Dose Reconstruction Methods and Source Term Assessment using Data from Monitoring Networks and Mobile Teams – A German Approach

M. Bleher, U. Stöhlker, F. Gering
Federal Office for Radiation Protection (BfS), Germany

International Expert's Meeting on Assessment and Prognosis in Response to a Nuclear or Radiological Emergency (IEM9)

Outline

- German measurement and information system (IMIS) and decision support system RODOS
- Ground contamination maps and dose reconstruction method
- Update of the German Measurement Program
- R+D project: source term reconstruction method
- Experience with spectrometric dose rate probes

Integrated Measurement and Information System (IMIS) and Decision Support Systems RODOS

IMIS

- Dose rate monitoring (BfS)
  - 1750 monitoring stations
- Gamma-spectrometry (DWD)
  - 40 monitoring stations
  - Activity in air
  - Activity on ground
  - Amount of precipitation
- Mobile equipment
  - 6 (BfS) + 16 (Länder)
  - Activity on ground
  - Dose rate

RODOS

- Atmospheric dispersion
- Deposition and Transfer
  - Activity deposited on ground
  - Activity in food
- Dose assessment
  - Inhalation, Ingestion
  - External Exposure

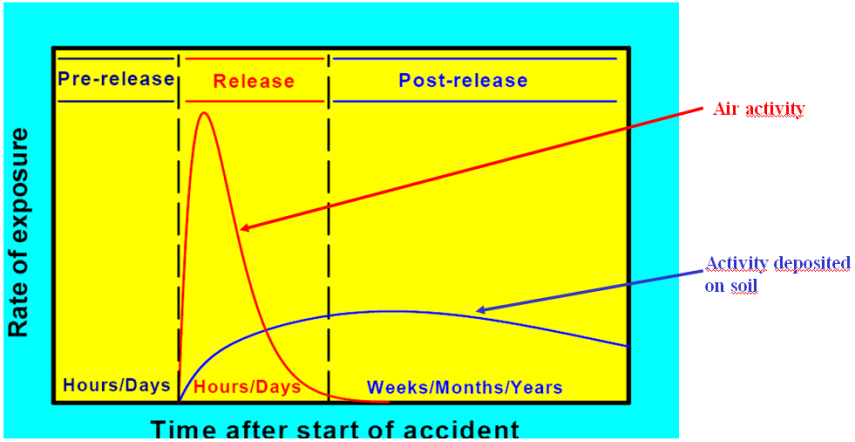
Affected areas?

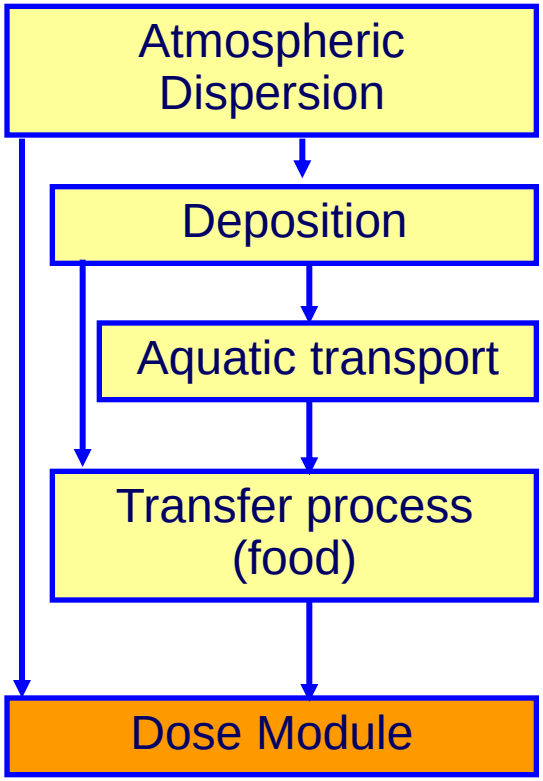
Radio-nuclides?

Contamination?

Decision support system RODOS

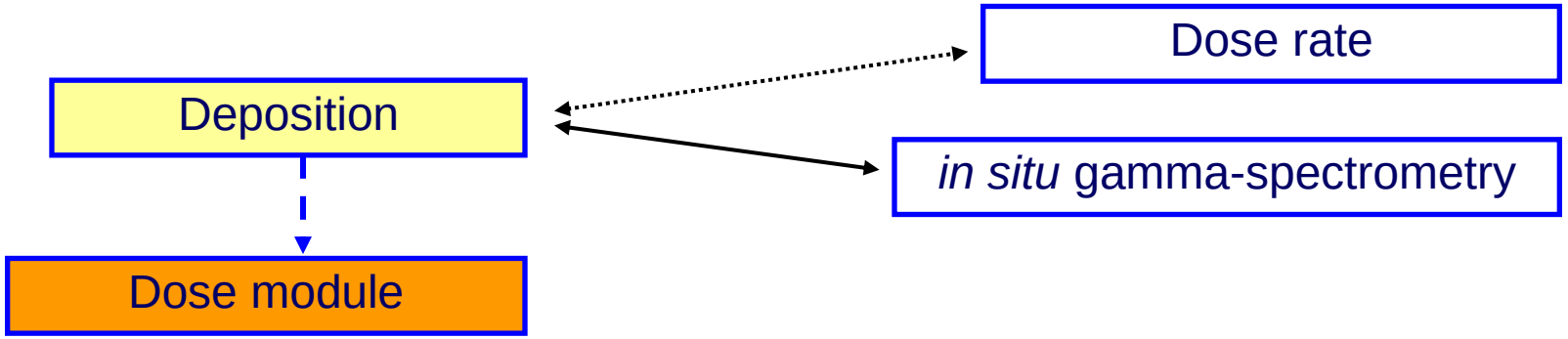
- Pre-Release
  - Source-term, atmospheric dispersion, deposition conditions
- During cloud passage
  - Source-term, atmospheric dispersion, deposition conditions
  - Measured data:
    Air activity, dose rate, in situ gamma-spectrometry





Decision support system RODOS

- After cloud passage
  - Finished atmospheric dispersion and deposition process



→ Prognostic data for activities deposited on ground are replaced by **measured data**
Dose reconstruction method
(Data assimilation techniques)

- Module calculations are used to assess doses (ingestion, external exposure) from the activities deposited on ground

Ground Contamination Tool M1
Deposition mapping by dose rate and in situ gamma spectrometry data

- Main purpose of the Ground Contamination Tool is the determination of ratios between ADER and relevant radionuclides at those locations where **both**, ADER and nuclide specific information is available.
- This allows to estimate the nuclide specific concentration at locations where only ADER is measured.
- Shortly after cloud passage phase, the method enables large area contamination mapping

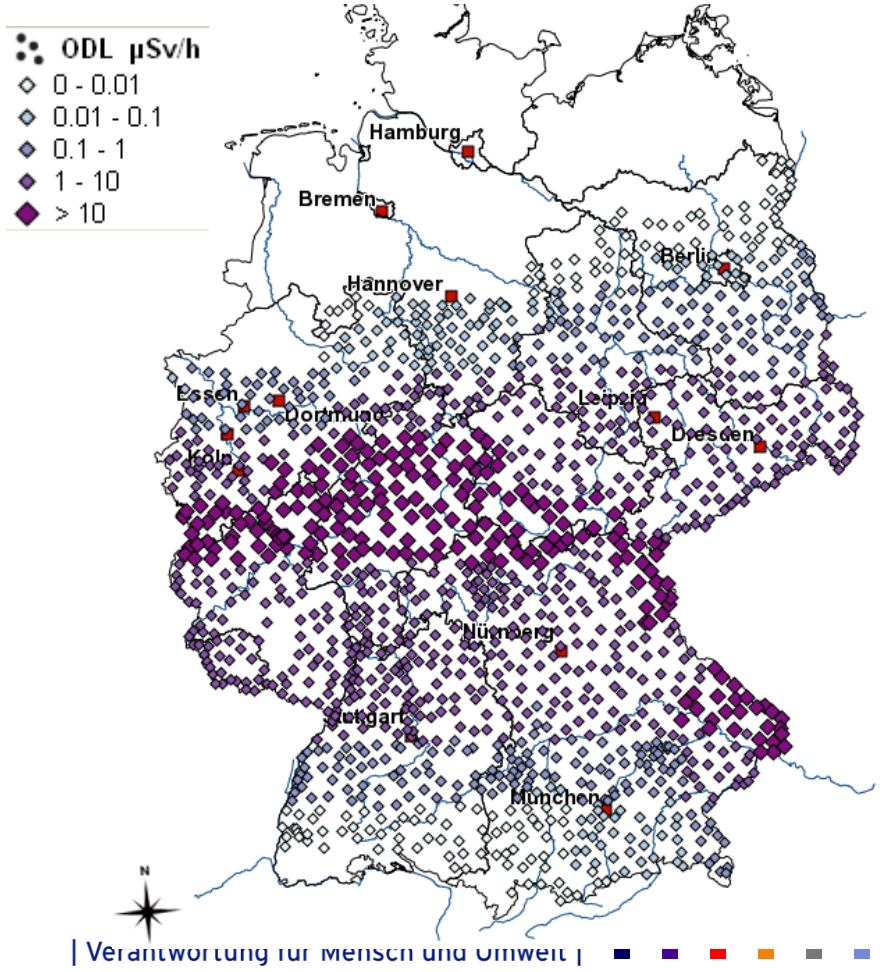
- Step 1: **Supporting points** (ADER and insitu data from measurements):
  - Net dose rate: ADER
  - Activity on ground for nuclide i (from in situ data): AG(i)
  - Nuclide vector: $f(i) = AG(i) / \{ADER - ADER(BG)\}$

- Step 2: **Interpolation points** (only at locations where ADER data are measured)
  - Spatial interpolation of nuclide vector f(i)
  - Net dose rate: ADER (derived from measured dose rate)
  - Assessment of activity deposited on ground

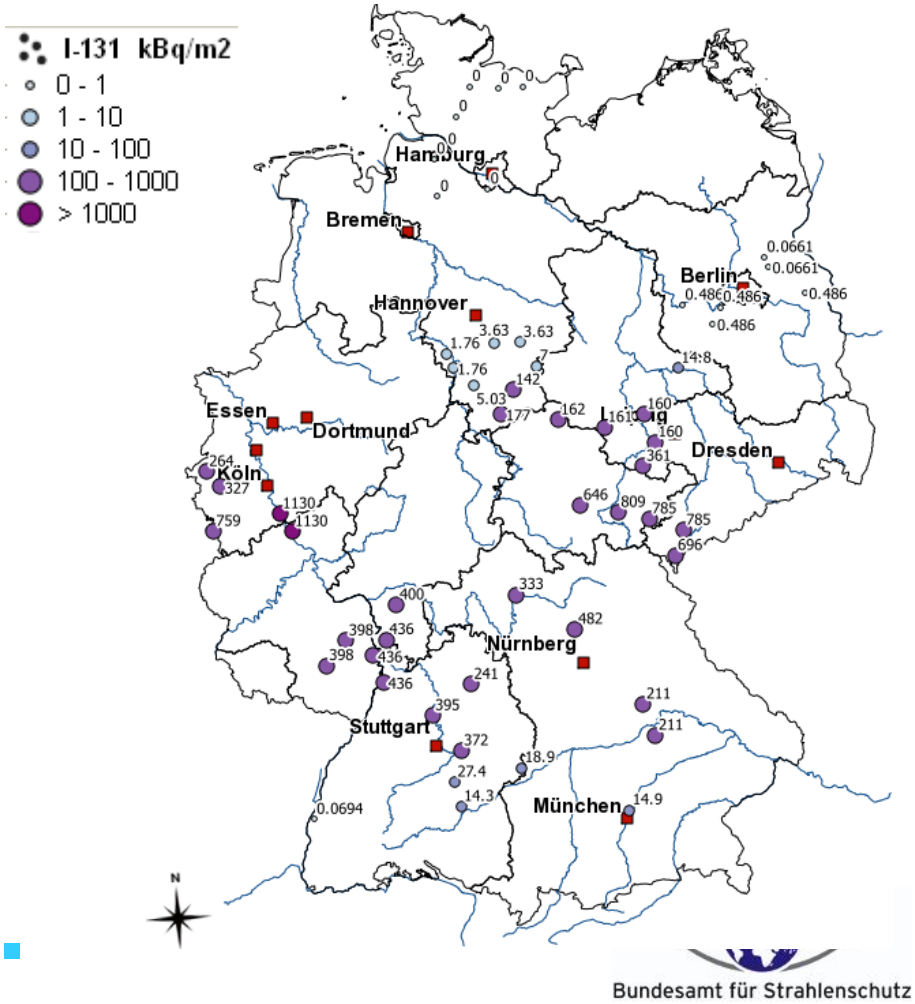
$$AG(i) = f(i) \{ADER - ADER(BG)\}$$

Ground Contamination Tool M1
IMIS exercise with simulated data

For monitoring stations:
Simulated net dose rate



For locations with 50 real measurements:
Simulated I-131 activity

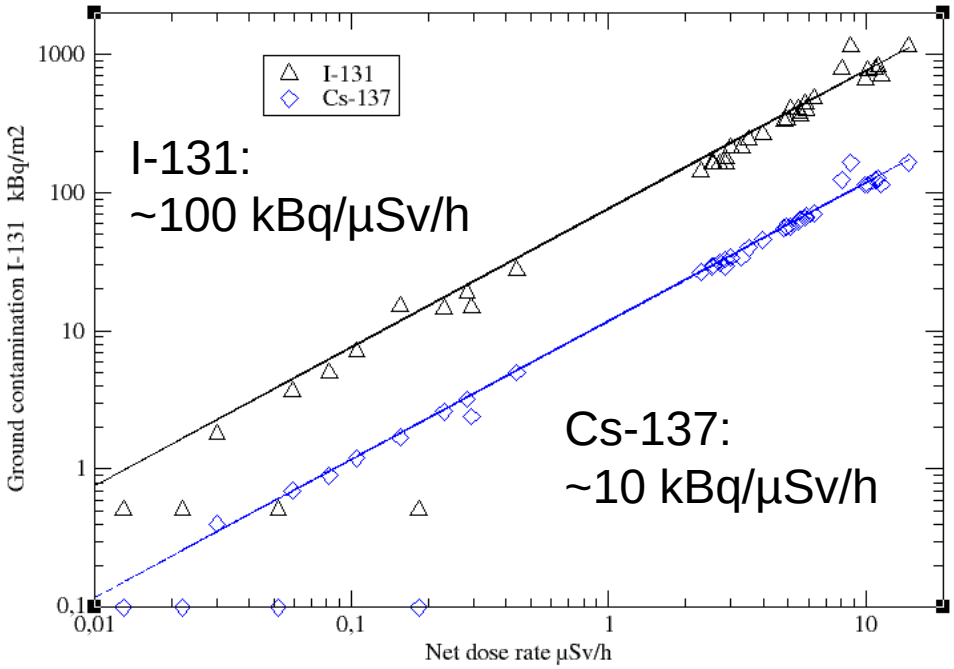


| Verantwortung für Mensch und Umwelt |

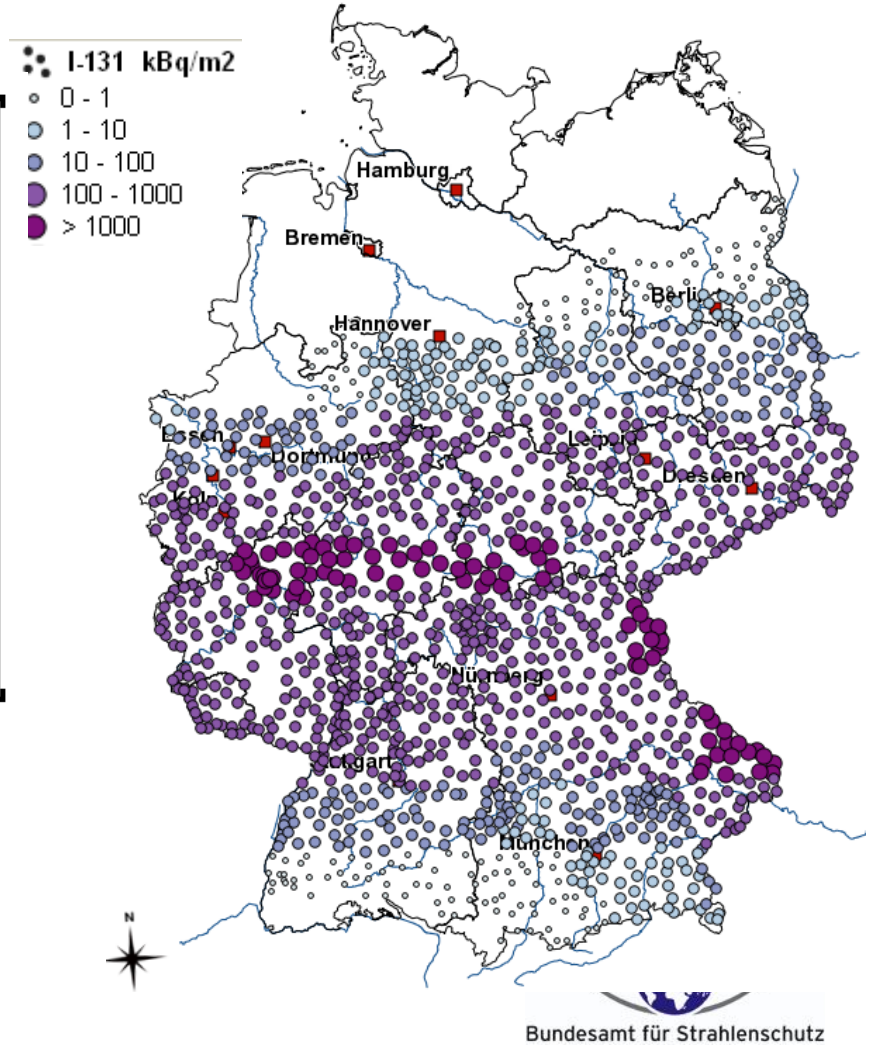
Bundesamt für Strahlenschutz

Ground Contamination Tool M1
IMIS exercise with simulated data

Correlation of net dose rate and activity deposited on ground



Assessed I-131 Activity



The method enables timely large area contamination mapping in the first days after an accidental release event

Ground Contamination Tool M2
Integration of aero gamma data

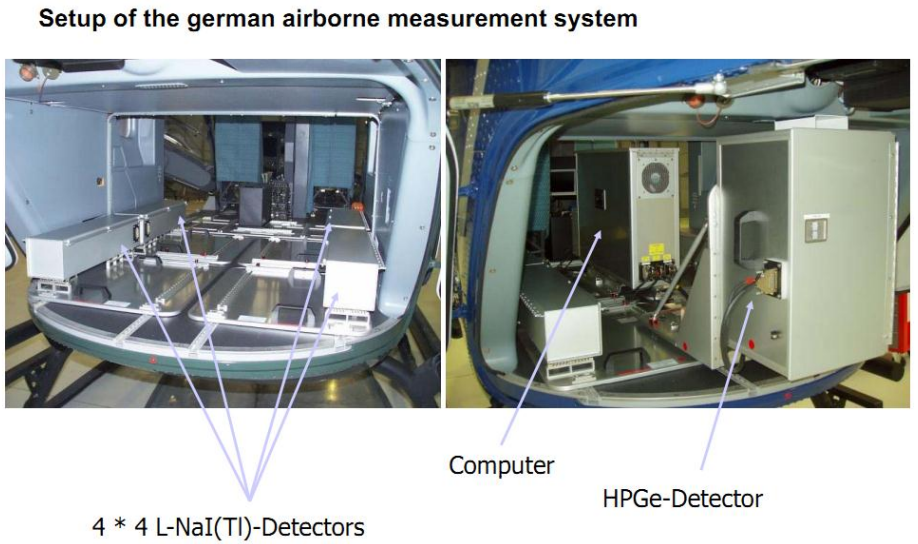
Aero gamma spectrometry
(2 BfS Systems)

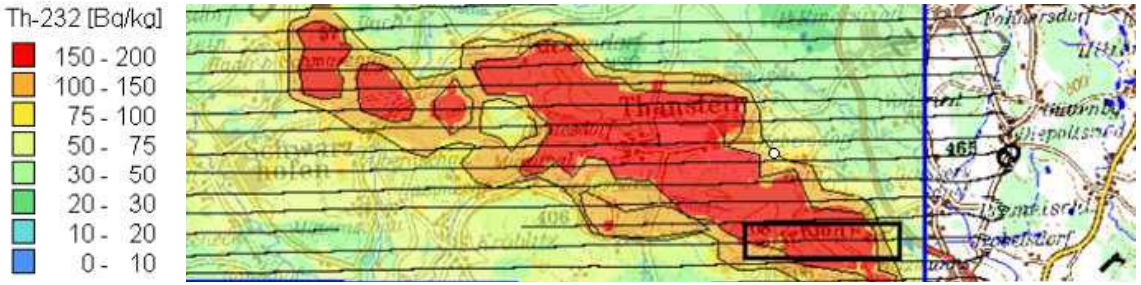
- 4 x 4 l NaI-Detectors
- HPGe detectors

Contamination in rural areas

About 50 km²/ flight hour

LLD ~ 5 kBq/m² Cs-137





Data from C. Strobl, M. Thomas

In combination with method M1 applied for:

Areas near release or with small scaled contamination patterns (wet deposition)

Ground Contamination Tool M3
Integration of vehicle based dose rate data

Vehicle based dose rate measurements
(6 BfS Systems)

- mobile teams with plastic scintillator
- measured dose rate every second
- position detection via GPS
- natural background rejection algorithm

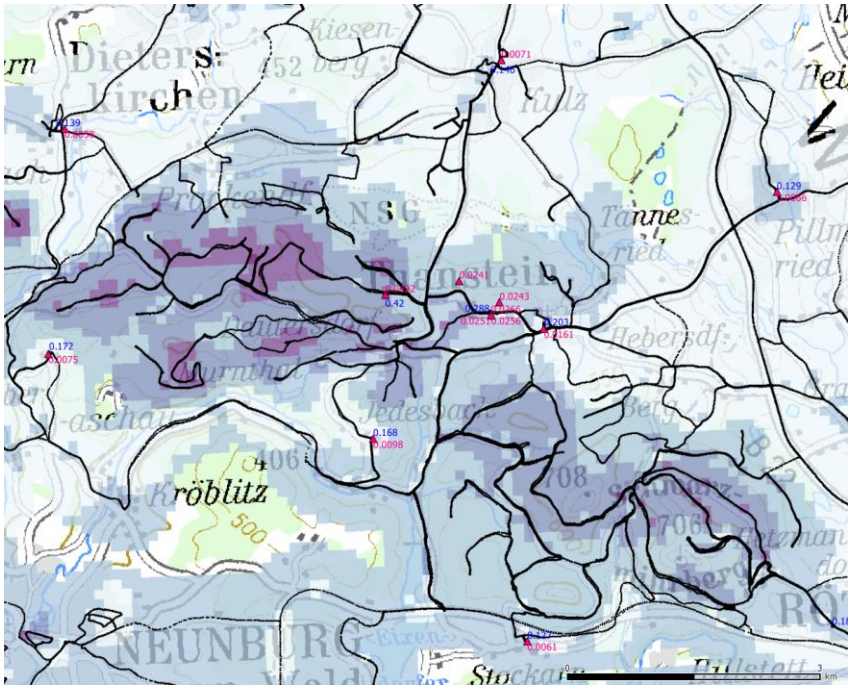
Contamination in urban areas

About 30 km per unit and hour

Dose rate ~ 0.1 µSv/h

↓

Activity ~ 20 kBq/m² Cs-137 + Cs-134

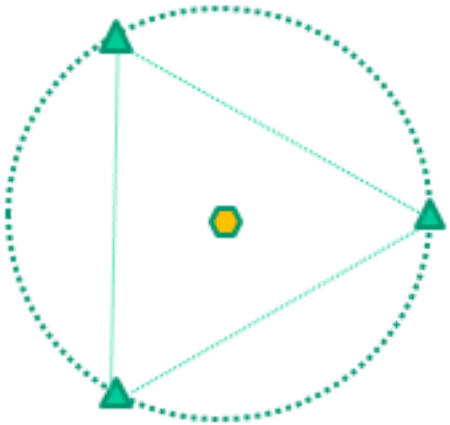


Measurement exercise June 2014:
Vehicle based dose rate +
in situ gamma spectrometry data

In combination with method M1 applied for:
Urban areas near release or with small scaled contamination patterns (wet deposition)

Expected dose rate range and nuclides
Simulated dose rate using RODOS and German release scenarios

Release Bq	I-131	Cs-137	after … h
FKA	$3\ 10^{17}$	$3\ 10^{16}$	21
FKF	$2\ 10^{16}$	$3\ 10^{14}$	57
FKI, FKH	$3\ 10^{15}$	$3\ 10^{11}$	57



Maximal dose rate [mSv/h]					
Weather	Source term	Wind direction			
		106 m	285 m	1010 m	2040 m
1 m/s B	FKA	657	327	71	26
	FKF	5,9	3,9	1,2	0,57
	FKI	0,62	0,59	0,39	0,30
5 m/s C	FKA	3,0	46	29	12
	FKF	0,18	2,90	2,0	0,77
	FKI	0,01	0,12	0,69	0,42

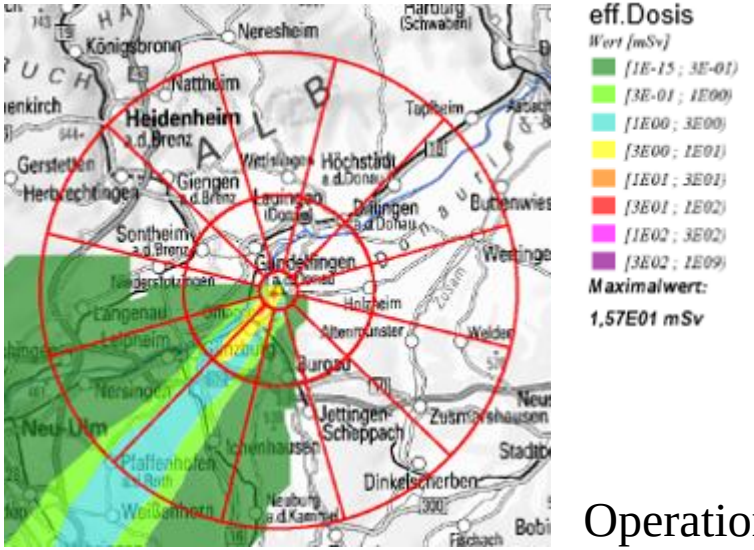
3 detectors in the vicinity of NPP to get early spectrometric information

see R&D project DETECT

Bundesamt für Strahlenschutz

EP+R exercise Core-2014

RODOS: Effective dose (7d)
Realistic weather conditions
Filtered venting scenario



Zones: 2, 10, 25 km

Countermeasures

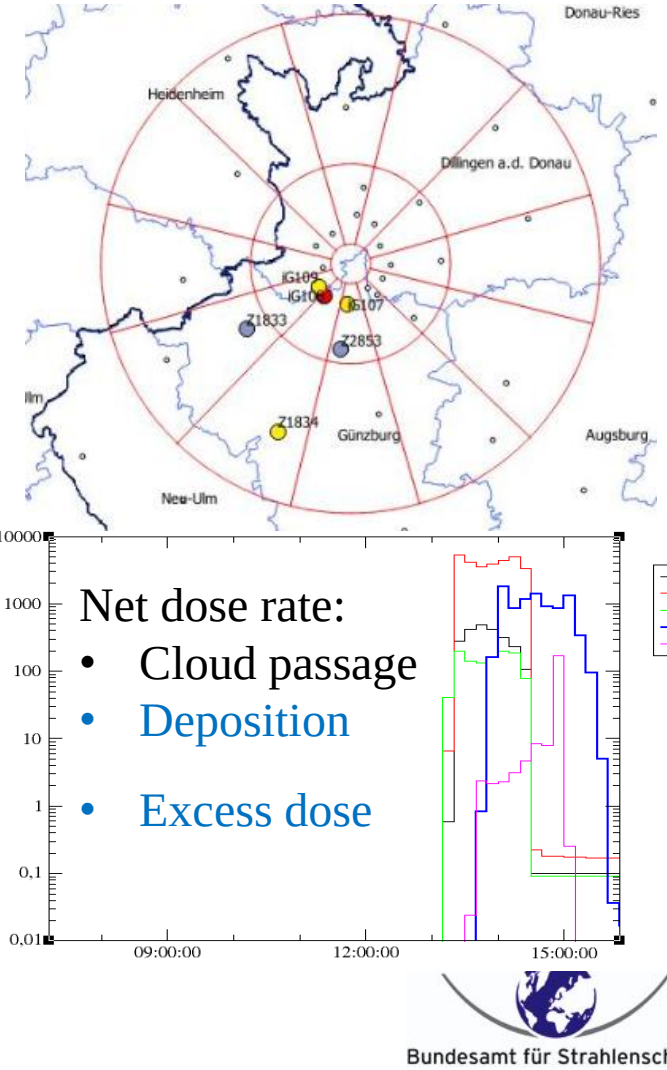
- Evacuation: 5 km zone
- Shielding
- Pre-distribution of stable Iodine

Operational intervention levels (OIL) for dose rate:

1000 µSv/h

100 µSv/h

Simulated net dose rate

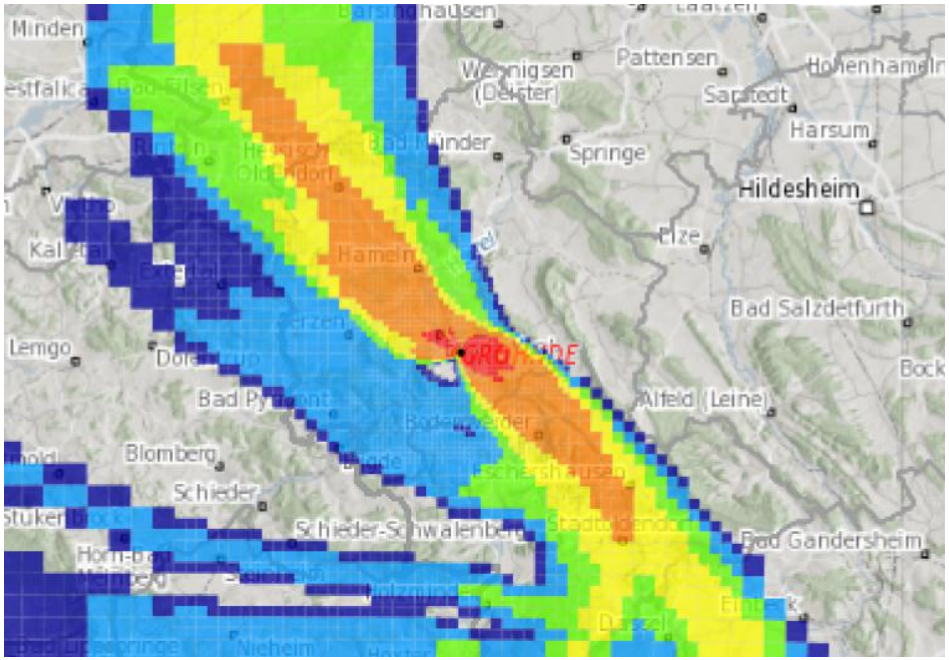


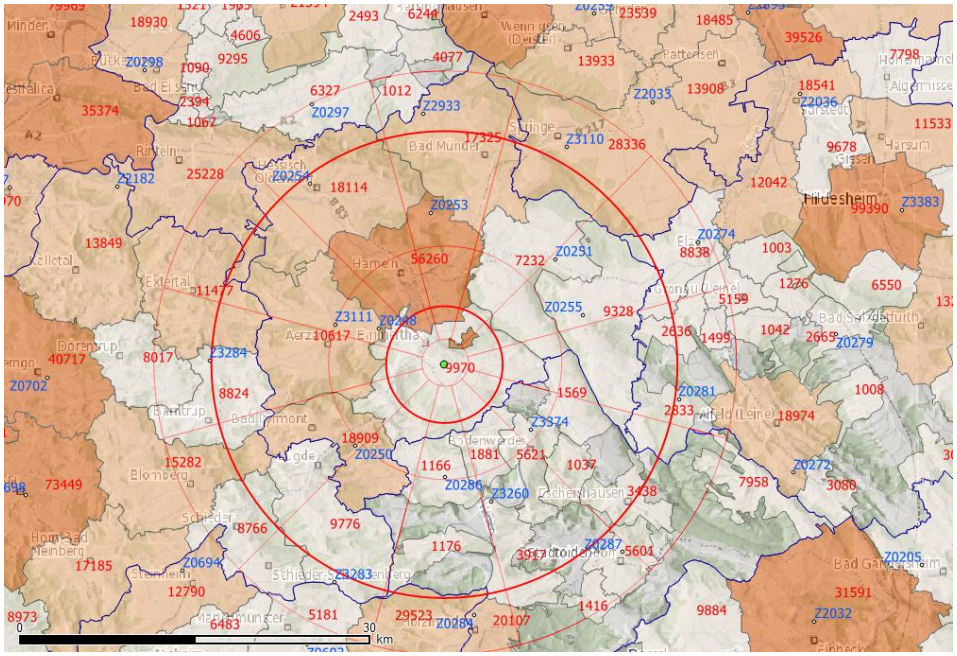
Bundesamt für Strahlenschutz

EP+R exercise

RODOS: Effective dose mSv
NNP Grohnde, real weather from
Severe core melting accident
2015-04-08 08:00 FKA scenario

Locations of monitoring station (blue)
Central and middle zone (5 + 20 km)
Inhabitants of towns (red)



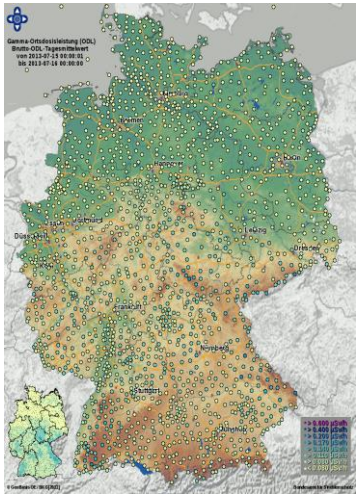


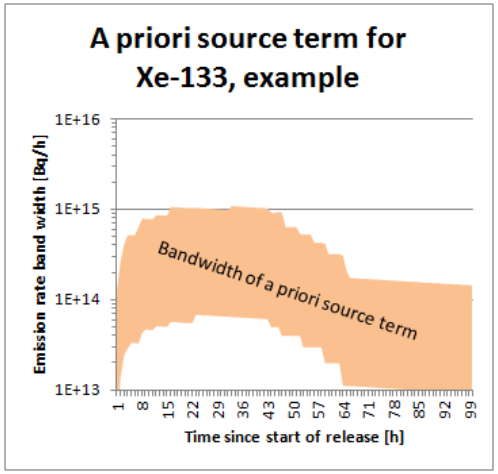
Additional: FKI and FKF scenario

Source term reconstruction method
Data assimilation & inverse Modelling
R+D project: Principle of the method

Input Data

- **Weather data** in the environment of the nuclear facility (past for inverse calculation and future for prognosis).
- **„A priori“ source term**: Rough estimation of a source term with bandwidth, using information about the plant and the incident, if available (so called „a priori“ data).
- **Time dependent measurements** of dose rates or nuclide specific activity concentrations in the atmosphere or on ground in the environment of the radioactivity emitting nuclear facility.





Bayes method

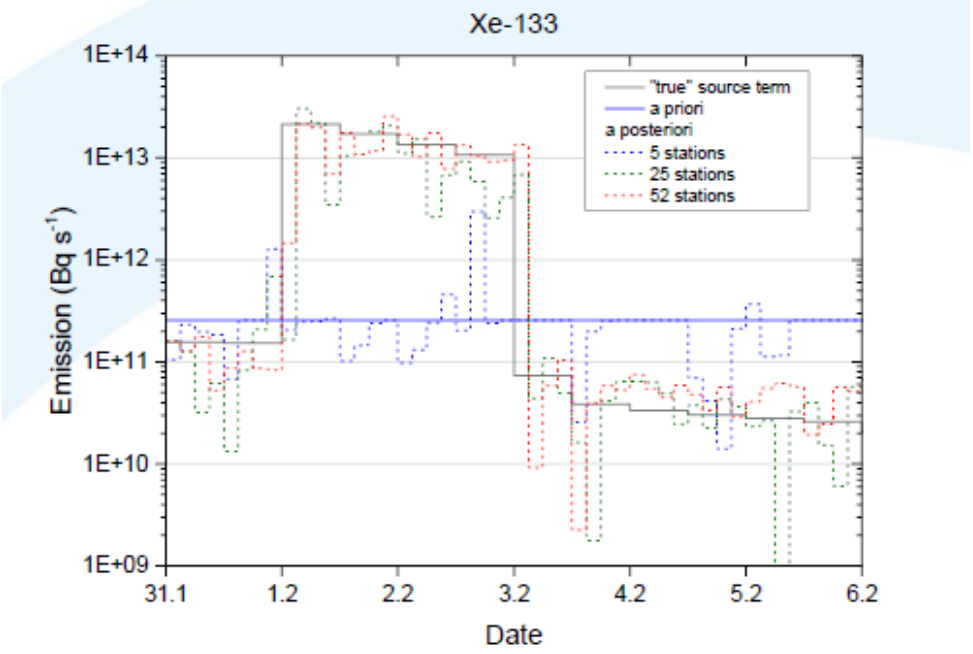
Output:

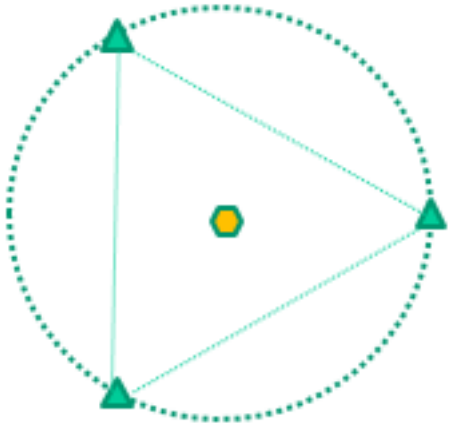
“A posteriori“ source term

Source term reconstruction method
Data assimilation & inverse Modelling
R+D project: Principle of the method

Status:

- Module for calculating the „a priori“ source term
- Method for radionuclide concentrations (dose rate)
- Module for analyzing the „a posteriori“ source term
- Sensitivity studies by use of simulated source term





Spectrometric probes
in the vicinity of NPP
to get early information

Spectrometric probes: General requirements

Sensitivity (LLD)
1kBq/m²: dose rate: ~1nSv/h above background

→ LaBr3

Energy resolution: Fukushima like spectra:
- energy resolution < 2.0 % @ Cs-137

→ CdZnTe

Maximum dose rate:
From RODOS simulations
- ADER in the vicinity of NPP up to 1000 mSv/h

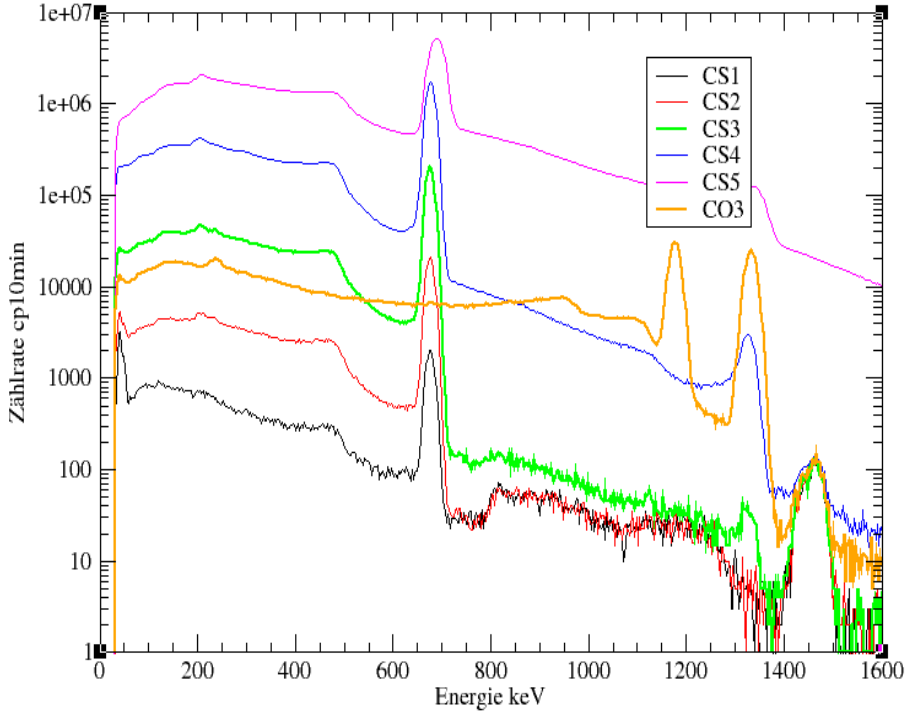
→ 2 CdZnTe detectors

Maximum dose rate range of microSPEC (CdZnTe)

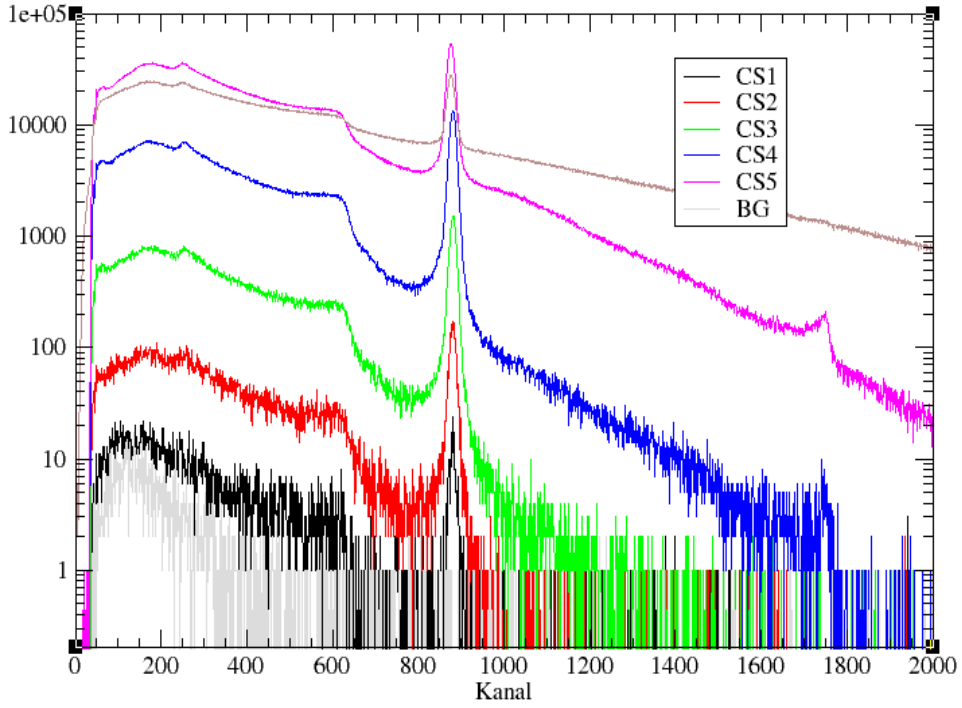
Volume mm3	Max ADER mSv/h	Peak/ Compton
1500	**4**	**8.3**
1000	8	7.5
500	12	6.6
60	100	5.3
14	400	4.4
5	**900**	**4.3**
1	3500	2.6

Calibration experiment SSDL Neuherberg

LaBr3 probe (Saphymo)



CdZnTe probe (Prototype BfS)



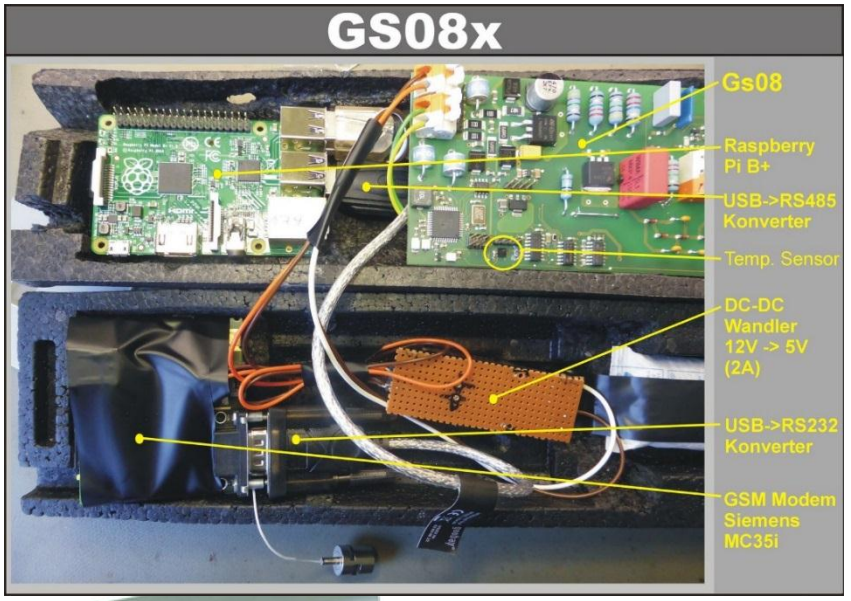
Cs-137: 0,1 to 1000 µSv/h

	µSv/h
CS1	0,119
CS2	1,293
CS3	12,27
CS4	121,81
CS5	1098

Introduction of spectrometric ADER detectors at BfS

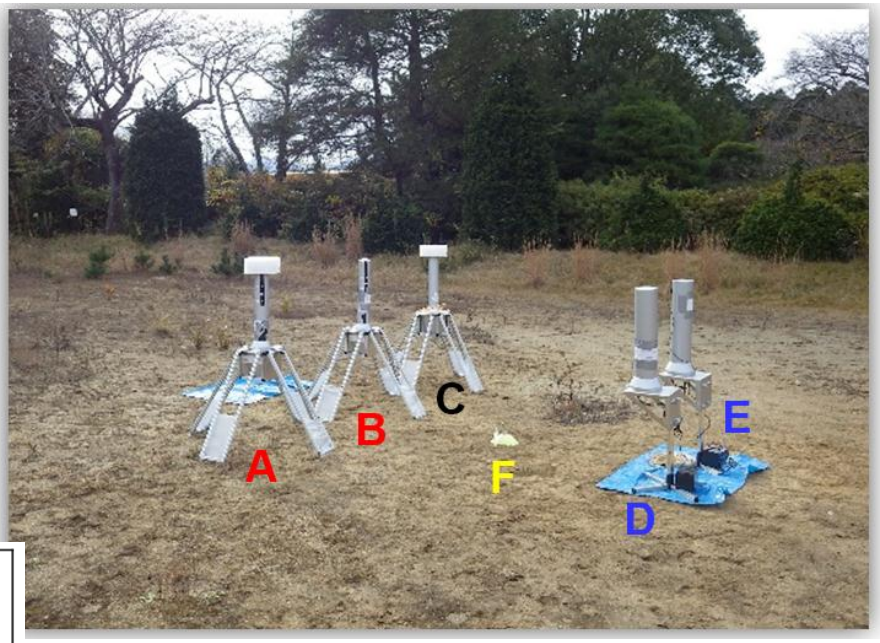
LaBr3 detector 4 km from
French NPP Fessenheim

3/2015
LaBr3 System
Field test with
up to 6 CdZnTe protoypes



Comparison of different spectroscopy ADER probes during RANET-2014 Workshop in Fukushima

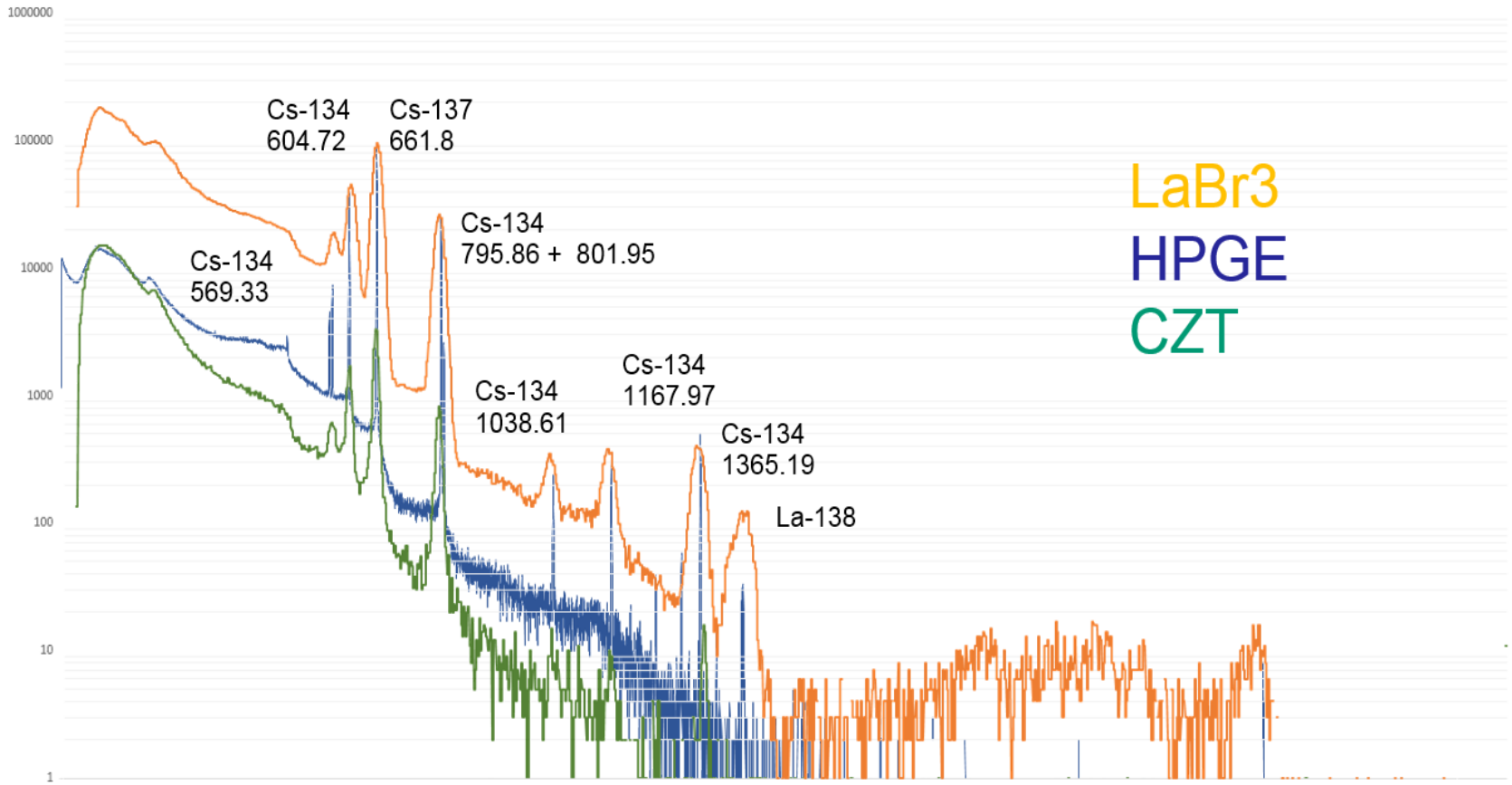
Stationary Probes at MPJP-KES-01	ODL [µSv/h]
A=GS08x-2	15,2
B=GS08x-1	14,9
C=GS08	15,0
D=SpectroTracer 2	14,8
E=SpectroTracer 1	14,2



Stationary Probes at MPJP-KES-01	Cs-134 [Bq/m2] (B=0)	Cs-137 [Bq/m2] (B=0)	Verhältnis
F=Insitu (HPGE)	0,66E+06	2,06E+06	3,12
D=SpectroTracer 2 ($LaBr_3$)	0,65E+06	2,00E+06	3,08
E=SpectroTracer 1 ($LaBr_3$)	0,71E+06	2,22E+06	3,13

Comparison between insitu (HPGe) and spectroscopy ADER (LaBr3) probes

RANET-2014 Workshop Fukushima



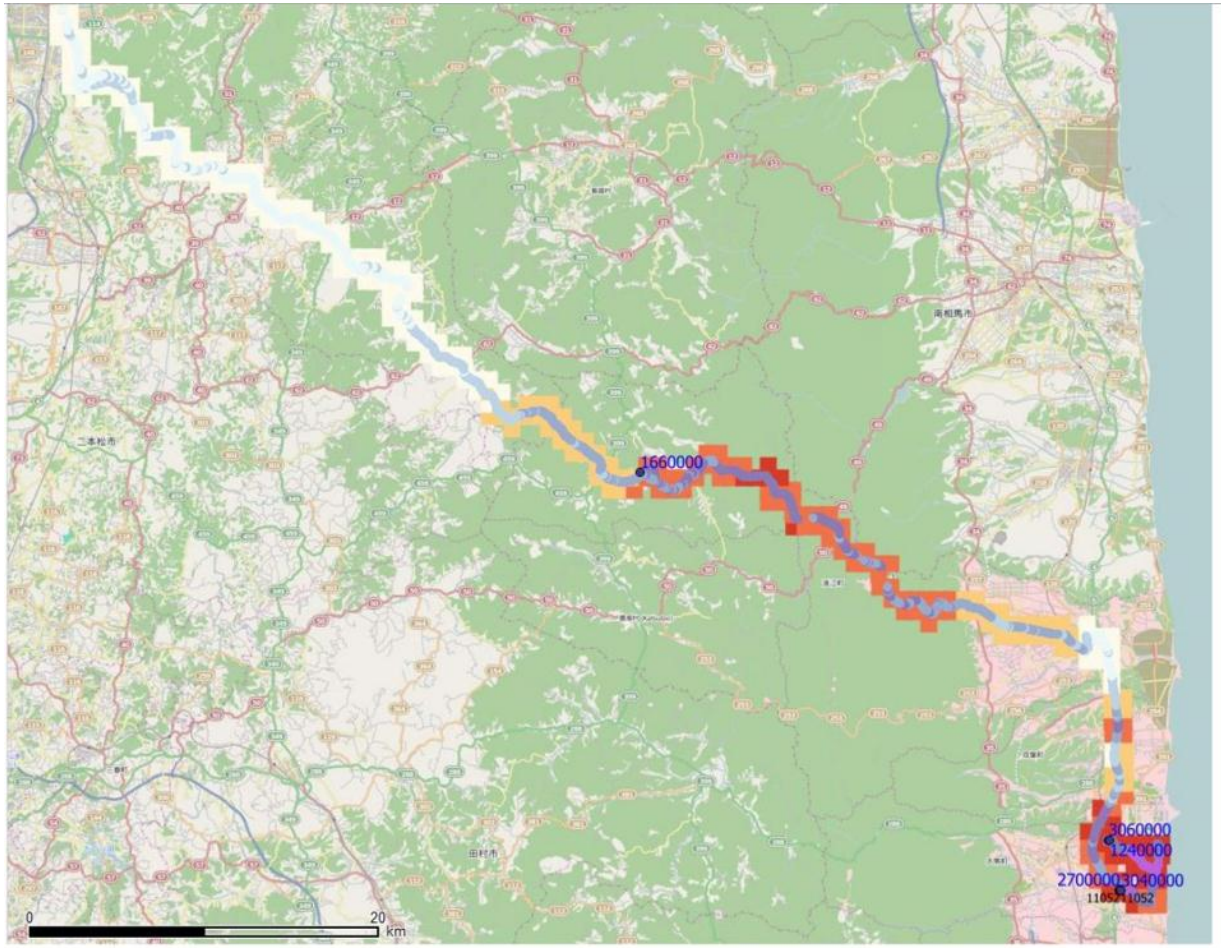
Ground Contamination Tool
RANET-2014 Workshop Fukushima

Ground Contamination Tool applied for Cs-137 and Cs-137 in the Fukushima Daichi area

Location	Cs-134 [Bq/m2] B=1	Cs-137 [Bq/m2] B=1	ADER [µSv/h]	ratio	CS137/ODL	CS134/ODL
2014-11-18						
MPJP-KES-05	9,74E+05	3,04E+06	12,6	3,12	241270	77302
MPJP-OPP-XX	9,86E+05	3,06E+06	15,5	3,10	197419	63613
MPJP-OPP-01	4,01E+05	1,24E+06	5,9	3,09	210169	67966
2014-11-20						
MPJP-OJuHS-01	7,14E+05	2,20E+06	10,8	3,08	203704	66111
MPJP-OJuHS-03	7,38E+05	2,30E+06	10,8	3,12	212963	68333
MPJP-OJuHS-05	5,17E+05	1,60E+06	8,79	3,09	182025	58817
MPJP-KES-01	1,17E+06	3,67E+06	17,5	3,14	209714	66857
MPJP-KES-02	1,14E+06	4,41E+06	20,9	3,87	211005	54545
MPJP-KES-04	1,34E+06	4,23E+06	18,8	3,16	225000	71277
			Mean	**3,2**	**210363**	**66091**
			Stand.Dev.	0,2	16553	6653
			relative Diff.	0,07	0,08	0,10

Ground Contamination Tool
RANET-2014 Workshop Fukushima

Ratio Cs-137/ADER = 210363 Bq/m² / μSv/h (relaxation length 1cm)



Fukushima Prefecture
17 – 21 November 2014

ADER in 10^{-6} Sv/h

- <0.3
- 0.3 - 1
- 1 - 3
- 3 - 10
- 10 - 30
- > 30

Cs-137 Ground contamination in 1000 Bq/m²

- < 100
- 100 - 300
- 300 -1000
- 1000 - 3000
- > 3000

Cs-137 Ground contamination data from HPGe in Bq/m²

Measured data from DE-FAT-1
Car-borne monitoring
between 2014-11-18T00:00:00Z
and 2014-11-18T07:00:00Z

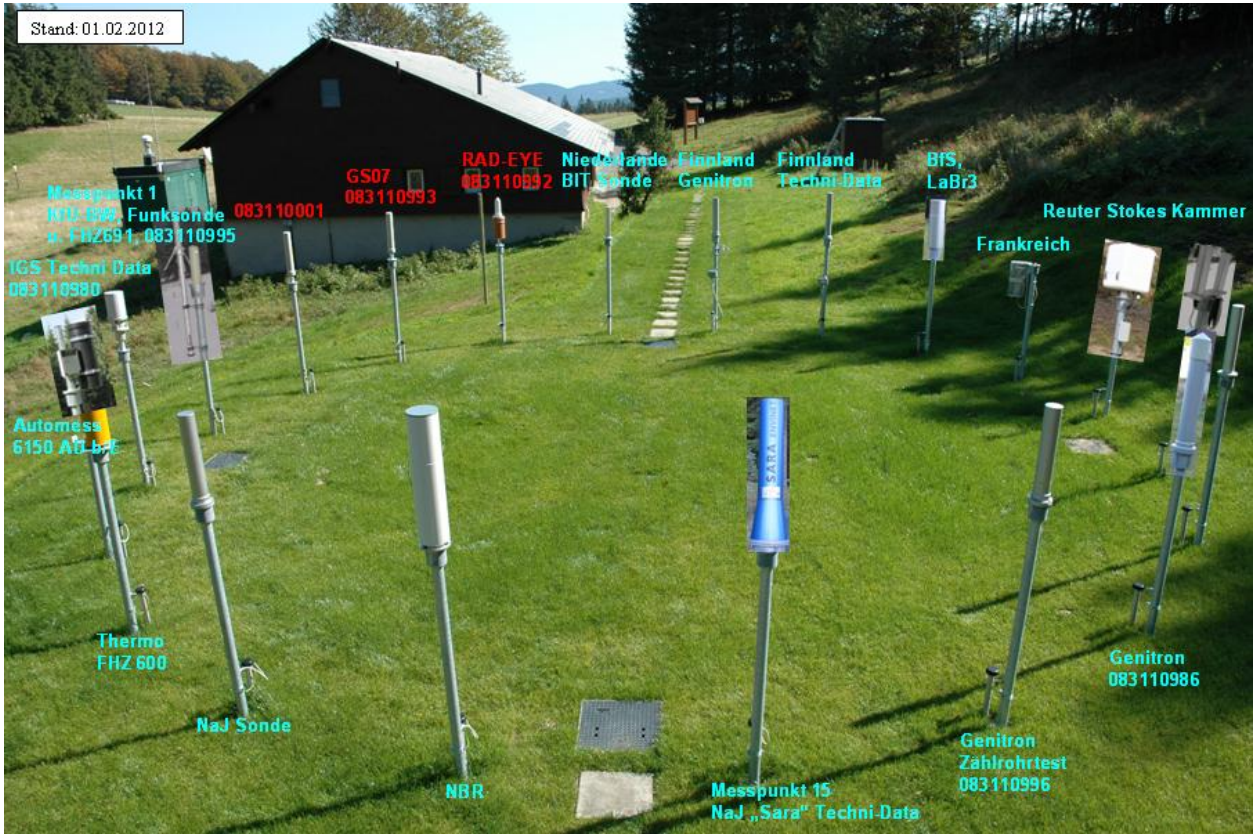
by DE-EBS-1

Bundesamt für Strahlenschutz

Summary and outlook

- Combination of dose rate data and spectrometric information is very helpful
  - For dose reconstruction methods in the early phase
  - For source term reconstruction methods
- Combination data from stationary systems and from mobile teams is needed
- Spectrometric dose rate probes with energy resolution of 2 % have the potential to improve the needs of emergency preparedness
- BfS is able to share experience with spectrometric dose rate probes

Thank you!



INTERCAL
Long term inter-comparison experiment

Mount Schauinsland near Freiburg

Questions? mbleher@bfs.de