Iodine-131 Working Group Report

Paweł Krajewski

Working Group 3

The Chernobyl I-131 release:

model validation and assessment of the countermeasure effectiveness working group

activities 2003-2007

In total 13 participants (IWG leader P. Krajewski)

IAEA Scientific Secretary:

Tiberio Cabianka (2003-2004)

Vladimir Berkowsky (2004-2007)

	Model	Participant Name	Country	Organization
1	**LIETDOS**	Ms T. NEDVECKAITE , Mr. V. FLISTOVICZ, (BIOMASS) PLAVSK, MAZOVIA, PRAGUE	Lithuania	Institute of Physics
2	**OSCAAR**	Mr T. HOMMA (BIOMASS) PLAVSK, MAZOVIA, PRAGUE	Japan	Japan Atomic Energy Agency (JAEA)
3	**UniVes**	Mr B. KANYÁR (BIOMASS) PLAVSK, MAZOVIA, PRAGUE	Hungary	University of Pannonia (former University of Veszprém)
4	**CLRP** Scenario MAZOVIA provider	Mr P. KRAJEWSKI (BIOMASS) PLAVSK, MAZOVIA, PRAGUE	Poland	Central Laboratory for Radiological Protection
5	**ASTRAL**	Ms C. DUFFA (New) PLAVSK	France	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
6	**Ecosys-87 (Finland)**	Mr M. AMMANN (New) PLAVSK, MAZOVIA, PRAGUE	Finland	Radiation & Nuclear Safety Authority (STUK)
7	**Plavsk Dose Calculator**	Mr S. SIMON (New) PLAVSK	USA	National Cancer Institute
8	**SPADE V.4.6**	Mr D. WEBBE-WOOD (New) PLAVSK	UK	Food Standard Agency
9	**CLIMRAD**	Mr O. VLASOV (New) PLAVSK, MAZOVIA, PRAGUE	Russian Federation	Medical Radiological Research Center
10	**IRH-model** Scenario PLAVSK provider	MS I. ZVONOVA (New) PLAVSK, MAZOVIA, PRAGUE	Russian Federation	Institute of Radiation Hygiene
11	Scenario PRAGUE providers	Ms I. MALATOWA (VAMP) Ms M. BARTUSKOVÁ PRAGUE	Czech Republic	National Radiation Protection Institute

background

Radioiodine releases have occurred in many radiation accidents, and because data on the results of these releases are often incomplete, models for estimating ^{131}I transport and exposure are essential in dose assessment efforts.

The risk of thyroid gland irradiation is one of the most serious problem in accidental exposures at nuclear facilities and constitutes relatively high radiological impact

activities of IWG are focused primarily at evaluating:

the predictive capability of environmental models

in relation to assessing the thyroid exposure due to

radioiodine ^{131}I via inhalation and ingestion pathways

main targets of IWG

check models applicability to evaluating the effectiveness of countermeasures

Countermeasures:

- iodine prophylaxis
- limitation of fresh milk consumption
- restriction of cows pasturing

check models performance in the assessment of ^{131}I doses in situations where of ^{137}Cs deposition have been used as the basis for ^{131}I concentration in air and fallout reconstruction

major areas of emphasis

- identification the most important sources of bias and uncertainty in the model predictions
- improvement of modelling procedures
- improvement of the accuracy of model predictions

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- improvement of the accuracy of model predictions

additional aspect of IWG activity

The credible assessment of radiation doses to the thyroid in areas affected by the release of radioiodine is important:

- **in the short term after a release**
  for providing confirmation that special medical aid to the affected population and measures of social protection is required

- **in the longer term after a release**
  to provide basis for epidemiological studies and for informing the public of the impact of the release

the IWG activities are focused on:

- collection of measurement data sets
- quality checking of data for use in the modeling and evaluation of appropriate scenarios for model validation purposes
- comparison of model outputs with independent data sets, including „blind testing" (without disclosing observed data) ,
- assessement of discrepancies in predictions and identification of the most important sources of discrepancies

milestones

before 1st EMRAS meeting
(1-5 September 2003)
9 modellers
10 scenarios proposals

1st IWG Meeting
1st Combined Meetings at the Agency Headquarters in Vienna
1–5 September, 2003

2nd IWG Meeting
held at the CIEMAT, MADRID, SPAIN,
31 May - 2 June 2004

3rd IWG Meeting
2nd Combined Meetings at the Agency Headquarters in Vienna
8–11 November, 2004

4th IWG Meeting
held at the PAA, WARSAW, POLAND
29 - 31 August 2005

5th IWG Meeting
3rd Combined Meetings at the Agency Headquarters in Vienna
21 - 25 November, 2005

^{131}I PLAVSK Scenario

^{131}I MAZOVIA Scenario

^{131}I PRAGUE Scenario

6th IWG Meeting
held at NRPI,PRAGUE, CZECH REPUBLIC
6–9 June 2006

7th IWG Meeting
4th Combined Meetings at the Agency Headquarters in Vienna
6 - 10 November, 2006

8th IWG Meeting
(held at Institute of Radiation Hygiene , ST. PETERSBURG, RUSSIAN FEDERATION
3–7 September 2007

end of IWG validation exercises

8th IWG Meeting
5th Combined Meetings at the Agency Headquarters in Vienna
5 - 9 November, 2006

evaluation of ^{131}I WG TECDOC

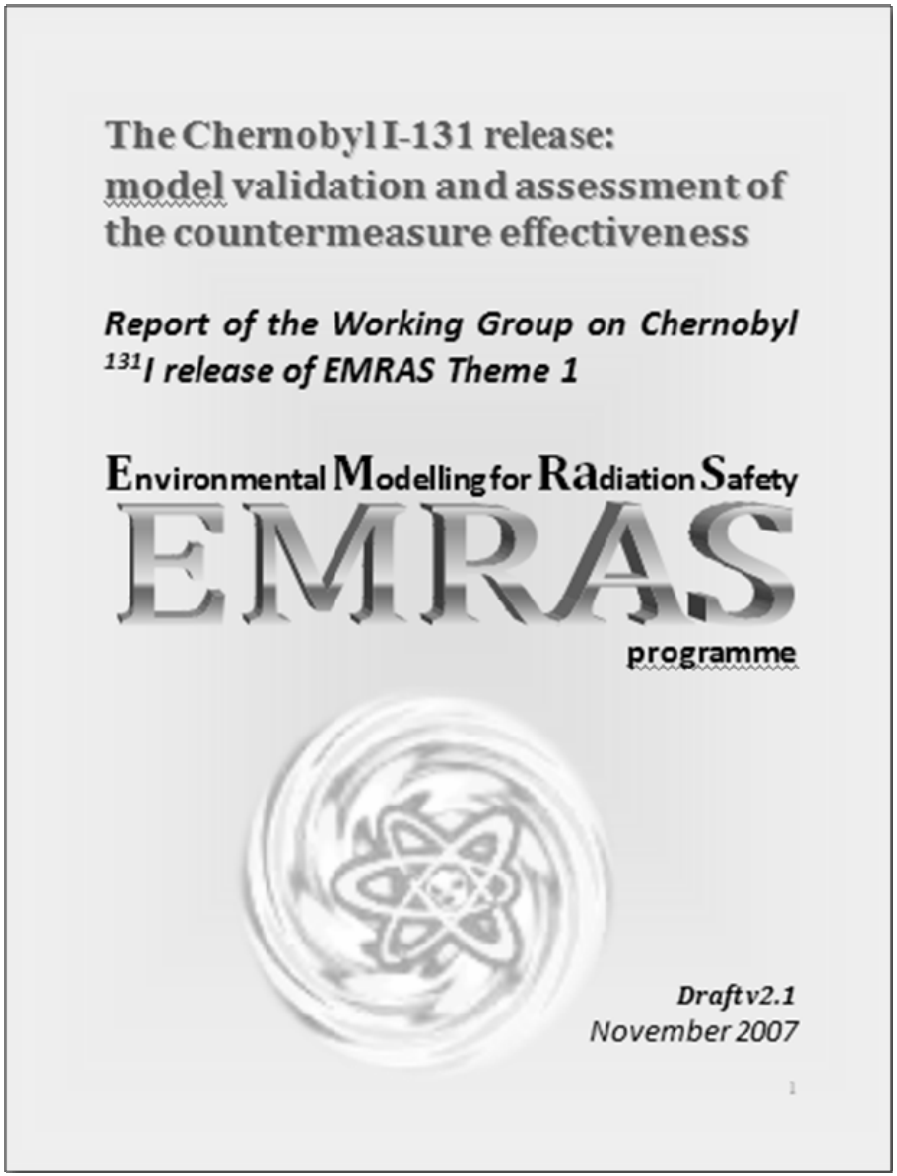
final ^{131}I WG TECDOC
December 2007

in the period 2003 – 2007
three scenario have been evaluated

^{131}I PLAVSK Scenario (Chernobyl)
11 modellers

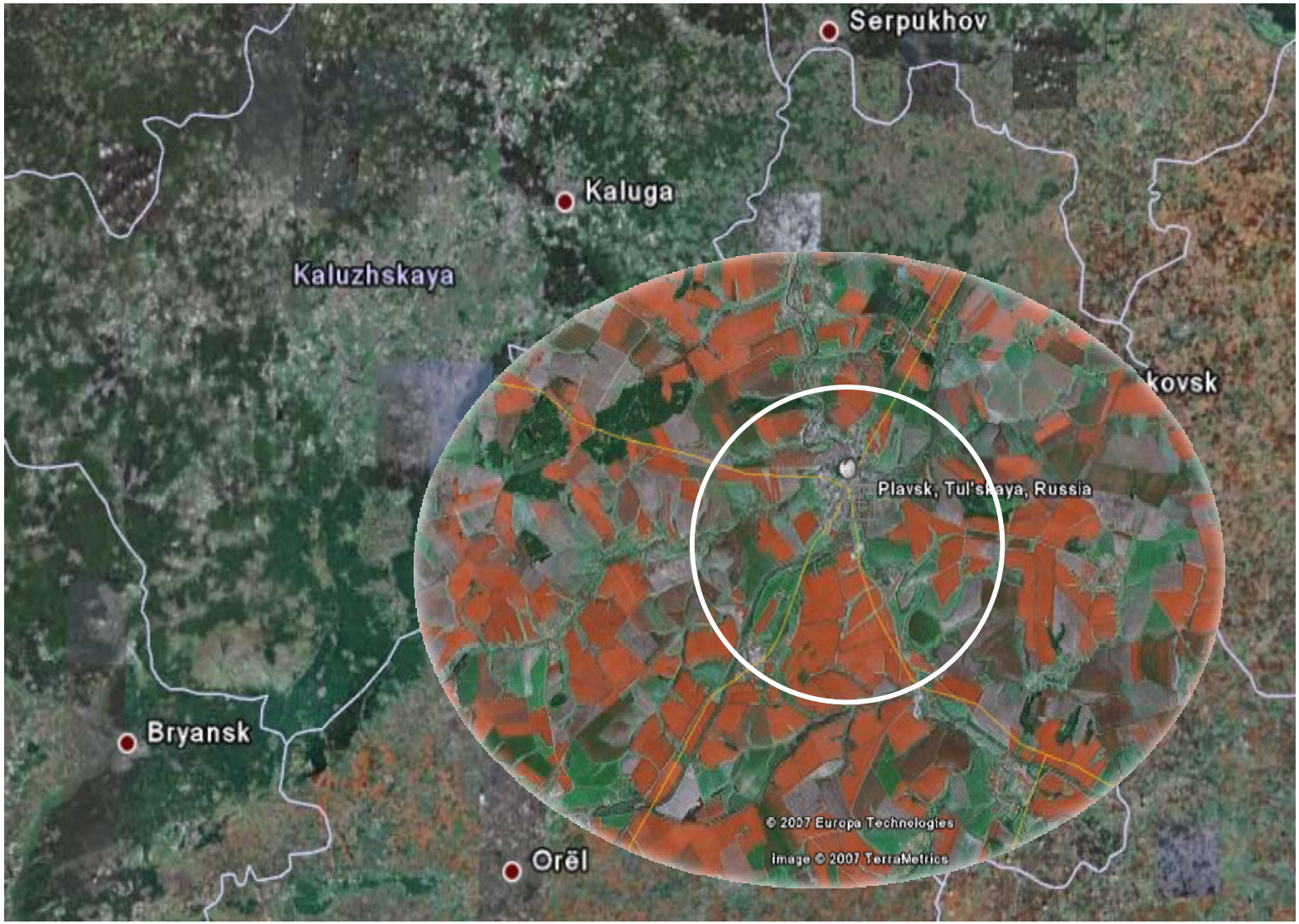
^{131}I WARSAW Scenario (Chernobyl)
8 modellers

^{131}I PRAGUE Scenario (Chernobyl) **10 modellers**


The Chernobyl I-131 release:
model validation and assessment of the countermeasure effectiveness
Report of the Working Group on Chernobyl 131I release of EMRAS Theme 1
Environmental Modelling for Radiation Safety
EMRAS
programme
Draft v2.1
November 2007

^{131}I PLAVSK Scenario (Chernobyl)

primely prepared by SENES, (description, electronically available input data)

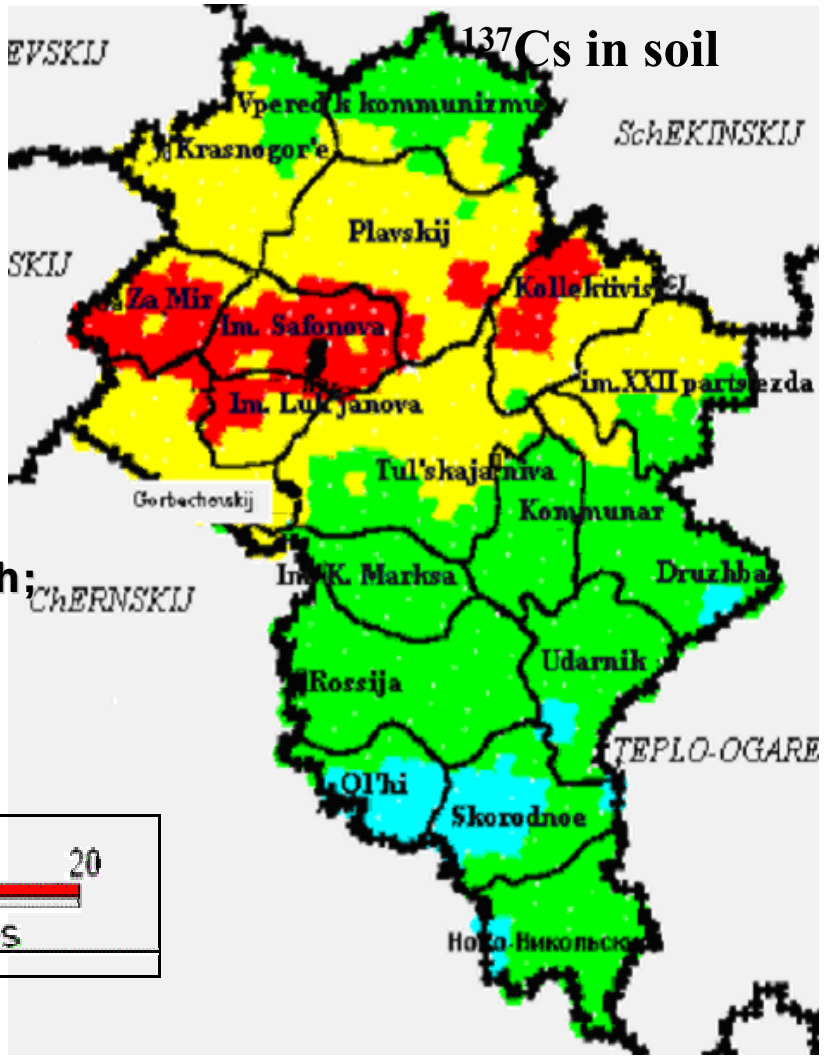


^{131}I PLAVSK Scenario (Chernobyl)

1	Krasnogor'e
2	Za Mir
3	Im. Safonova
4	Plavskij
5	Vpered k kommunizmu
6	Im. Luk'janova
7	Gorbachevskij
8	Tul'skaja niva
9	Im. K. Marksa
10	Rossija
11	Kollektivist
12	Kommunar
13	Druzhba
14	im.XXII parts'ezda
15	Udarnik
16	Ol'hi
17	Skorodnoe
18	Novo Nikol'skij

Area

40 km width;
60 km high



>37 kBq/m^2 ; 37–185 kBq/m^2; 185–370 kBq/m^2; 370–555 kBq/m^2; 555 kBq/m^2

^{131}I PLAVSK Scenario (Chernobyl)

- **model validation problem!**
  reconstruction of ^{131}I deposition using ^{137}Cs as a tracer,
- **scenario advantages!**
  numerous measurements of ^{131}I thyroid contents

  adequate data set of ^{131}I/^{137}Cs ratio in soil (on 28 May 1986)

^{131}I PLAVSK Scenario (Chernobyl)

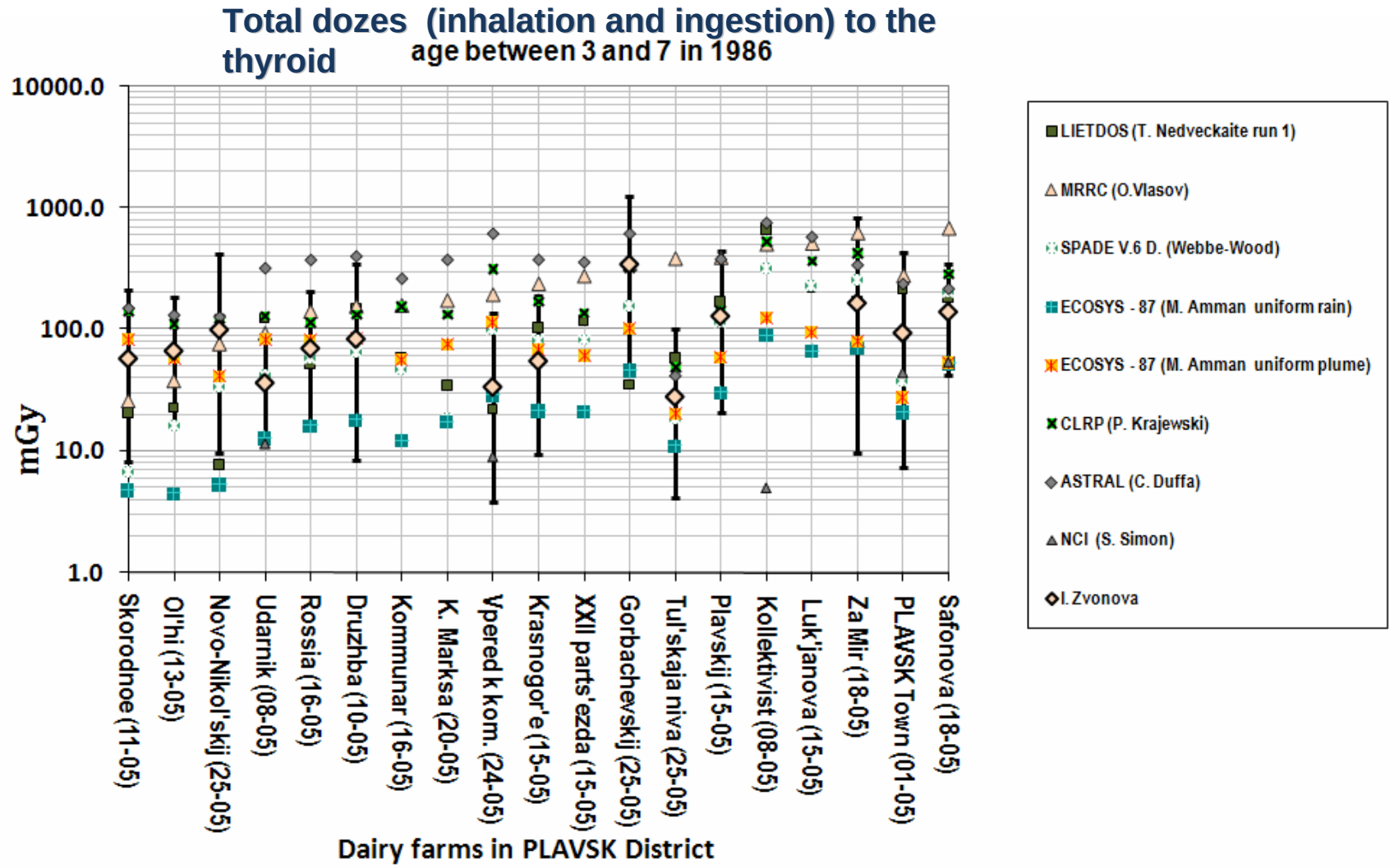
- **end points considered for model validation:**
  - ^{131}Ideposition (soil concentration)
  - a time dependent ^{131}I concentration in milk in the period 27 April –30 May 1986 for 18 milk farm situated at different ^{131}I deposition density
  - ^{131}I thyroid burden for different age groups:
    - 1-2, 3-7, 8-12, 13-17, adult for urban population (Plavsk town);
    - 1-2, 3-7, 8-12, 13-17, adult for specified rural locations

- **end points considered for model intercomparison:**
  - committed doses to thyroid from ingestion
  - inhalation dose contribution to the total dose- needs reconstruction of ^{131}I air concentration from deposition

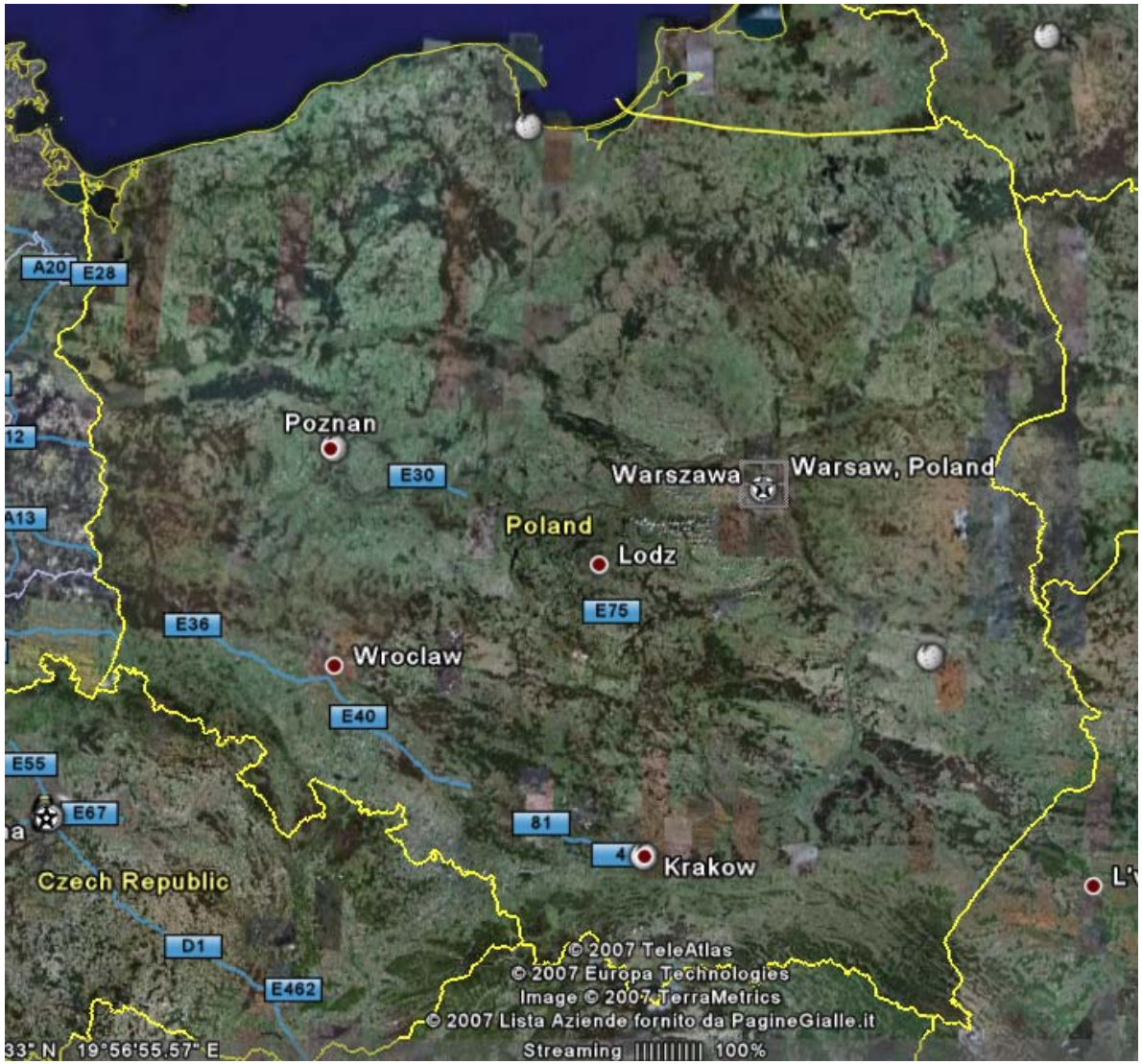
^{131}I PLAVSK Scenario (Chernobyl)

The participants of IWG has been asked to provide uncertainty analysis of thyroid doses when relatively short time of rain during the cloud passage yielded the mixed (dry&wet) and consequently inhomogeneous ^{137}Cs deposition and when the time when cows had been put on pasture was not exactly known.

^{131}I PLAVSK Scenario (Chernobyl)



^{131}I WARSAW Scenario (Chernobyl)



^{131}I WARSAW Scenario (Chernobyl)

crucial points for model validation!

- ❑ effectiveness of thyroid blocking!
- ❑ inhomogeneous ^{131}I deposition

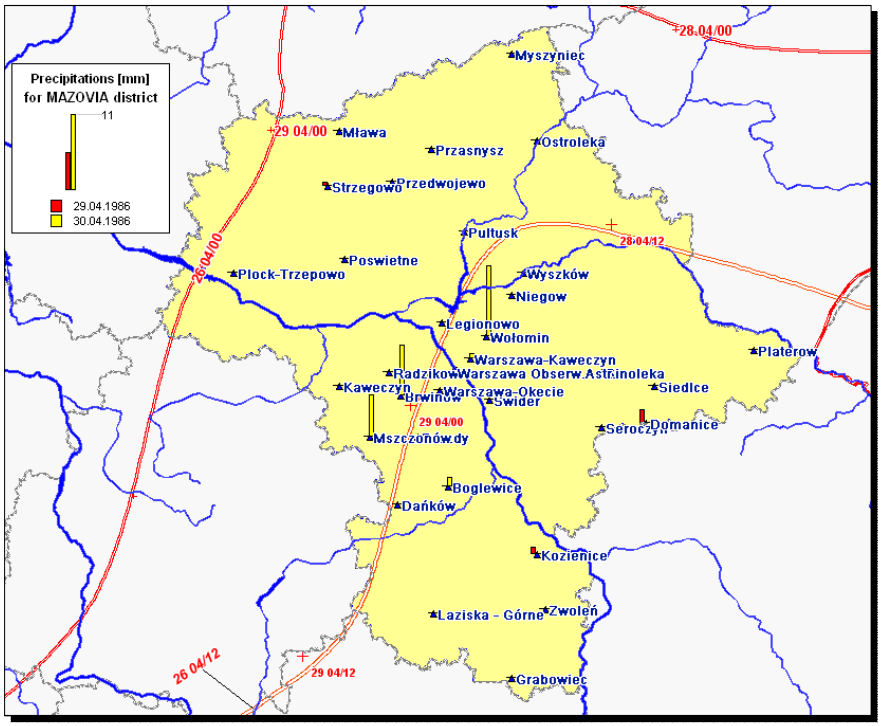
end points considered for model testing:

- ❑ ^{131}I concentration in milk
- ❑ ^{131}I thyroid burden for different age groups for two specified location

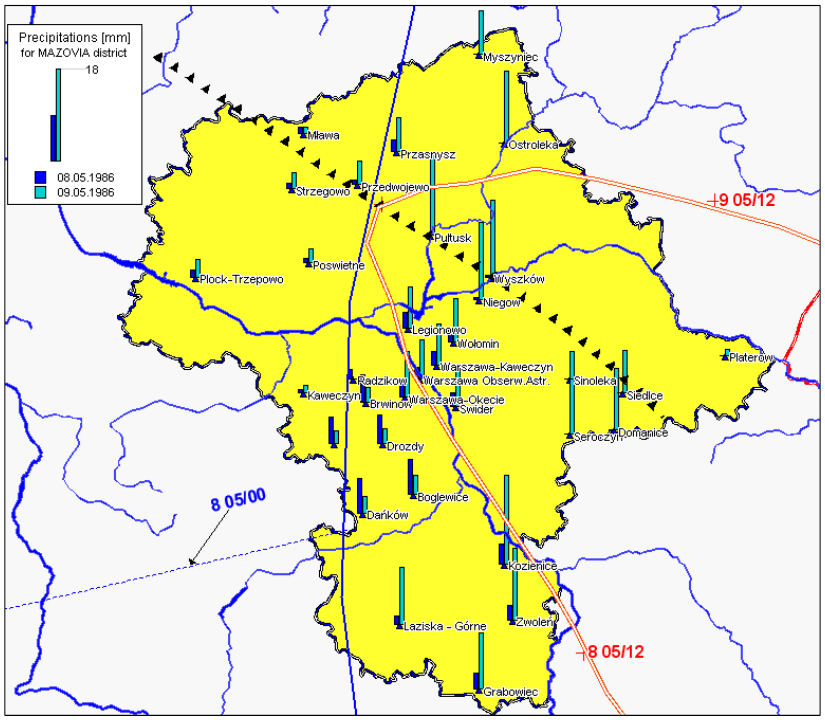
effectiveness ofcountermeasures

- ❑ administration of stable iodine solution,
- ❑ limitation of fresh milk consumption
- ❑ restriction of cows pasturing

weathering constant

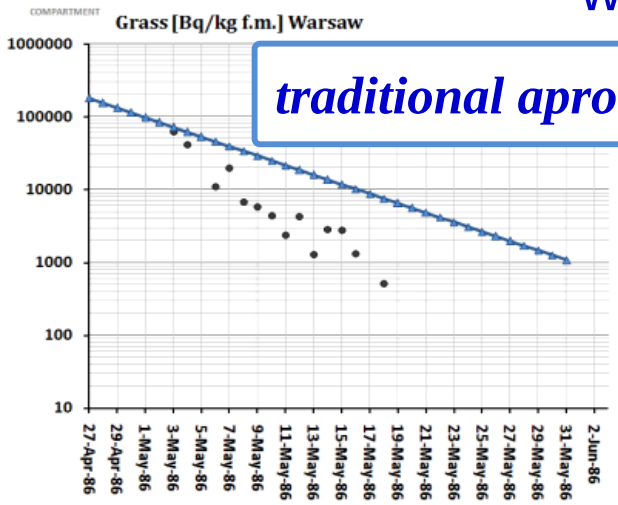


Localization of rain-falls on 29 and 30 April 1986 in Mazovia province.



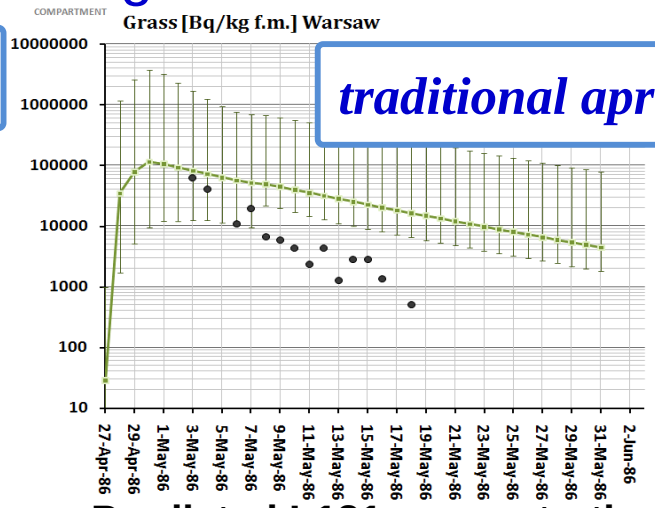
Localization of rain-falls on 8 May and 9 May 1986 in Mazovia province.

weathering constant



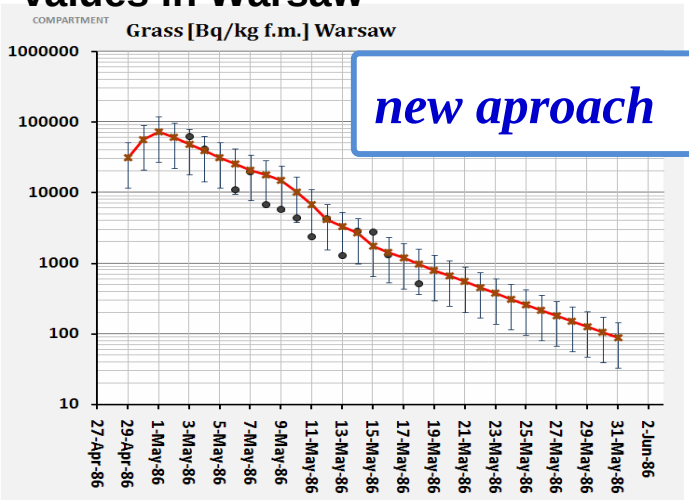
traditional aproach

Predicted I-131 concentration in grass for Warsaw by ECOSYS-97 (M. Ammann) versus measured values in Warsaw



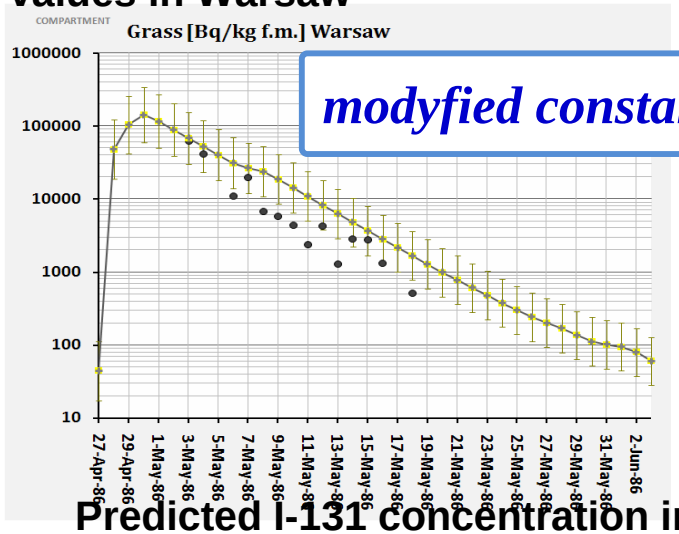
traditional aproach

Predicted I-131 concentration in grass for Warsaw by OSCAAR (T. Homma) versus measured values in Warsaw



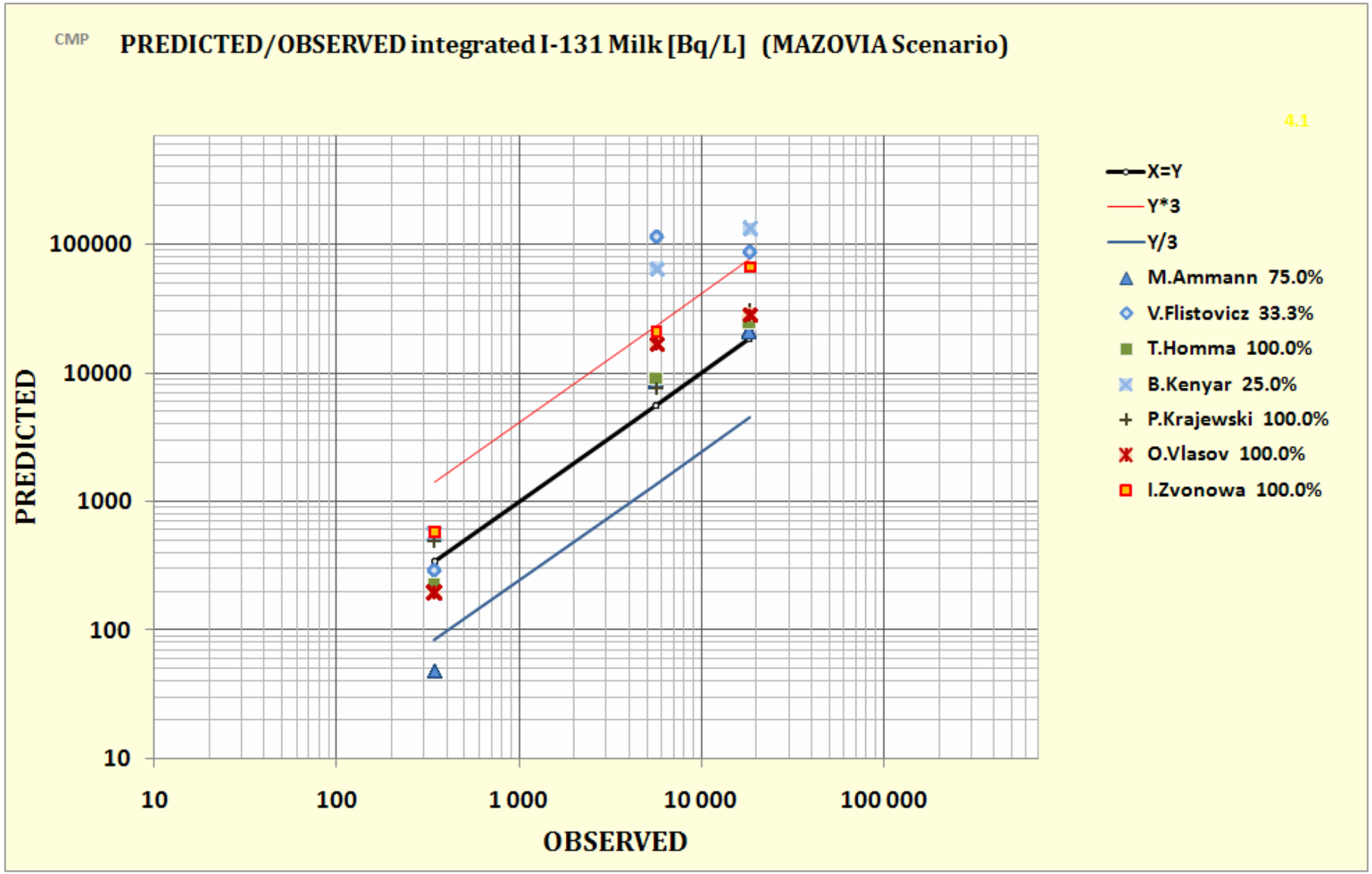
new aproach

Predicted I-131 concentration in grass for Warsaw by CLIMRAD (O. Vlasov) versus measured values in Warsaw



modyfied constant

Predicted I-131 concentration in grass for Warsaw by CLRP (P. Krajewski- scenario provider)) versus measured


CMP
PREDICTED/OBSERVED integrated I-131 Milk [Bq/L] (MAZOVIA Scenario)
4.1
PREDICTED
OBSERVED
100000
10000
1000
100
10
10
100
1 000
10 000
100 000
X=Y
Y*3
Y/3
M.Ammann 75.0%
V.Flistovicz 33.3%
T.Homma 100.0%
B.Kenyar 25.0%
P.Krajewski 100.0%
O.Vlasov 100.0%
I.Zvonowa 100.0%

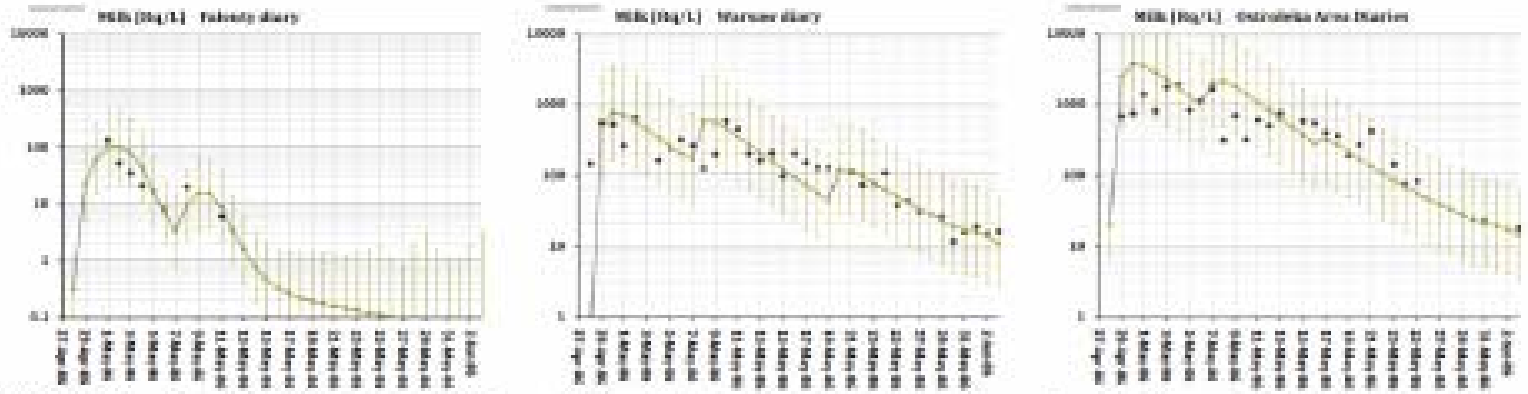


FIG. 45. Predicted I-131 concentration in milk for Falenty diary (cows kept in cowsheds), Warsaw diary (cows partly on a pasture) and Ostroleka diaries (majority cows on a pasture) by CLRP (P. Krajewski-scenario provider) versus measured values

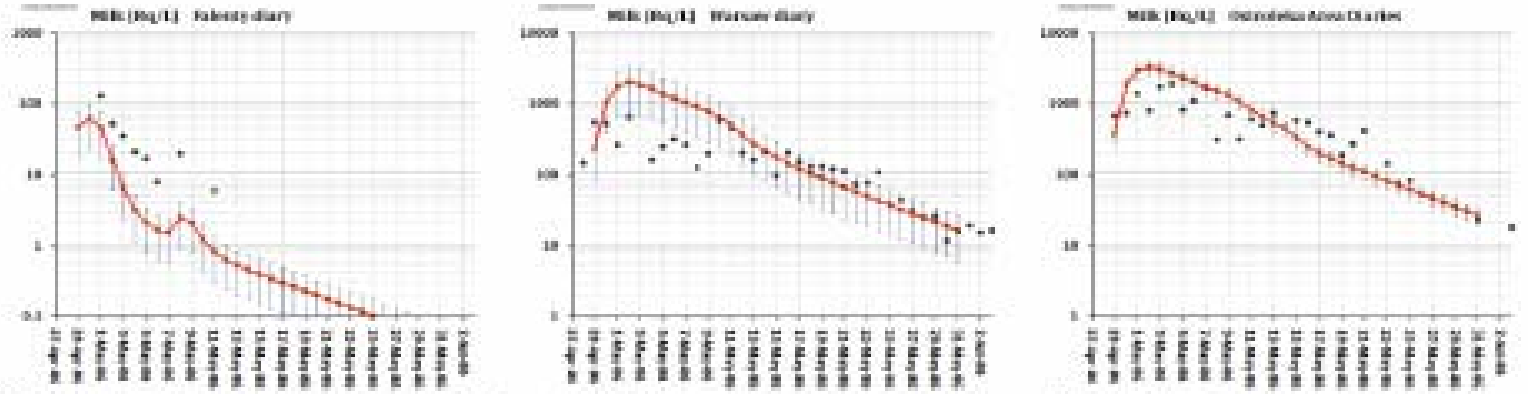


FIG. 46. Predicted I-131 concentration in milk for Falenty diary (cows kept in cowsheds), Warsaw diary (cows partly on a pasture) and Ostroleka diaries (majority cows on a pasture) by CLIMRAD (O. Vlasov) versus measured values

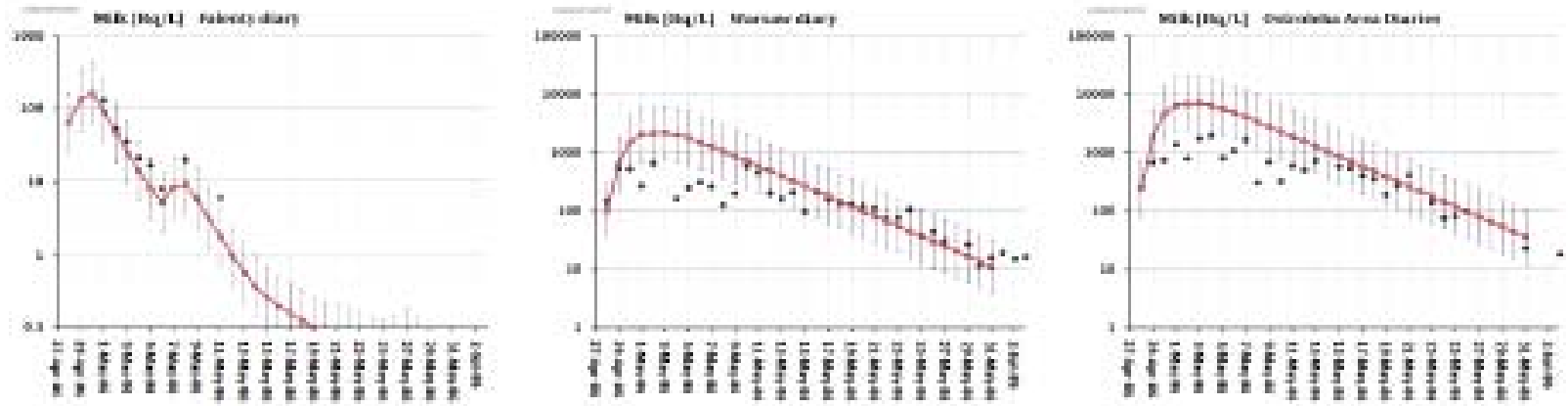


FIG. 47. Predicted I-131 concentration in milk for Faleniy diary (cows kept in cowsheds), Warsaw diary (cows partly on a pasture) and Ostroleka diaries (majority cows on a pasture) by IRH-model (I. Zvonova) versus measured values

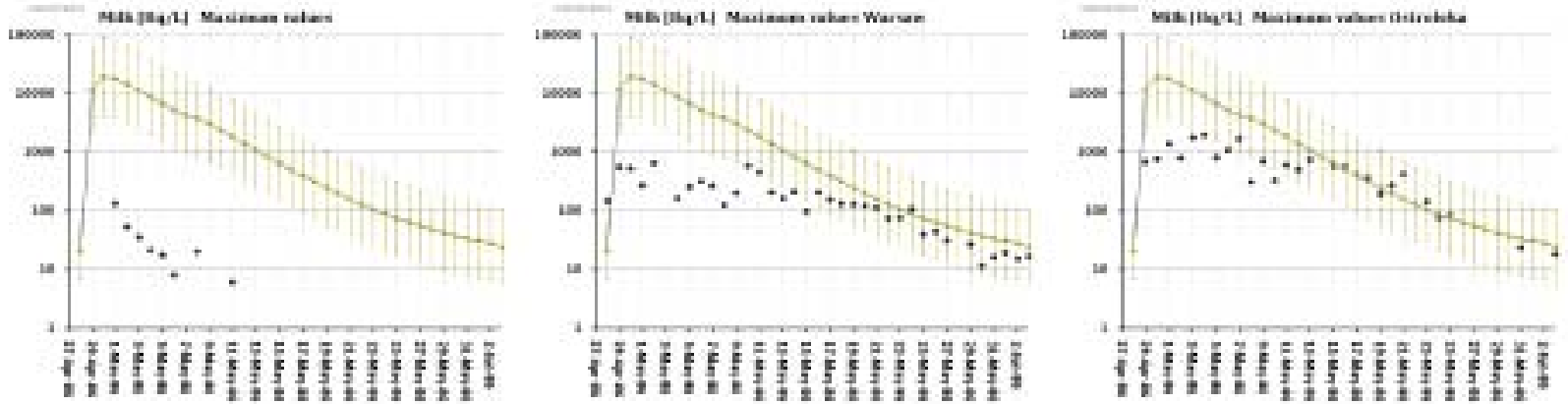
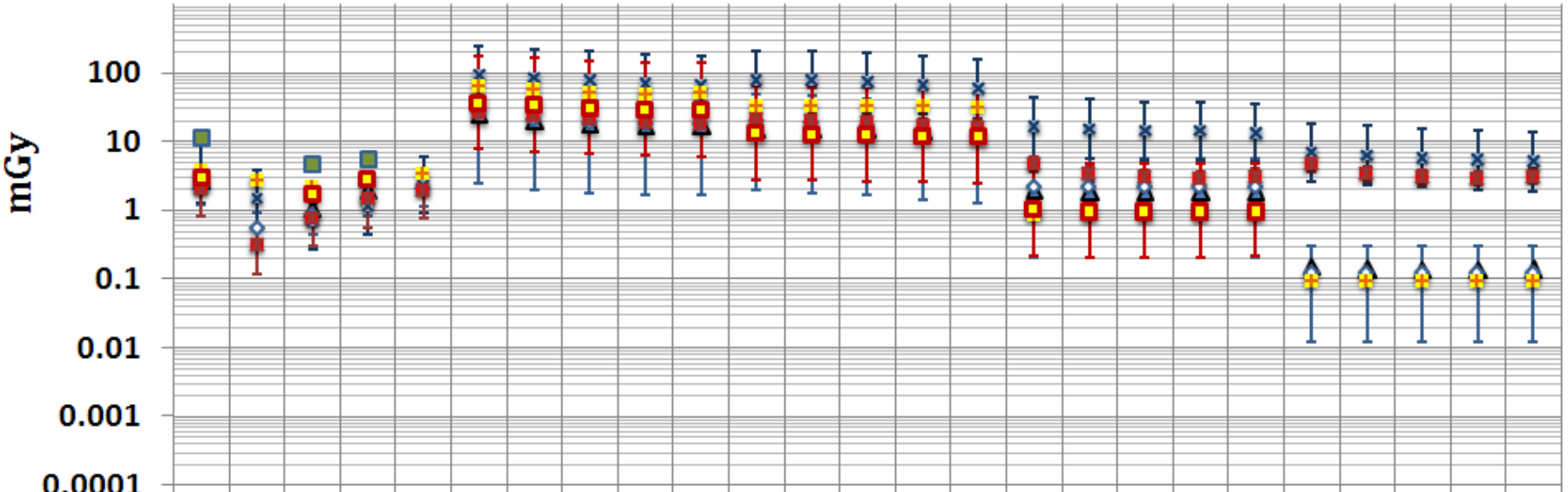


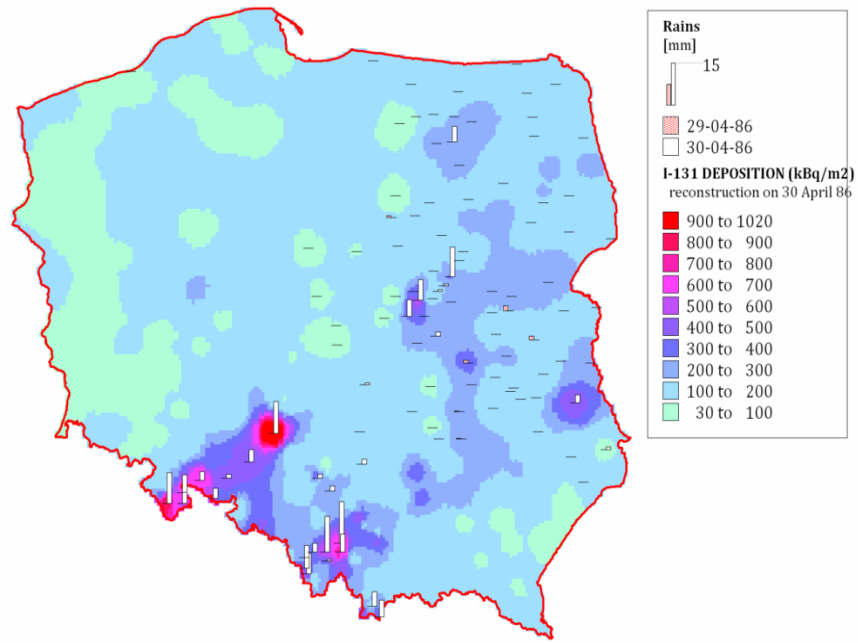
FIG. 48. Calculated maximum I-131 concentration in milk for Faleniy, Warsaw diary, Ostroleka diaries by CLRP (P. Krajewski-scenario provider) assuming no pasturing limitation versus measured values

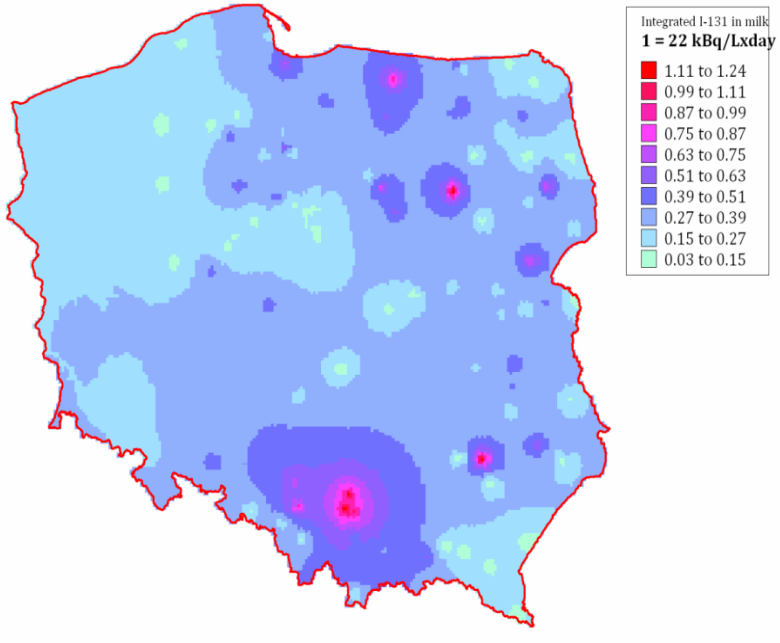
Doses of Ostroleka inhabitants (age 10)



	No I	28/4	29/4	30/4	1/5	C28/4 No I	C28/4 28/4	C28/4 29/4	C28/4 30/4	C28/4 1/5	C1/5 No I	C1/5 28/4	C1/5 29/4	C1/5 30/4	C1/5 1/5	C15/5 No I	C15/5 28/4	C15/5 29/4	C15/5 30/4	C15/5 1/5	C1/6 No I	C1/6 28/4	C1/6 29/4	C1/6 30/4	C1/6 1/5
M.Ammann	2.67		1.05	1.95		24.55	19.93	17.45	16.70	17.17	15.59	15.58	15.15	14.11	12.66	1.91	1.90	1.89	1.89	1.89	0.15	0.14	0.14	0.14	0.14
V.Flistovicz	2.28	0.58	0.86	1.53	2.11	27.51	21.63	19.51	18.19	18.35	20.69	19.45	17.87	15.96	14.00	2.31	2.31	2.31	2.31	2.31	0.13	0.13	0.13	0.13	0.13
T.Homma	11.44		4.73	5.67																					
B.Kenyar	3.52	1.54	0.72	1.21	2.42	97.00	88.00	80.00	72.00	69.00	82.00	80.00	77.00	70.00	62.00	17.00	16.00	15.00	15.00	14.00	7.30	6.60	6.10	5.60	5.30
P.Krajewski	3.79	2.69	2.21	2.84	3.48	64.50	58.05	52.18	49.84	51.60	34.01	34.01	33.42	32.84	31.66	0.88	0.88	0.88	0.88	0.88	0.09	0.09	0.09	0.09	0.09
O.Vlasov	2.17	0.32	0.80	1.54	2.06	27.47	24.50	22.13	19.87	18.74	22.16	20.69	19.53	17.94	17.00	4.87	3.53	3.10	3.04	3.25	4.87	3.53	3.10	3.04	3.25
I.Zvonowa	3.08		1.81	2.88		38.23	34.73	32.20	30.08	29.19	13.51	13.25	13.03	12.56	12.15	1.05	1.01	1.00	1.01	1.03					
Logn AVG																									
L95 AVG																									
U95 AVG																									

^{131}I WARSAW Scenario (Chernobyl)



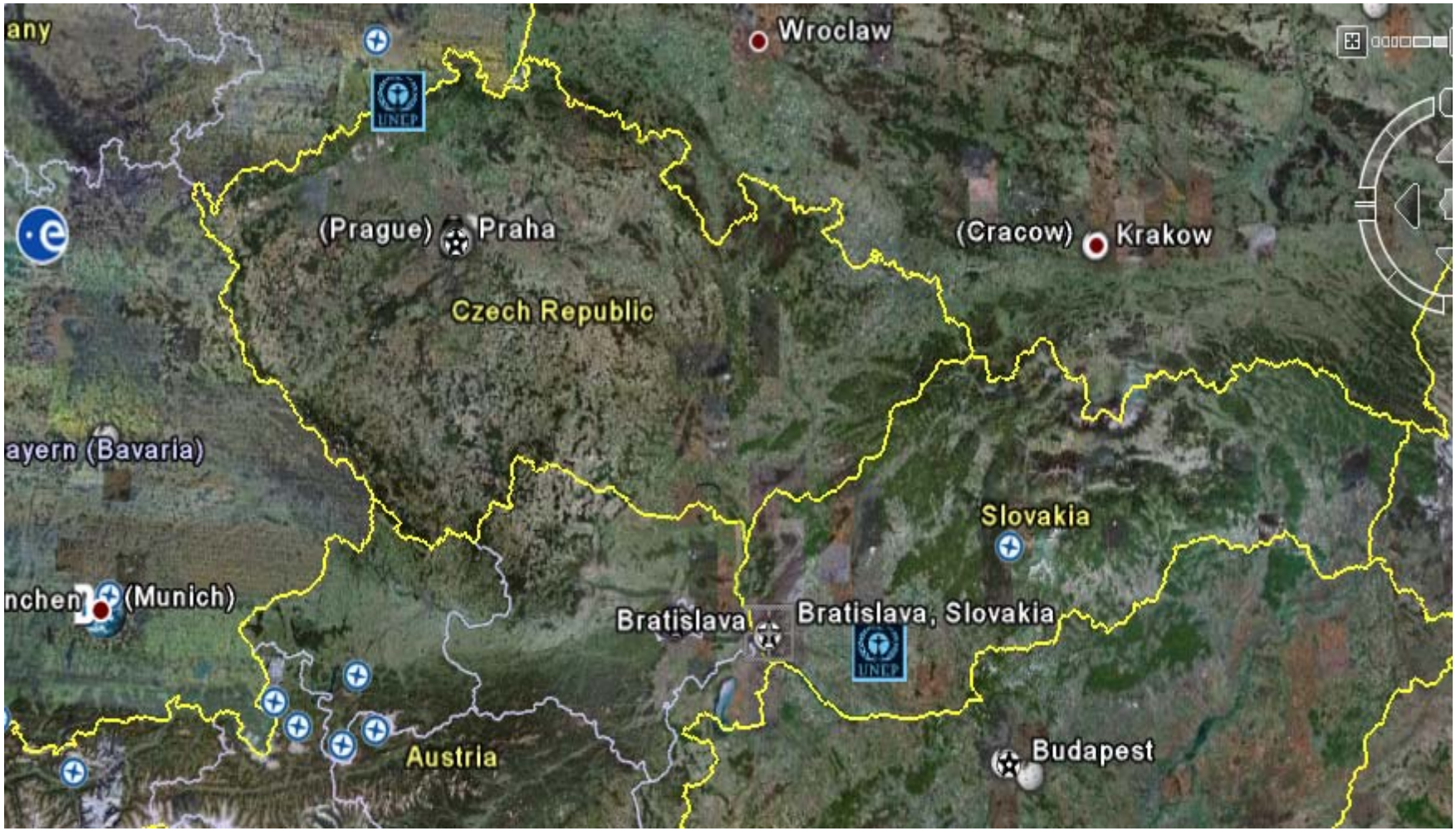


Reconstruction of ^{131}I deposition (calculated on 30 April 1986) from ^{137}Cs surface contamination

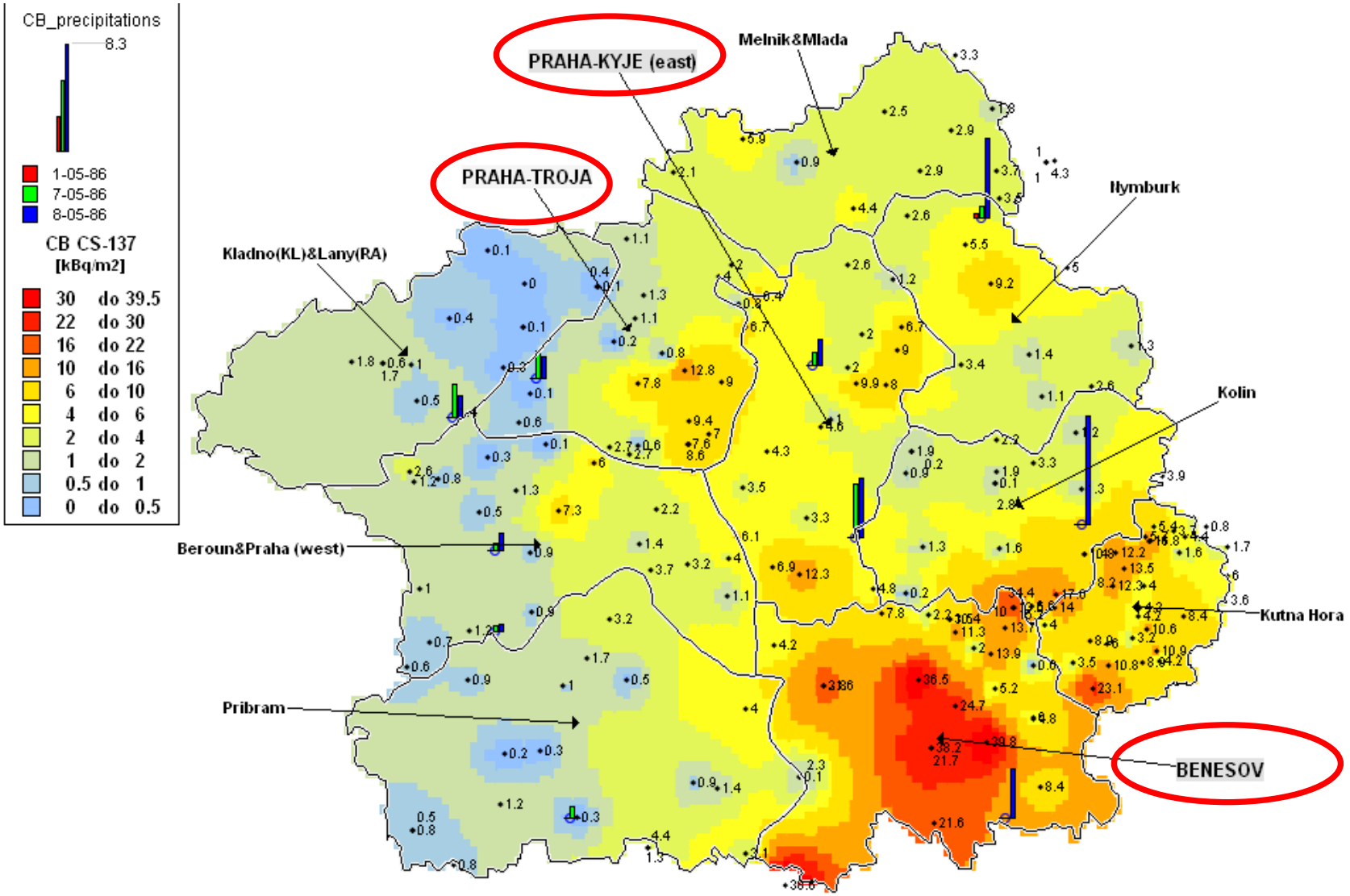
Effect of countermeasures

Spatial distribution of ^{131}I integrated concentration in milk averaged with IDW Shepard interpolator

^{131}I PRAGUE Scenario (Chernobyl)



^{131}I PRAGUE Scenario (Chernobyl)



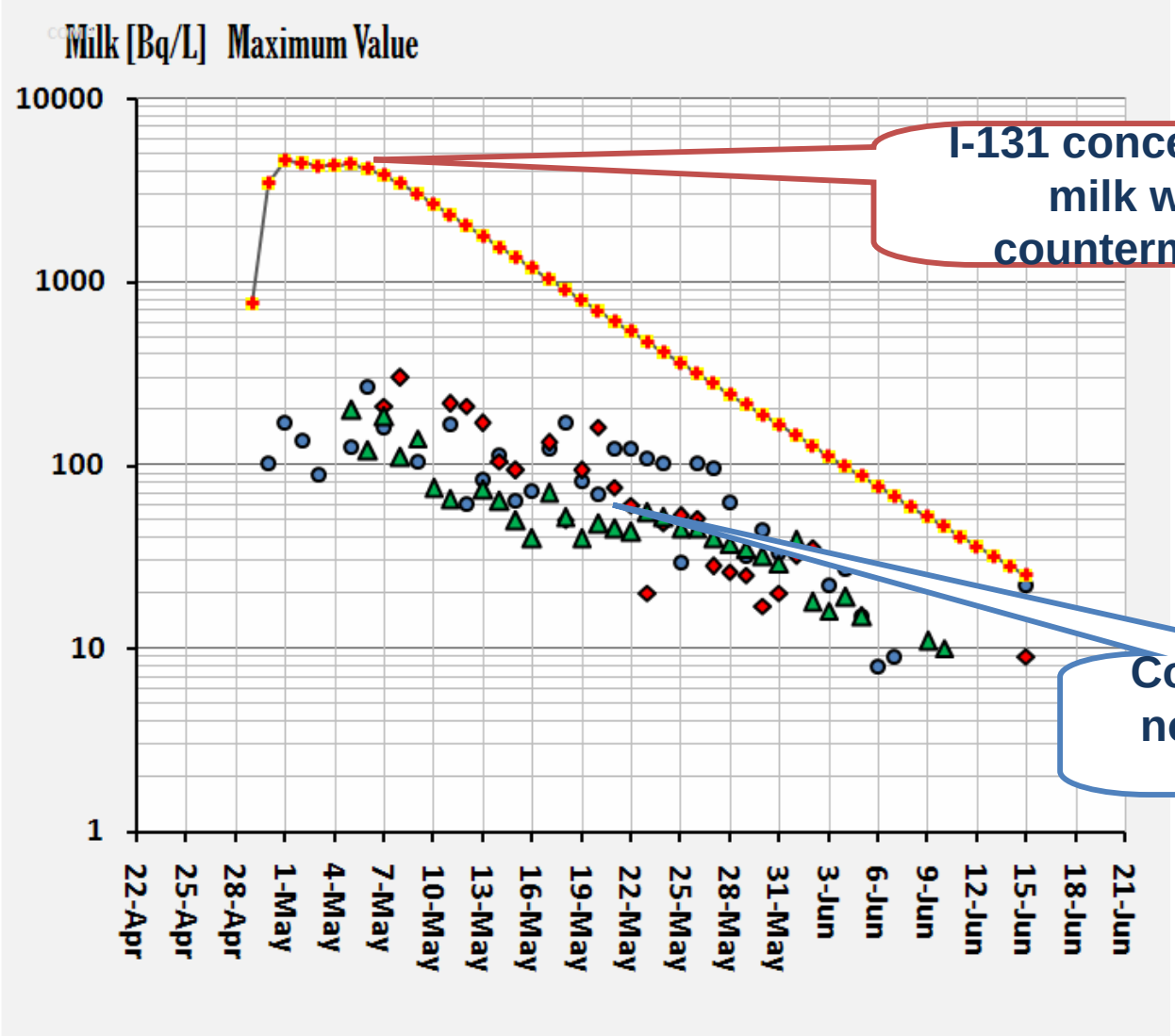
^{131}I PRAGUE Scenario (Chernobyl)

The third Prague Scenario has been focused on several aspects of the internal ^{131}I dose evaluation in a case where a special cow feeding regime was applied.

This regime consists in keeping cows in cowsheds and feeding them by silage mixture

In addition, the IWG participants were asked to estimate the ^{131}I concentration in milk for the hypothetical situation in which cows were pastured on open grassland near Prague.

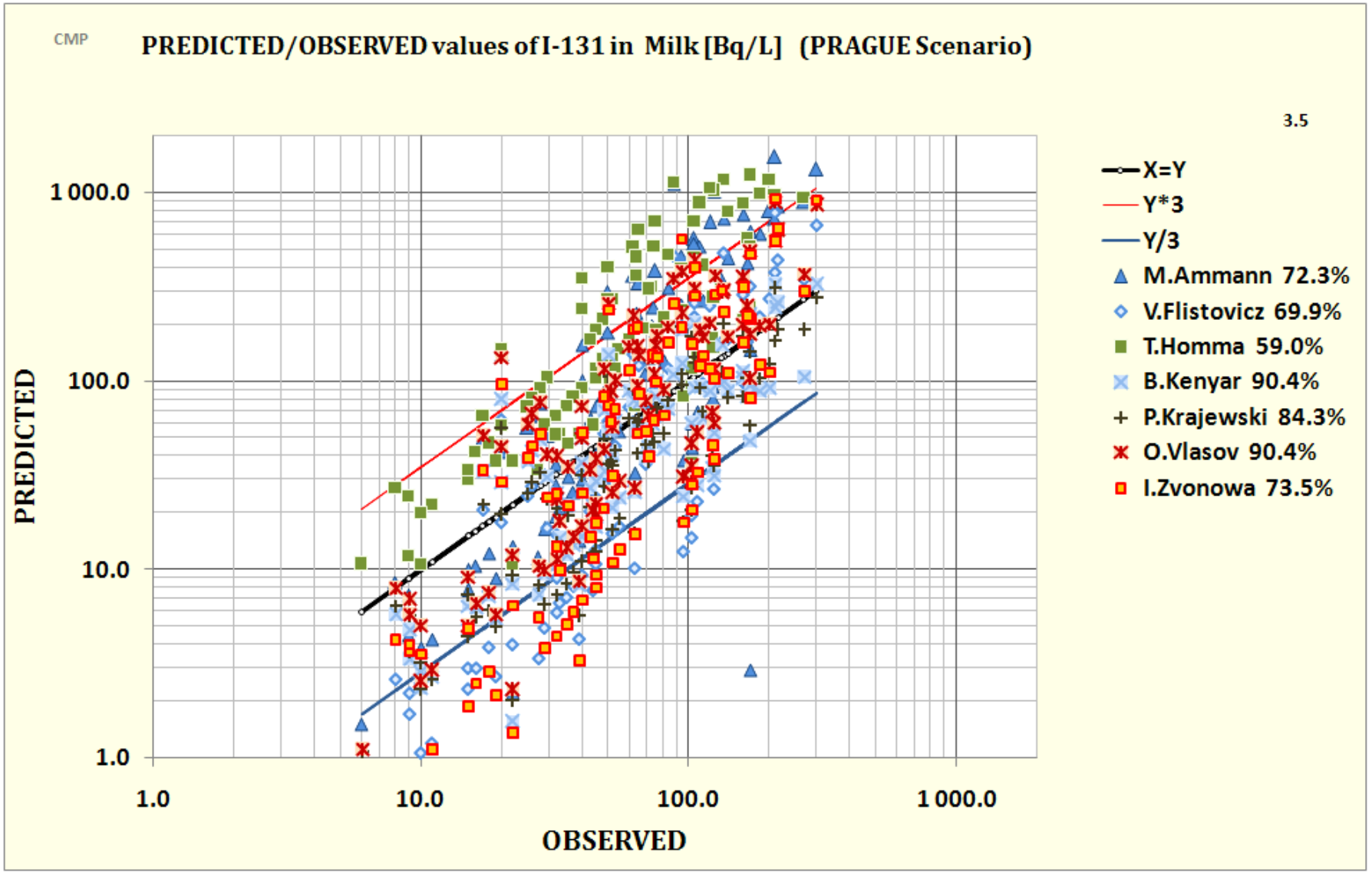
^{131}I PRAGUE Scenario (Chernobyl)



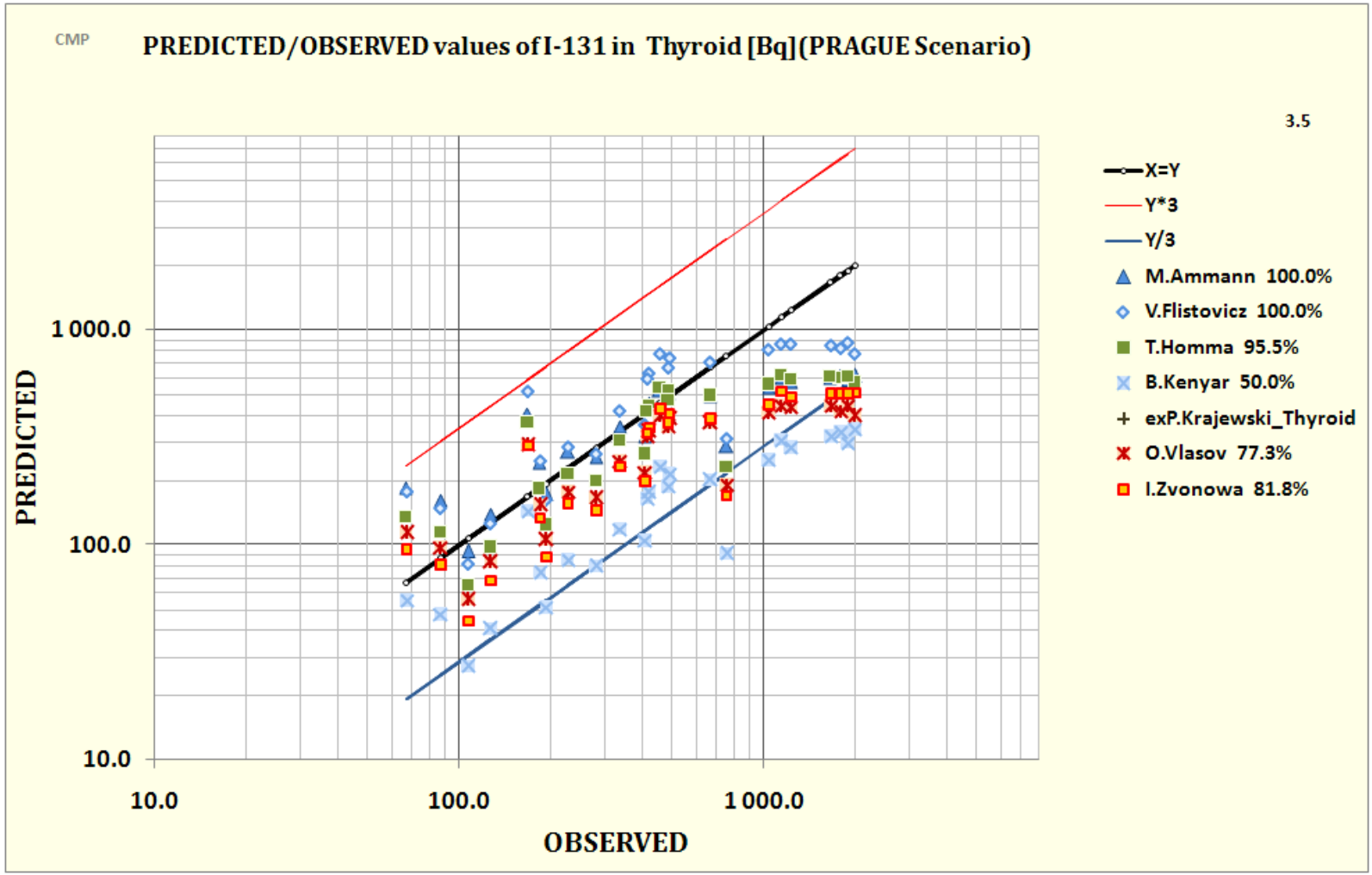
I-131 concentration in milk without countermeasures

Countermeasure – noncontaminated silage

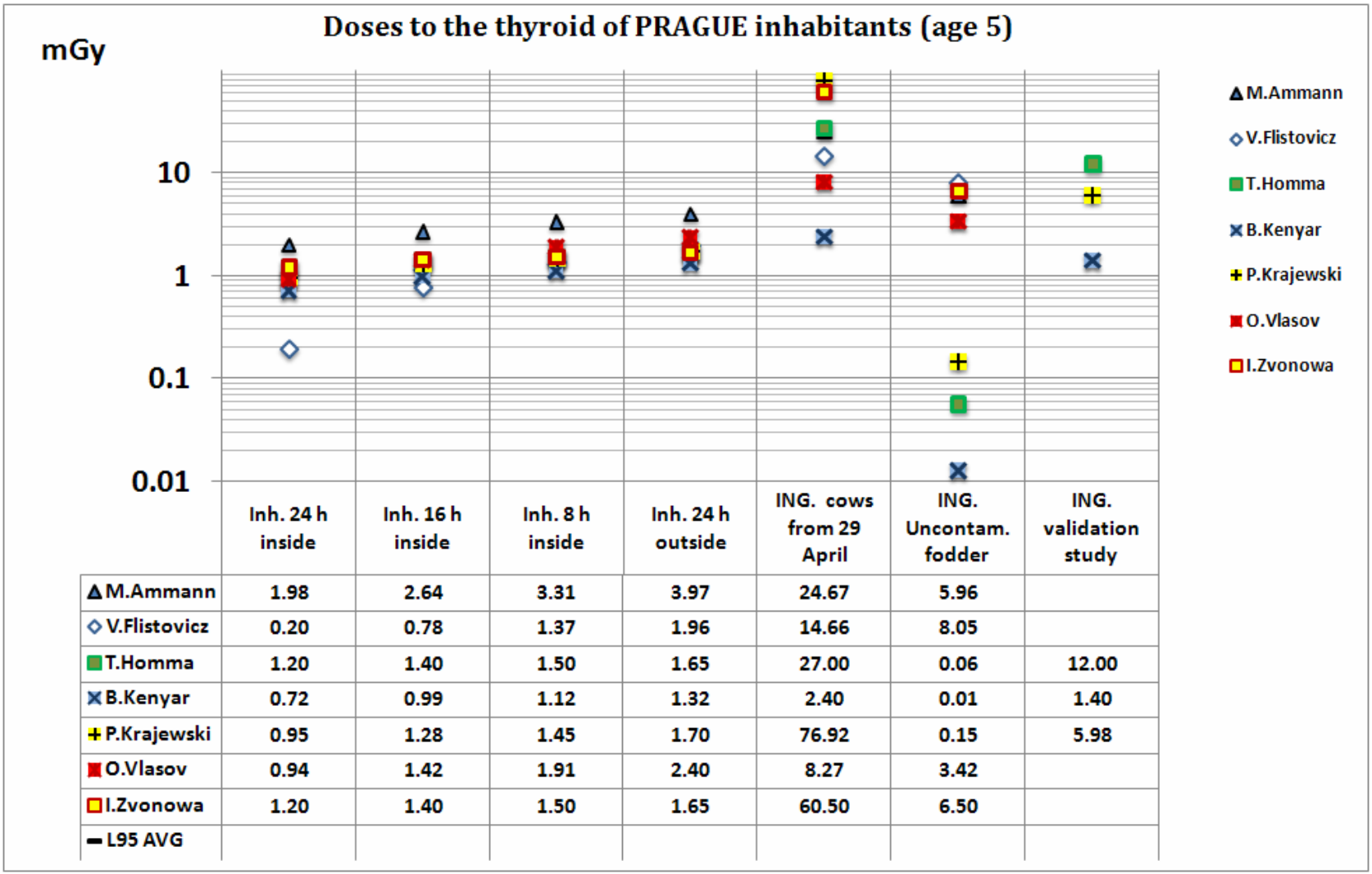
^{131}I PRAGUE Scenario (Chernobyl)



^{131}I PRAGUE Scenario (Chernobyl)



^{131}I PRAGUE Scenario (Chernobyl)



	Inh. 24 h inside	Inh. 16 h inside	Inh. 8 h inside	Inh. 24 h outside	ING. cows from 29 April	ING. Uncontam. fodder	ING. validation study
M.Ammann	1.98	2.64	3.31	3.97	24.67	5.96	
V.Flistovicz	0.20	0.78	1.37	1.96	14.66	8.05	
T.Homma	1.20	1.40	1.50	1.65	27.00	0.06	12.00
B.Kenyar	0.72	0.99	1.12	1.32	2.40	0.01	1.40
P.Krajewski	0.95	1.28	1.45	1.70	76.92	0.15	5.98
O.Vlasov	0.94	1.42	1.91	2.40	8.27	3.42	
I.Zvonowa	1.20	1.40	1.50	1.65	60.50	6.50	
L95 AVG							

IWG ISSUES

indentyfied sources of uncertainty in dose assessment:

1. Constant isotopic ratio $^{131}I/^{137}Cs$ provided fairly good approximation of 131I deposition, however **inhomogeneous ^{137}Cs deposition and relatively short time of rains during the cloud passage** indicates that the radioactive fallout for areas specified in scenarios can be classified as mixed (dry&wet) and a regional approach might be applied with more complex relationship ^{131}I deposition to ^{137}Cs deposition.

2. Uncertainty associated with prediction of ^{131}I concentration in air based on deposition data depends on **partition of airborne radioiodine in to different forms (particulate, elemental, organic) during the passage of radioactive cloud over the area of interest as well as meteorological conditions**.

3. **The time when cows have been put on a pasture** seems to be the most important factor of miss predictions of ^{131}I concentration in milk and consequently ingestion doses. It

IWG ISSUES

requirements of extended modelling activities:

1. Resident time of ^{131}I in the pasture grass, described by so called weathering constant need to be replaced by more complex model that would include changeable weathering conditions.
2. Model for grass interception fraction in a case of mixed (dry&wet) radioiodine fallout need to be carefully revised.
3. Assessement of inhalation doses for inhabitants of urban environment required validated metodology

IWG ISSUES

requirements of computer models flexibility

1. **Computer codes for radioecological assessment of radioiodine impact should be enough flexible, providing users the capability to start calculations from the most appropriate starting point determined by scenario and should provide possibility to validate code's predictions base on monitoring data .**

2. **An assessment of effectiveness of countermeasures should be required by emergency plan.**

   Example: possibility to calculate thyroid burden , whole body burden, and thyroid blocking

IWG ISSUES

requirements of validated methodology for realistic dose and dose uncertainty assessment :

In emergency circumstances, it may be foreseen that in reality, the rapid introducing countermeasures (distribution of stable iodine, transfer of animals to stored feed, restrictions of consumption contaminated food) cannot be arranged or planned and also there are no means to make items compulsory but only to raise the level of public recognition.

Therefore, the requirements of emergency response preparedness prompt validated methodology for realistic dose and dose uncertainty assessment, furthermore, the justification of different variants of protective action and evaluation of safety threshold

GENERAL CONCLUSIONS

Participation in the IWG scenarios exercise gave modelers a unique experience in modeling various short term countermeasures.

The three scenarios i.e. PLAVSK, MAZOVIA, PRAGUE described the Chernobyl originated atmospheric contamination of ^{131}I and served as the basis for calculations of atmospheric transport, deposition, and doses to humans from internal exposure pathways.

Modelers learned that countermeasures (especially rapidly introduced) are complex and their effects are hard to predict.

The effectivenees of countermeasures is often determined by several important factors:
1.social and economic situation,
2.efficiency of emergency response system,
3.public awareness and transparency of public information.

GENERAL CONCLUSIONS

- significant improvement in the performance of models compared with previous radioiodine assessment exercises
- more than 60% of predictions of the various models were with in a factor of three of the observations of ^{131}I concentration in milk and ^{131}I content of the thyroid
- discrepancies between the estimates of average doses to the thyroid produced by most participants did not exceed a factor of ten.
- however, estimated doses differed by up to two orders of magnitude when the participants attempted to evaluate the effectiveness of applied countermeasures using different methods and conceptual approaches.
- In general, the differences among the model predictions are rather due to differences in the interpretation of the scenario description than due to differences in the modeling approach.

Thanks for your attention

Paweł Krajewski

Most of the IWG documents are on the html analogue of ftp server:

http://www-ns.iaea.org/downloads/rw/fileshare/wss/default.asp?lg=a&fd=161