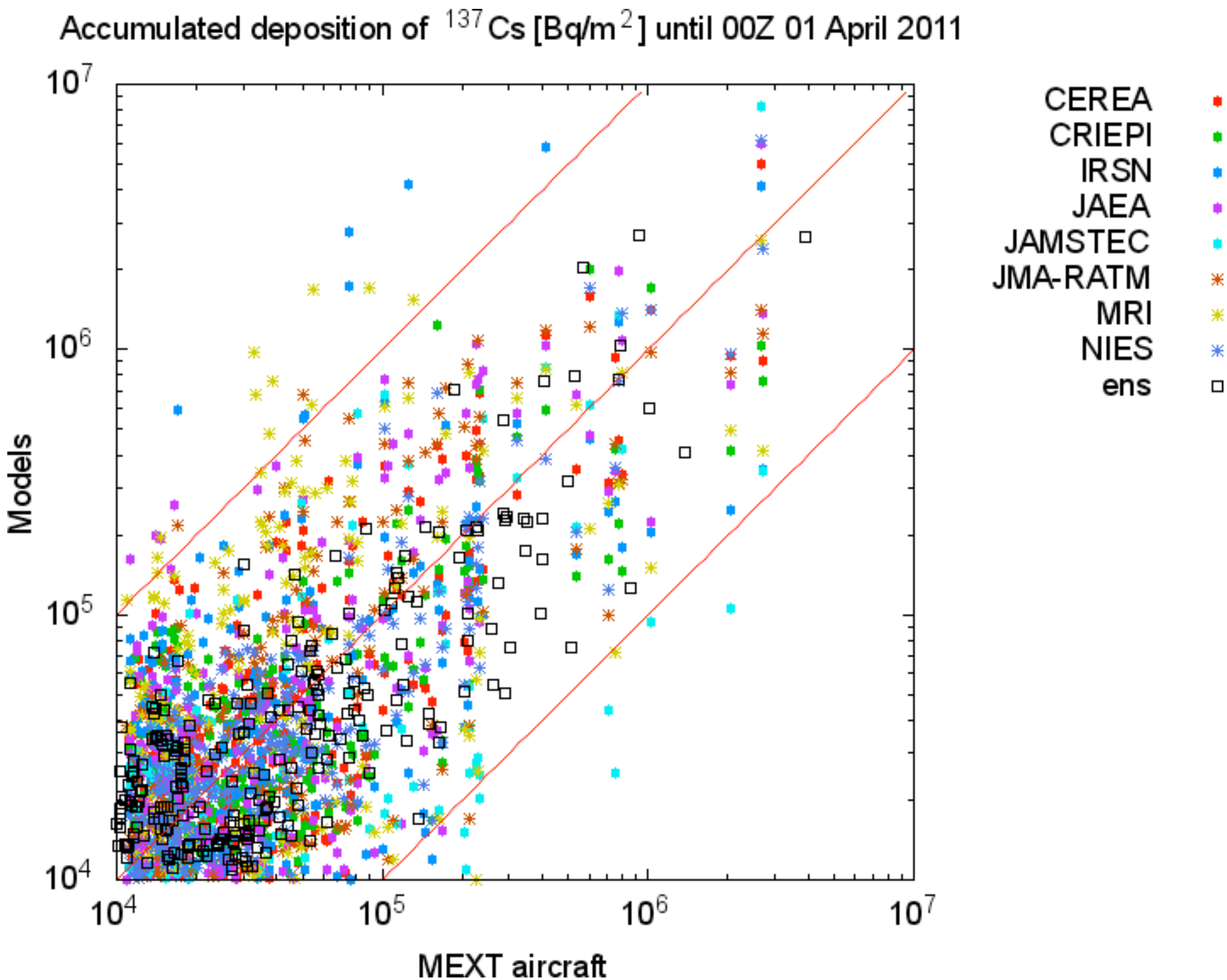
Acuumulated deposition of ^{137}Cs until April 2011

aircraft obs. by MEXT
(estimated value for 2012.5.31)



The location of rain bands differs among models, even though they are driven using same met. data (JMA-MSM), because it is needed to re-calculate met. field for each models' horizontal resolution and time interval.

Scatter plot of accumulated deposition of Cs137



Figures were based on the latest version of outputs for
IRSN and CEREA (Apr. 2013) and JMA-RATM (June 2013).
In general, models can reproduce accumulated deposition of Cs137 within factor of 10.

tabular for statistical analysis (Cs-137 deposition)

Organization	corr	FB	FMS	FOEX	%FA2	KSP	Metric1	Metric2	Metric3	Metric4
CEREA	0.79	0.09	74.32	-8.74	49.45	12.84	3.28	3.03	4.1	4.6
IRSN	0.39	0.3	63.39	-17.49	38.52	28.69	2.28	2.05	2.99	3.32
CRIEPI	0.6	-0.25	63.39	-19.95	40.44	22.4	2.85	2.62	3.45	3.85
JAEA	0.76	0.22	68.85	-8.74	40.16	22.68	3.1	2.81	3.92	4.33
JAMSTEC	0.62	-0.38	26.5	-37.43	13.93	54.37	2.44	2.32	2.7	2.84
MRI	0.49	0.17	45.9	-18.58	18.03	36.34	2.53	2.25	3.16	3.34
JMA	0.68	0.44	49.45	-17.76	27.87	35.79	2.64	2.43	3.29	3.57
NIES	0.85	0.03	68.31	-18.58	57.1	19.13	3.37	3.25	3.99	4.57
SNU	0.27	-0.81	42.08	-26.5	19.4	39.34	2.05	1.83	2.52	2.72
ensemble mean	0.77	0.04	70.41	-13.56	49.86	22.19	3.22	3.04	3.98	4.49

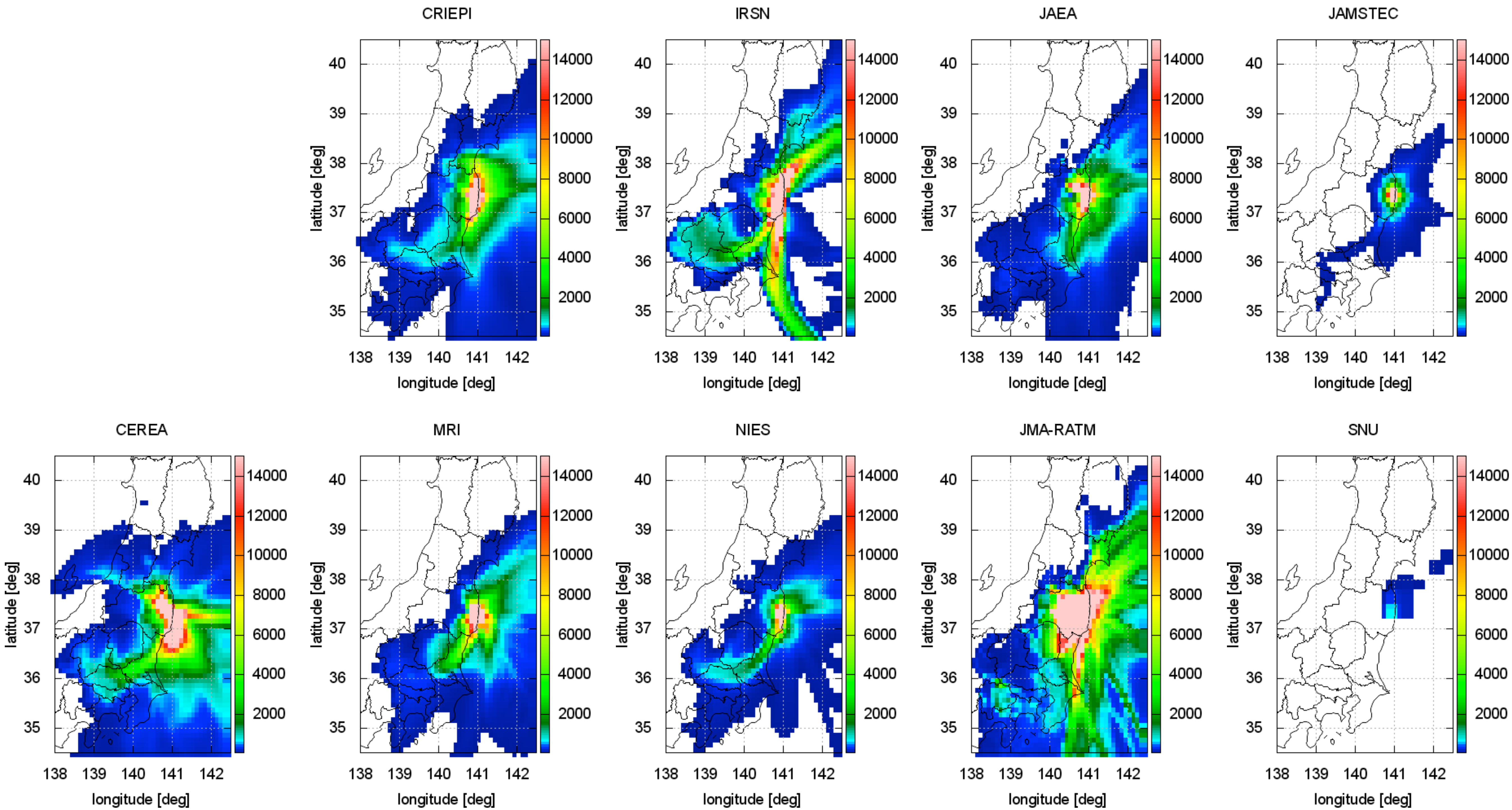
FB: fractional bias : ratio of averaged values (-50%~50%) : 0 means model=obs.
FMS : figure of merit in space : fraction of grids that exceeds critical value (1e4 Bq/m2).
FOEX : factor of exceedance : fraction of grids where modeled value exceeds obs.
%FA2 : fraction of grids where modeled value is within factor 2 of obs.
KSP : Kolmogorov-Smirnov Parameter : smaller is better
Metric1~4 : complex matrix with above-mentioned metrics

Estimated budget of 137Cs deposition within the target area

	over the land		over the sea		Total depo. over the target region	Total emission
	total dep.	percentage of wet dep.	total dep.	percentage of wet dep.		
MEXT aircraft	2.65		-		-	-
CEREA	3.35(17%)	68%	2.62(14%)	85%	5.97 (31%)	19.3
CRIEPI	2.37 (27%)	79%	0.90 (10%)	54%	3.27 (37%)	8.8
IRSN	3.14 (15%)	46%	5.52 (27%)	71%	8.66 (42%)	20.6
JAEA	3.79 (43%)	67%	1.22(14%)	65%	5.01 (57%)	8.8
JAMSTEC	1.95 (22%)	67%	1.45 (16%)	67%	3.40 (39%)	8.8
JMA	2.65(30%)	50%	1.18 (13%)	36%	3.83(44%)	8.8
MRI	3.31 (38%)	92%	1.72 (20%)	97%	5.03 (57%)	8.8
NIES	2.90(33%)	98%	1.06(12%)	96%	3.96 (45%)	8.8
SNU	1.29 (15%)	32%	1.76 (20%)	36%	3.05(35%)	8.8
ensemble mean	2.75(27%)	67%	1.94(16%)	67%	4.69(43%)	11.3
standard deviation	0.73(10%)	20%	1.36(5 %)	22%	1.68(9 %)	4.6

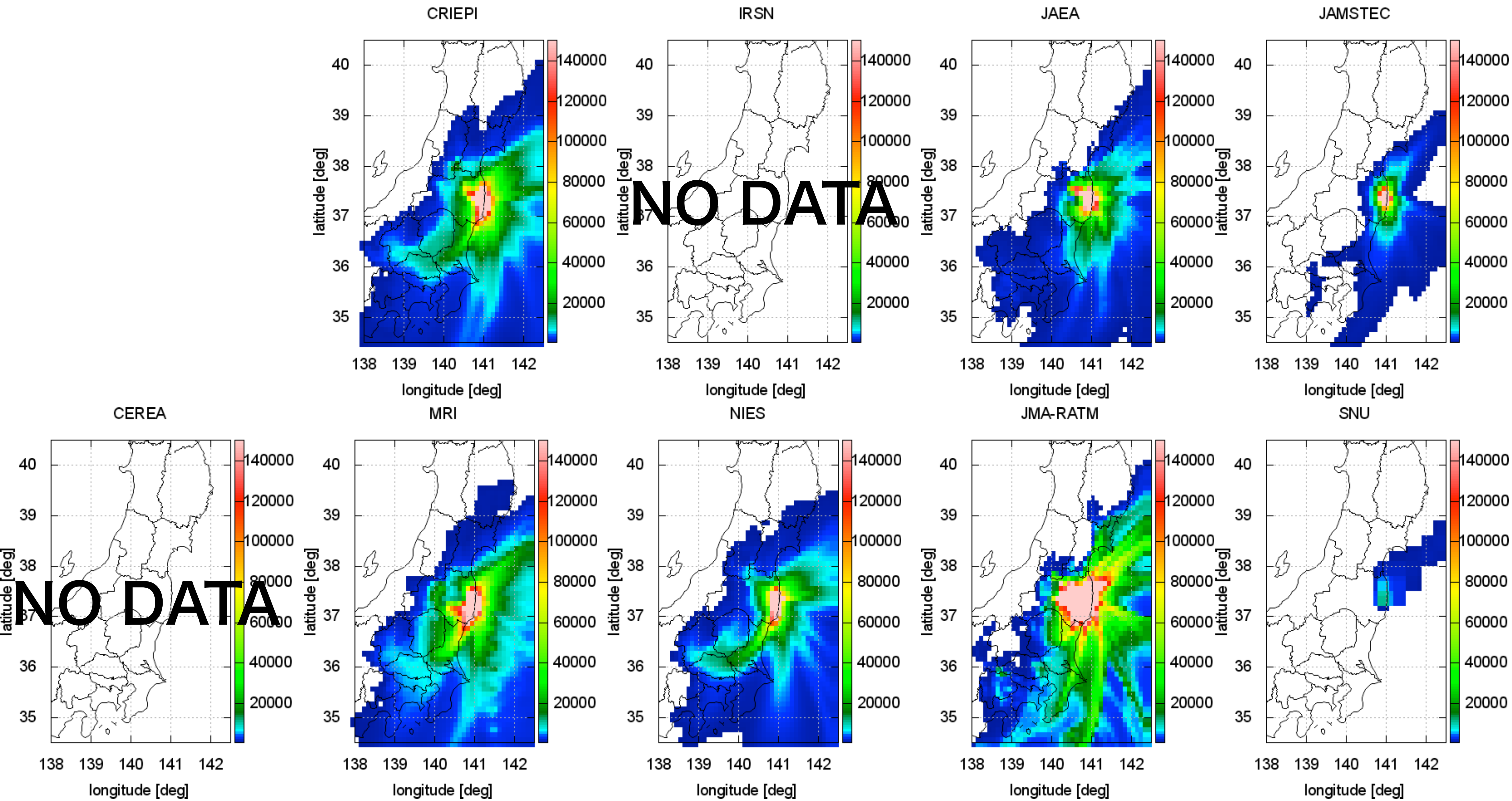
Total amount of accumulated deposition of 137 Cs over the land and sea until 0Z 1 April, 2011. Units are PBq. The MEXT aircraft observation was based on the value on 31 May, 2012. Percentages of each removal process to the total emissions are also shown for the model calculations

Accumulated concentration of ^{137}Cs [Bq/m^3*hr]



Accumulated concentration is rapidly decreases in JAMSTEC.
SNU tends to show higher values in northeast of FDNPP (it shows higher deposition in southeast of FDNPP).

Accumulated concentration of I-131 [Bq/m^3*hr]

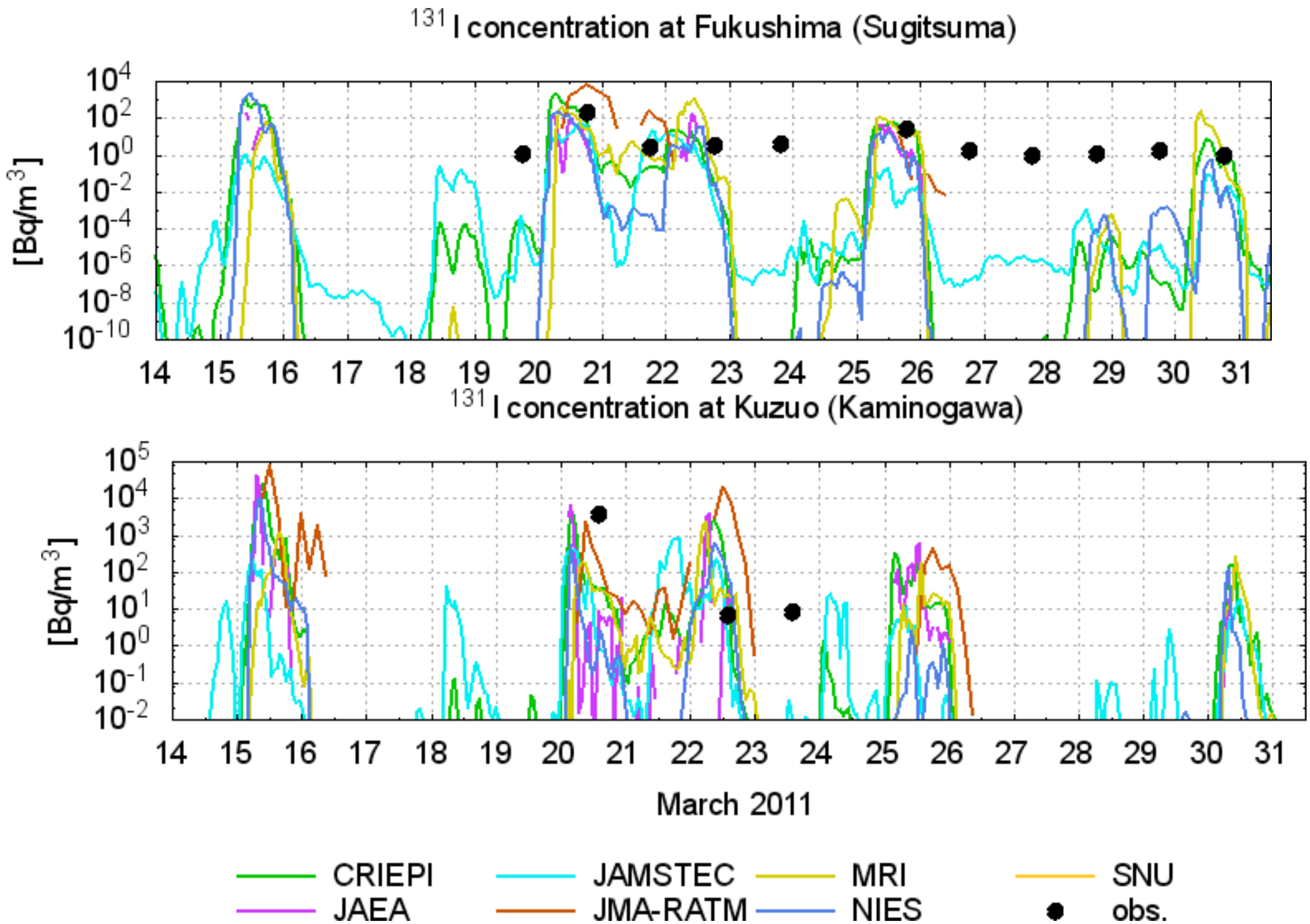


JMA-RATM clearly shows tracks of each release.
In the observation at Tokai-mura,
the averaged concentration of I-131 from 3/13 to 5/23 is12Bq/m3.
It means the accumulated concentration until 5/23 is about 20000Bq/m3*hr。
It means most of models can reproduce accumulated concentration of I-131 within factor of 2.

I-131 concentration near the surface (comparison with MEXT dust sampling)

Fukushima-shi

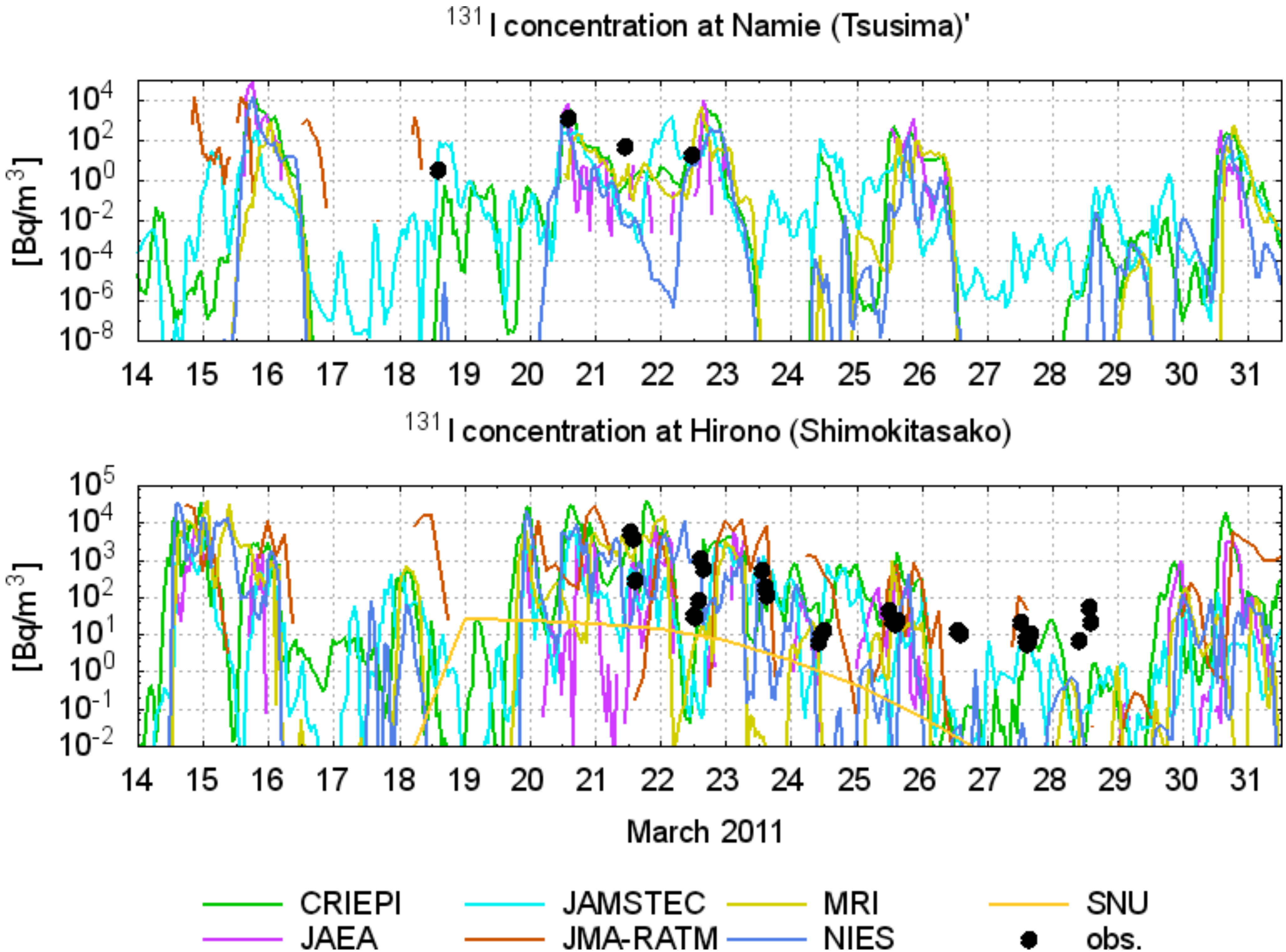
Kuzuo-mura



I-131 concentration near the surface (comparison with MEXT dust sampling)

Namie-cho

Hirono-cho



Summary

The results are summarized as follows:

1) meteorological fields play an important role in radionuclide deposition, and the differences in the model treatments of deposition and in the configuration of meteorological models, such as in their microphysics and convection parameters, might cause a large difference in the horizontal distribution of accumulated deposition;

2) the wet deposition process has a strong impact on the reproducibility of deposition, especially on March 15;

3) ensemble means might be useful for the estimation of accumulated deposition ("ensemble of different models with different *reasonable* parameters" might be better than "one cloud-resolving model"?)