Linking Radiometric Mapping and Remediation: UK and European Experience

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Presentation at International Symposium on Remediation of Site Contamination Caused by the Fukushima accident,
Paruse Iizaka, Fukushima City, 19th May 2012
Society for Remediation of Radioactive Contamination in the Environment

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Linking Radiometric Mapping and Remediation : Outline

- Introduction to radiometrics
- UK & EU experience : nuclear accidents, and site specific clean-up
- EU research outputs in radiometrics and remediation
- Some exploratory data from Japan
- How to link remediation and radiometrics?

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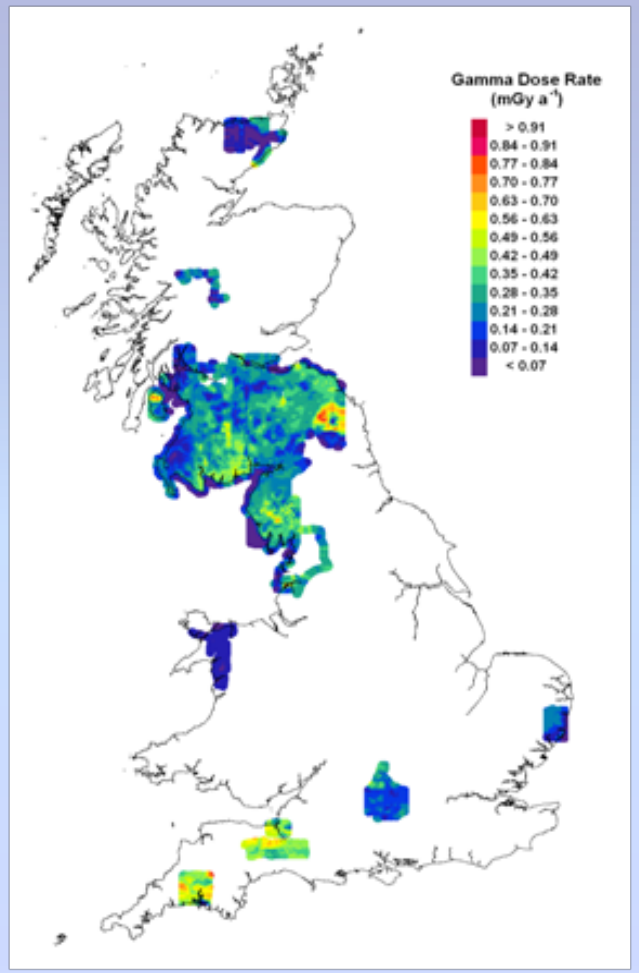
Airborne & Mobile Gamma Spectrometry for mapping radioactivity

- AGS is capable of rapid radiometric mapping of large areas
  - Sensitive gamma-ray detector mounted on aircraft
  - High volume NaI (or combined NaI/Ge system)
  - Low altitude survey flights (30-100m)
  - Large survey areas, high sampling density
  - ~1000's of observations per hour
  - 10^4-10^5 m^2 fields of view

- Mobile Gamma spectrometry
  - Geocoded gamma spectrometry operated from backpacks, small vehicle, UAV's, boats, hovercraft etc
  - More confined field of view – suited to detailed surveys of eg urban areas
  - Data capture rate 10^2 -10^3 per hour
  - 10-10^2 m^2 fields of view



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October 1957 Windscale Reactor fire

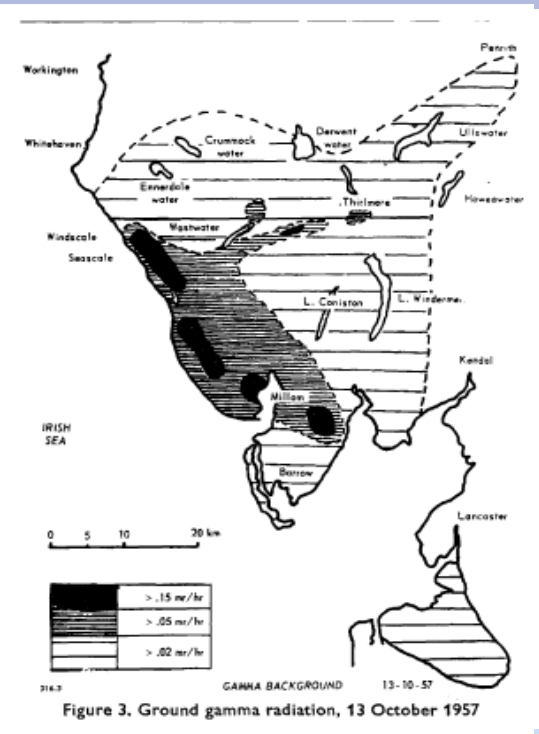


Figure 3. Ground gamma radiation, 13 October 1957

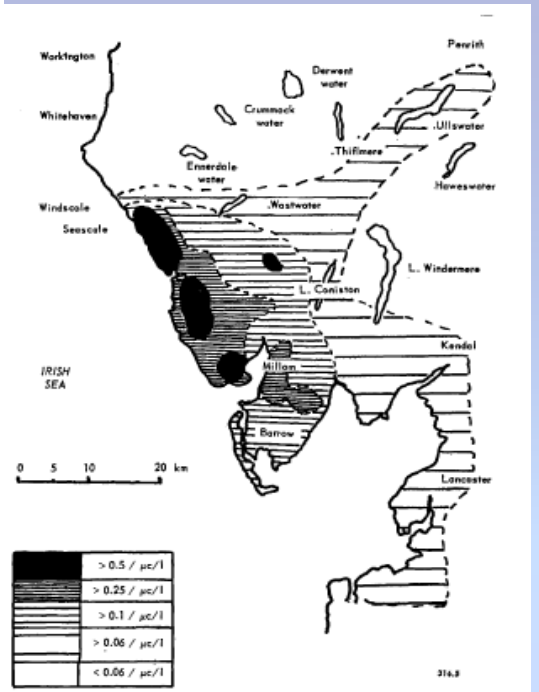
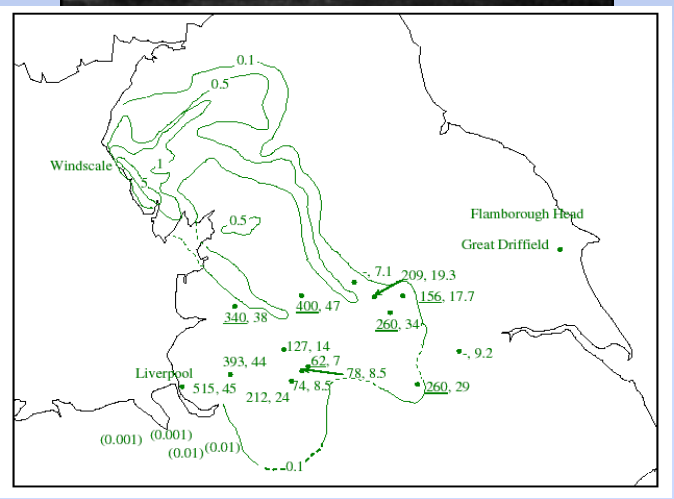


Figure 5. I^{131} in milk, 13 October 1957



^{131}I deposition in NW England and parts of Wales (after Chamberlain, 1959) and measurements of air concentration (from Stewart et al., 1961). From: Garland & Wakeford, *Atmospheric Environment* 41 (2007), 3904-3920

Dunster H J, Howells H and Templeton W L 1958 District surveys following the Windscale incident, October 1957 ***Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy (Geneva, 1 September–13 September 1958). Volume 18: Waste Treatment and Environmental Aspects of Atomic Energy*** **(Geneva: United Nations) pp 296–308**

Reprinted: J. Radiol. Prot. 27 (2007) 217–230

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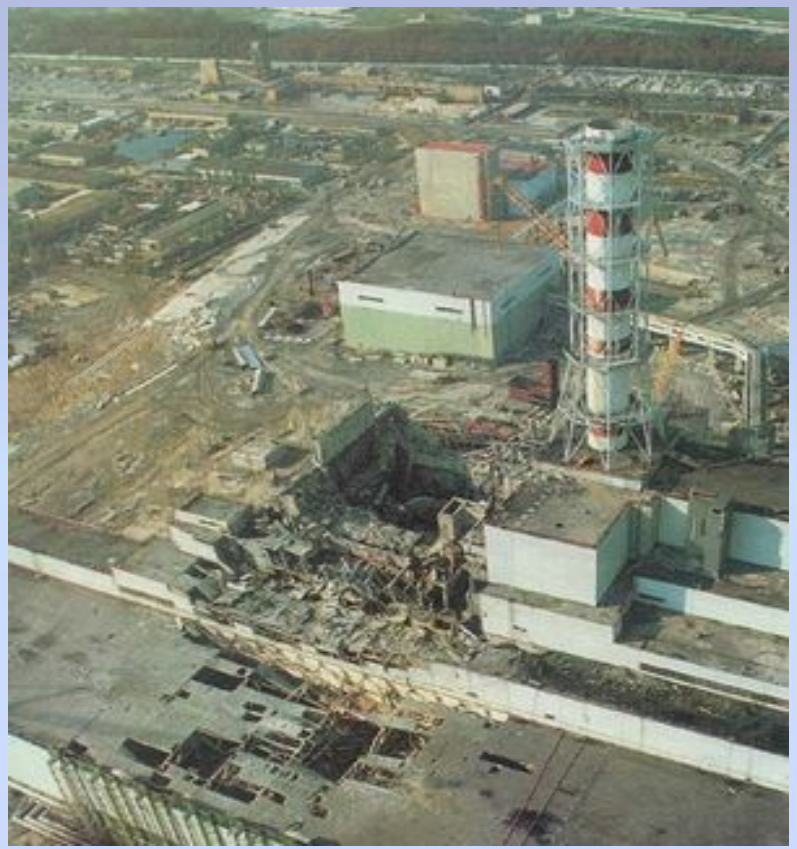
Chernobyl accident
28th April 1986



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Chernobyl 28th April 1986

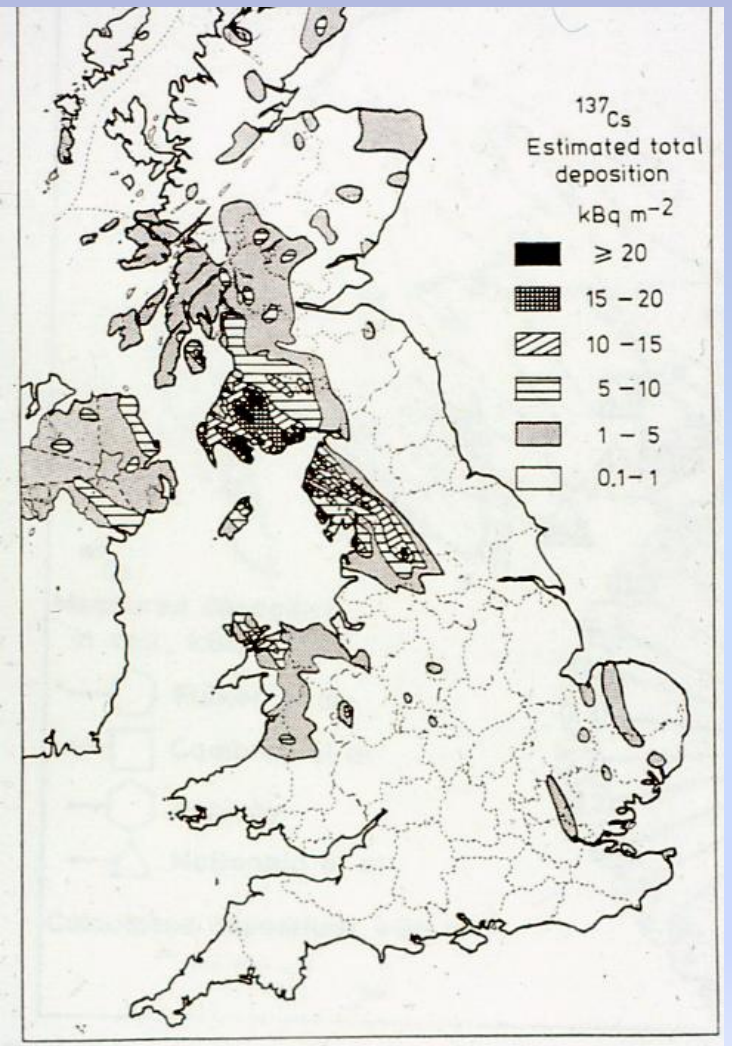
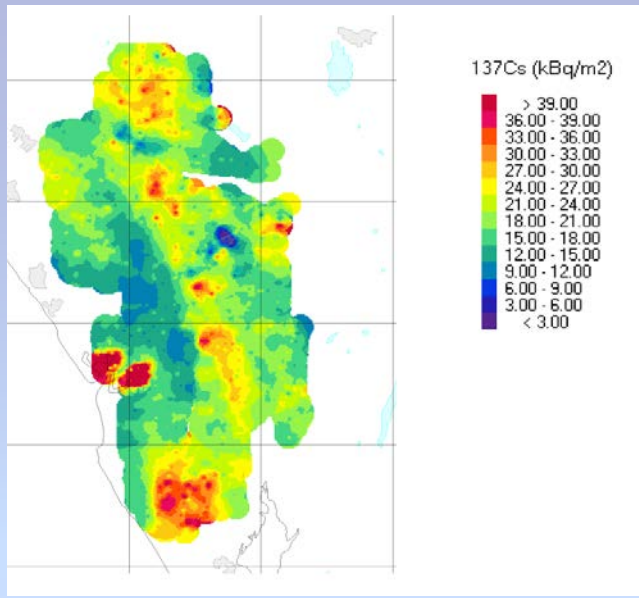
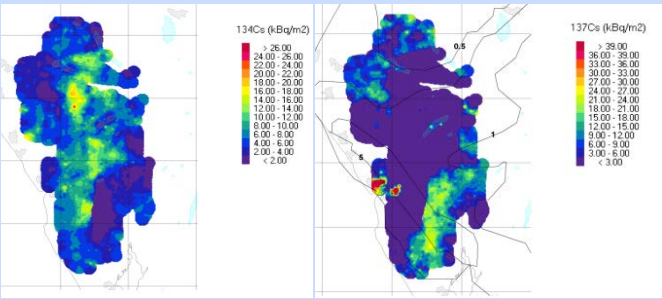


Fig. 2 Estimated total deposition of ^{137}Cs (kBq m^{-2}) over the United Kingdom due to Chernobyl releases, calculated from a washout factor of $6.5\ 10^{5}$, the rainfall data and air concentrations.

- 28th April Chernobyl
- UK fallout arrives early May
- Initial deposition estimates based on limited ground sampling and meteorological modelling
- Early SURRC surveys – SW Scotland, Western Isles, West Cumbria, North Wales
- Agricultural effects
- External radiation
- Whole Body monitoring





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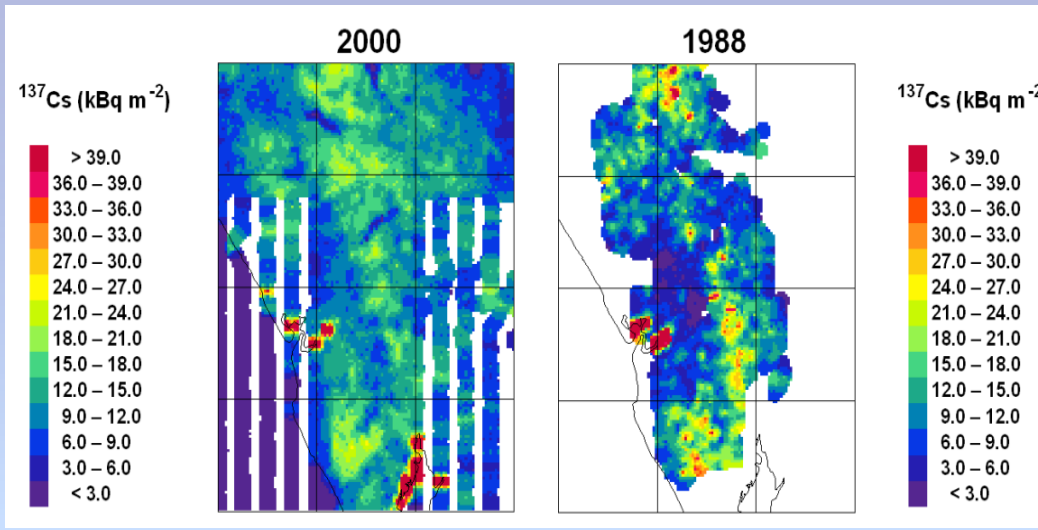
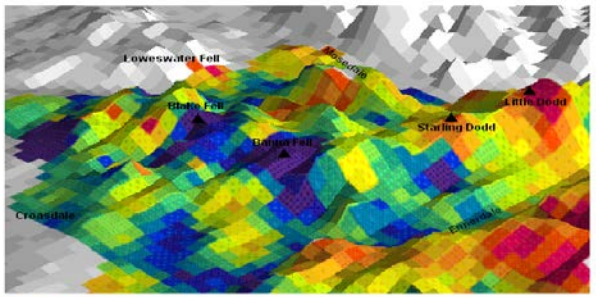
West Cumbria – Changes Between 1988 and 2000 - Livestock restriction zone

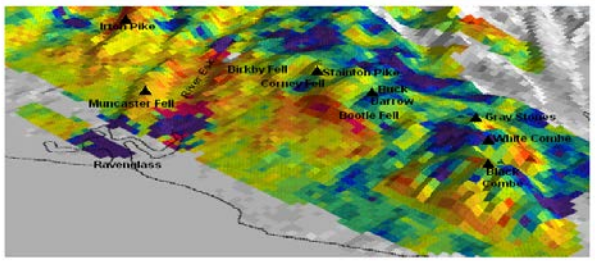
	1988	1988 decay corrected	June 2000
Total Area (TBq)	9.35±0.02	7.01±0.02	7.22±0.02
Black Combe (GBq)	496±3	372±3	319±1
Corney Fell (GBq)	704±3	528±3	469±2
Loweswater Fell (GBq)	636±3	477±3	453±1
Lowlands (GBq)	851±16	638±12	732±8

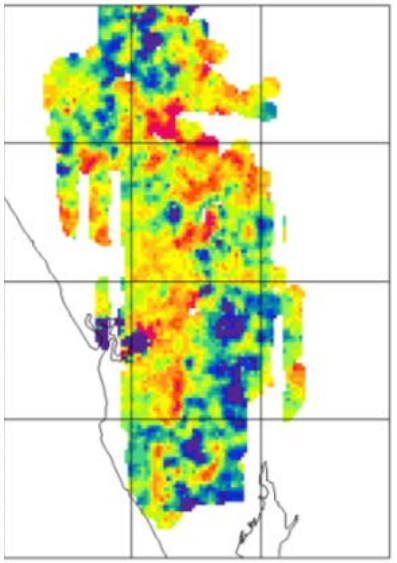


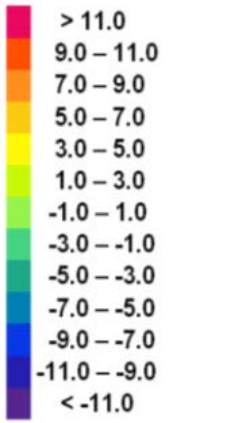
Total activity in area agrees to within 3%

Movement of activity from high to lower lying ground due to hydrological and colluvial processes









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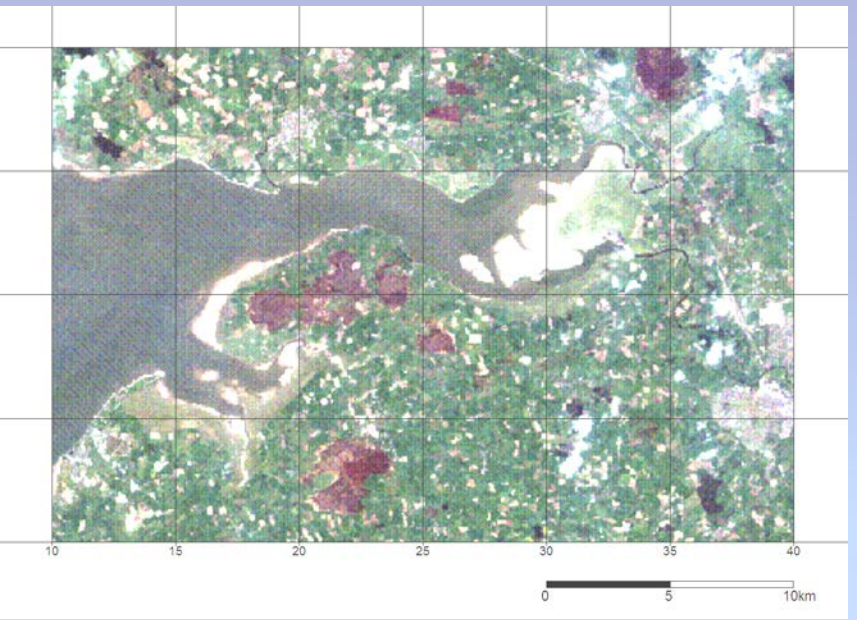
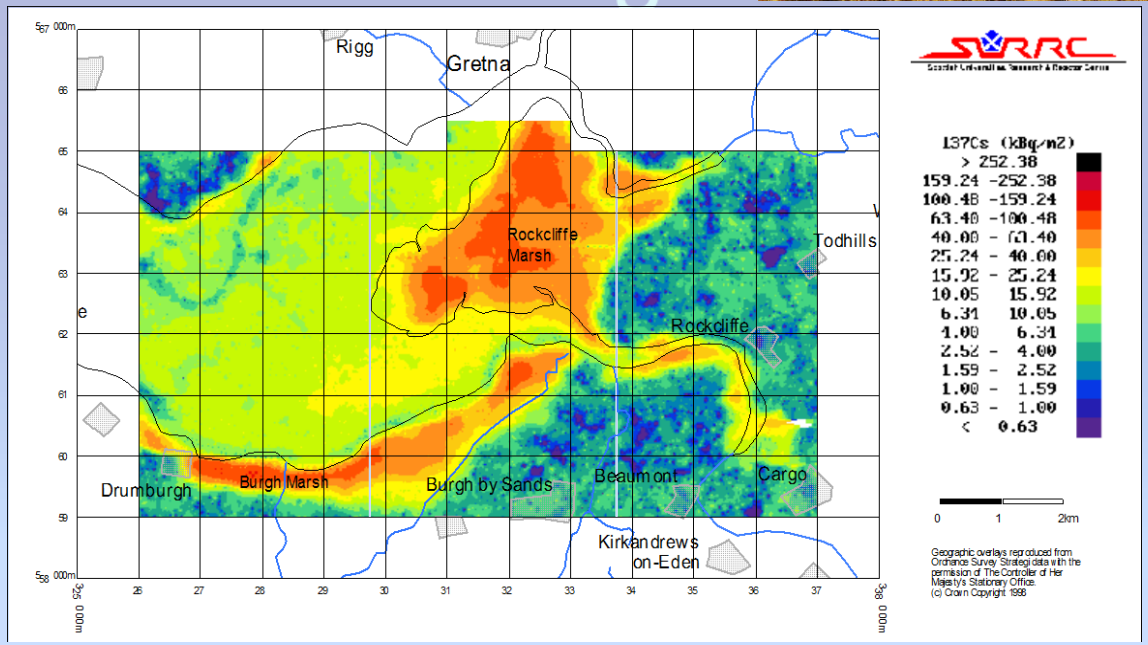
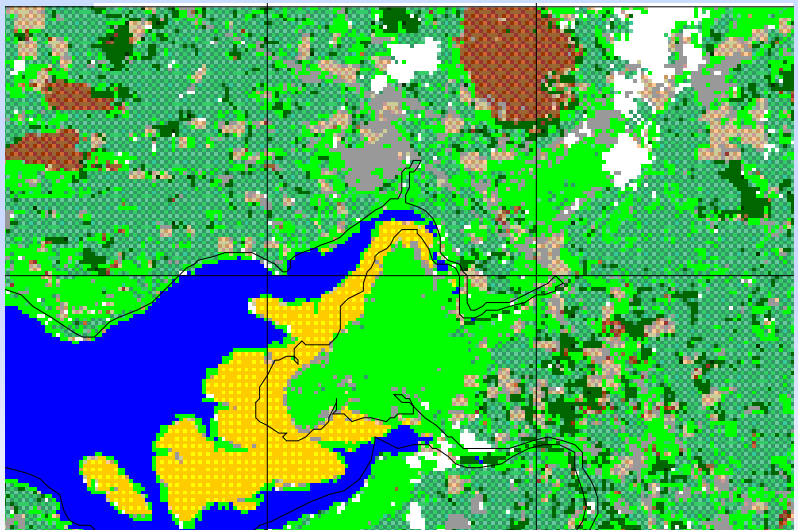
Inner Solway ^{137}Cs Distribution and the landcover setting







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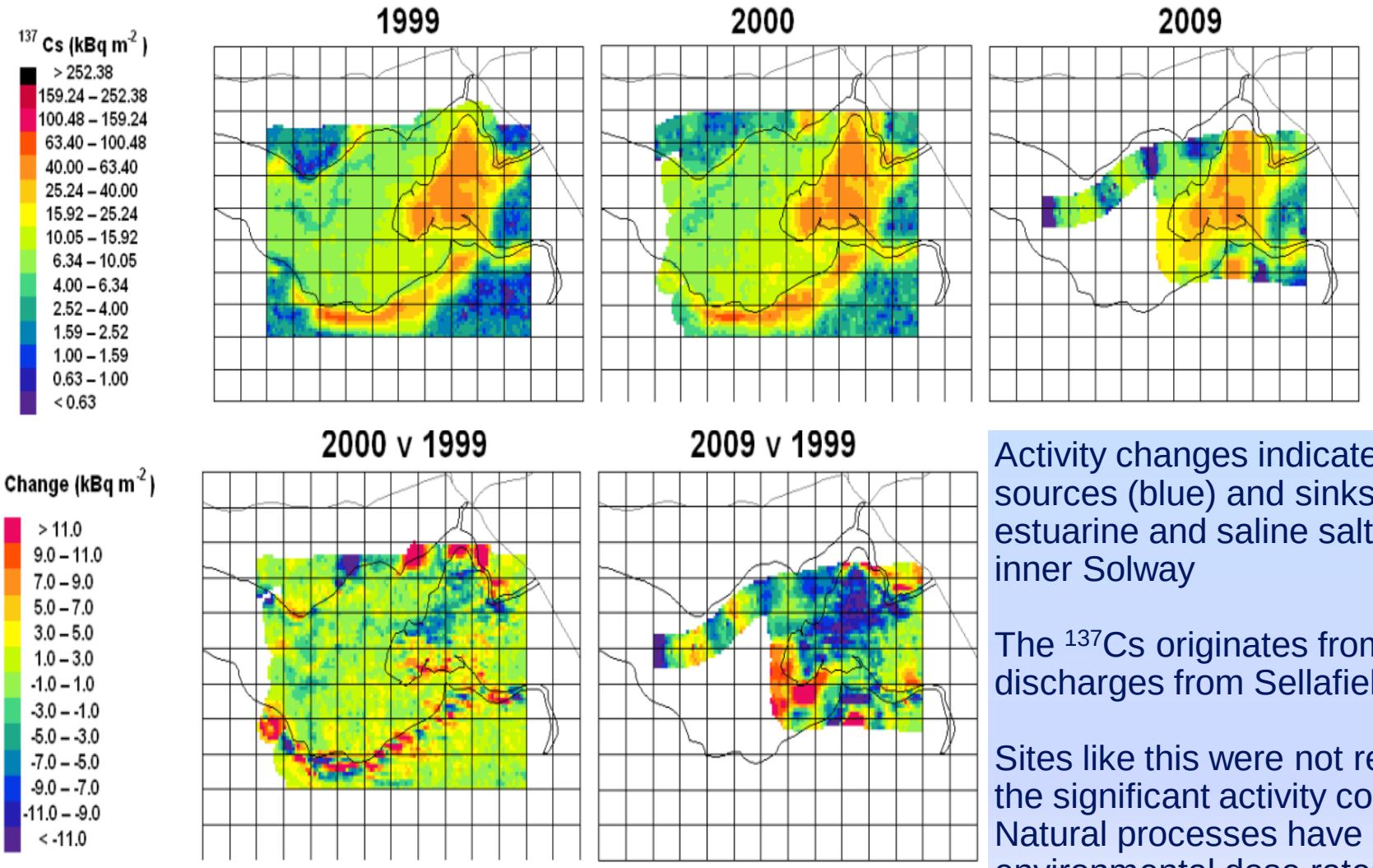
AGS : changes in the Solway ^{137}Cs – due to coastal sediment movements



Activity changes indicate sedimentary sources (blue) and sinks (red) in the estuarine and saline salt marshes of the inner Solway

The ^{137}Cs originates from past marine discharges from Sellafield reprocessing

Sites like this were not remediated despite the significant activity concentrations. Natural processes have however reduced environmental dose rates

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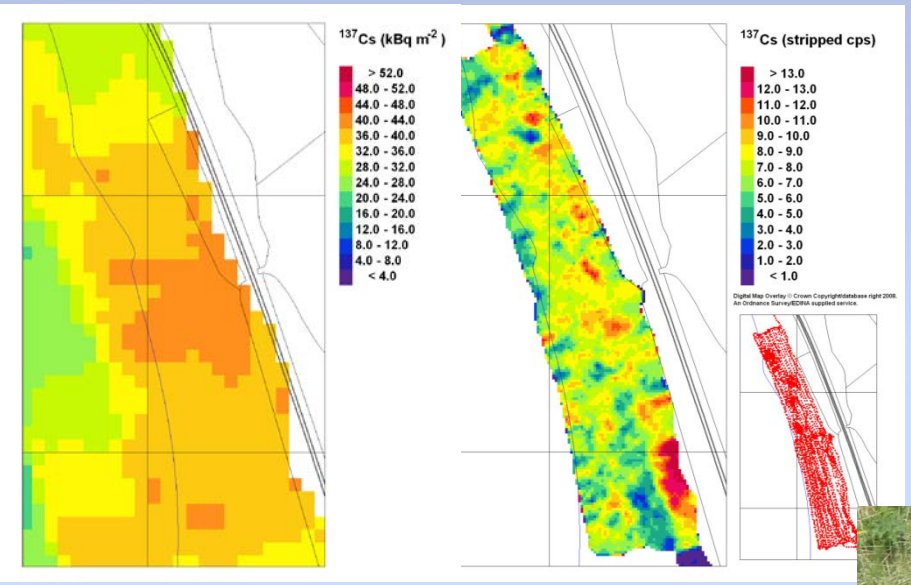
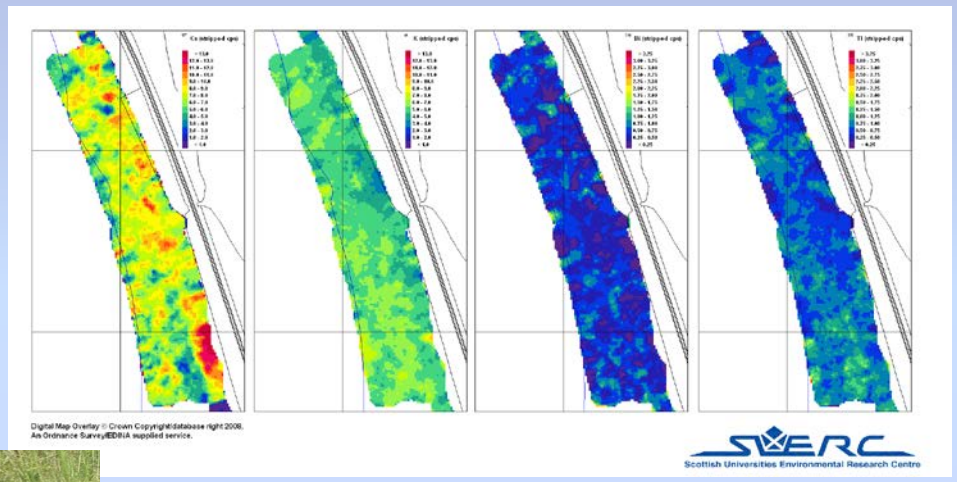
Backpack System
For detailed mapping at ground level

3x3” NaI(Tl), digiBASE™, netbook, EGNOS enabled GPS

March 2000 AGS **June 2010 Backpack**



^{137}Cs **^{40}K** **^{214}Bi** **^{208}Tl**



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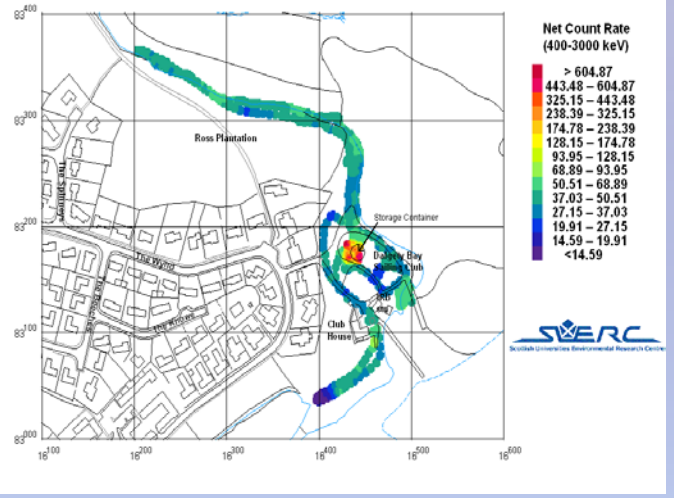
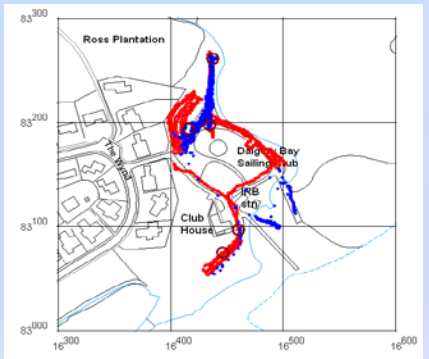
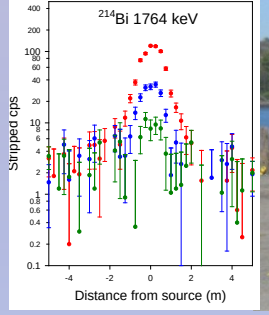
Dalgety Bay May 2012



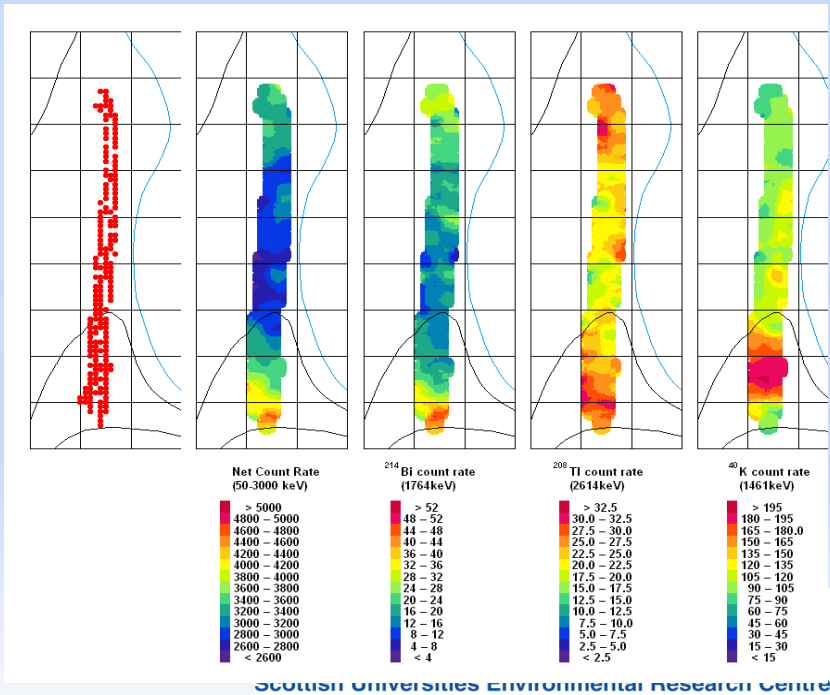
3”x3” “backpack” system on trolley – capable of locating near surface radium sources within 50 cm

- Radium contamination from former military airbase (1920-1959)
- Now high value housing
- Many 10-100 kBq sources recovered over last 20 years. Two 10-100 MBq finds this year
- Current investigations linked to remediation





Vehicular 2s measurements – capable of locating radium sources at lateral distances of 1m and burial depths of 30cm



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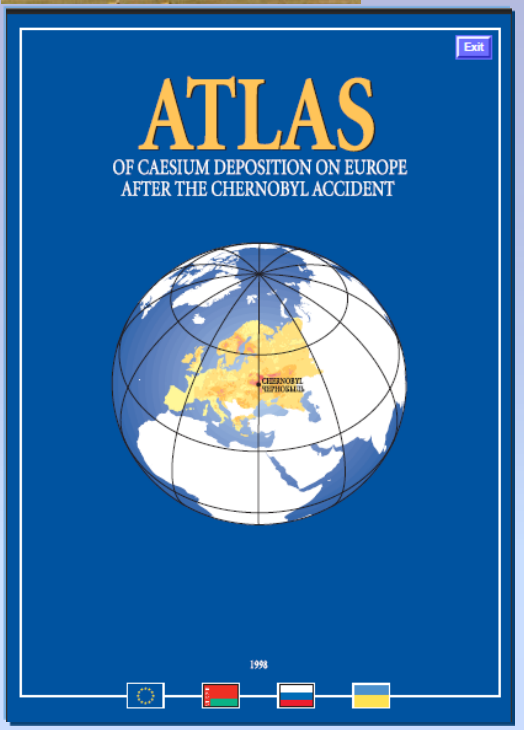
Atlas of Caesium Deposition on Europe after the Chernobyl accident



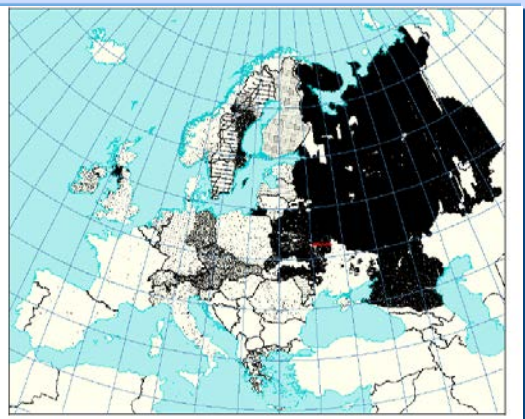
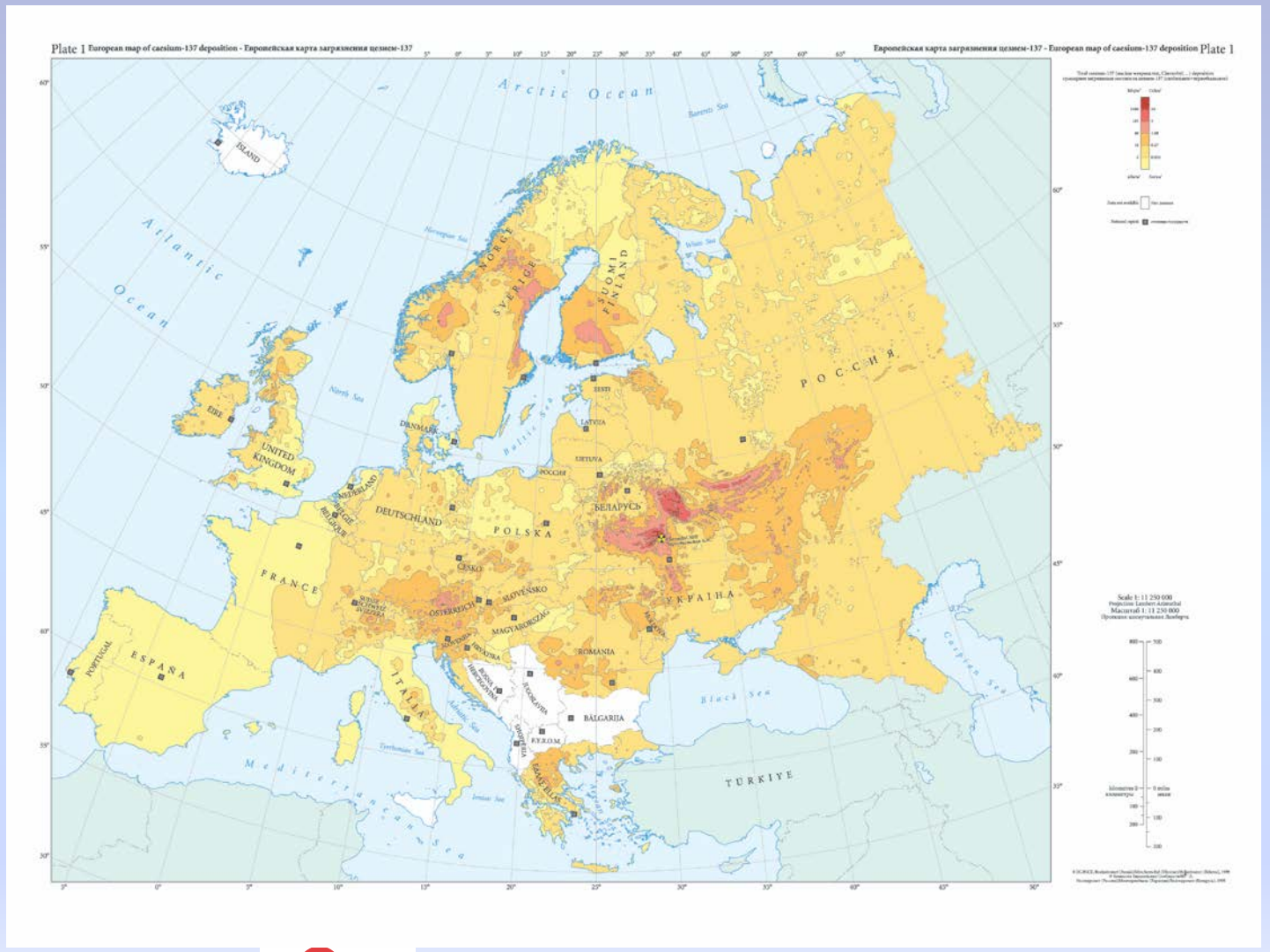


Fig. B.1: Spatial distribution of the caesium-137 deposition data used for the Atlas



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Chernobyl accident 28th April 1986

Table III.2: Areas in each country with caesium-137 deposition in excess of specified levels

Country	Local scale maps (In 1,000 km²)	
	> 40 kBq m^{-2} (>1.08 Ci km^{-2})	> 1480 kBq m^{-2} (> 40 Ci km^{-2})
Austria	11	
Belarus	46	2.6
Czech Republic	0.21	
Estonia	< 0.01	
Finland	19	
Germany	0.32	
Greece	1.2	
Italy (1)	1.3	
Norway	7.1	
Poland	0.52	
Rumania	1.2	
Russia (European part)	60	0.46
Slovak Republic	0.02	
Slovenia	0.61	
Sweden	24	
Switzerland	0.73	
Ukraine	38	0.56
United Kingdom	0.16	

(1) *Excluding Sicily*

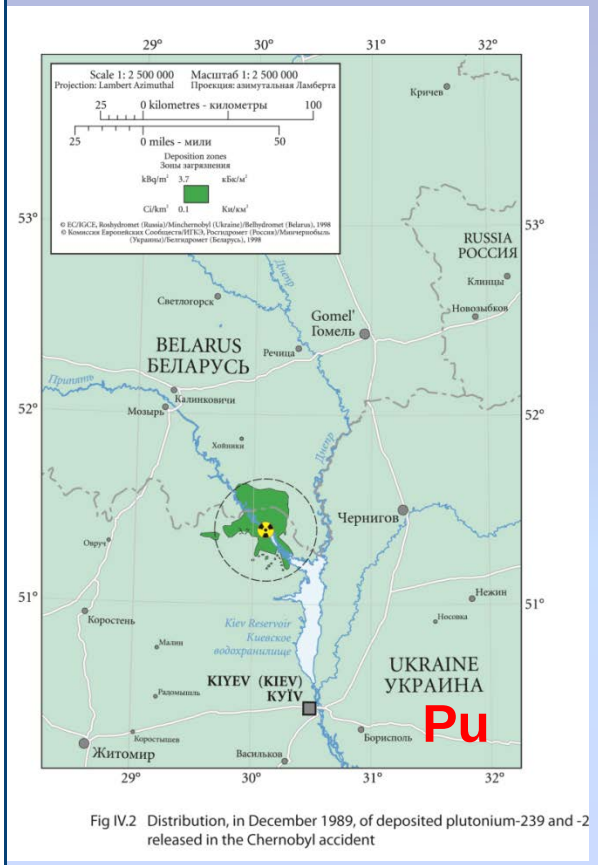

Fig IV.2 Distribution, in December 1989, of deposited plutonium-239 and -2 released in the Chernobyl accident

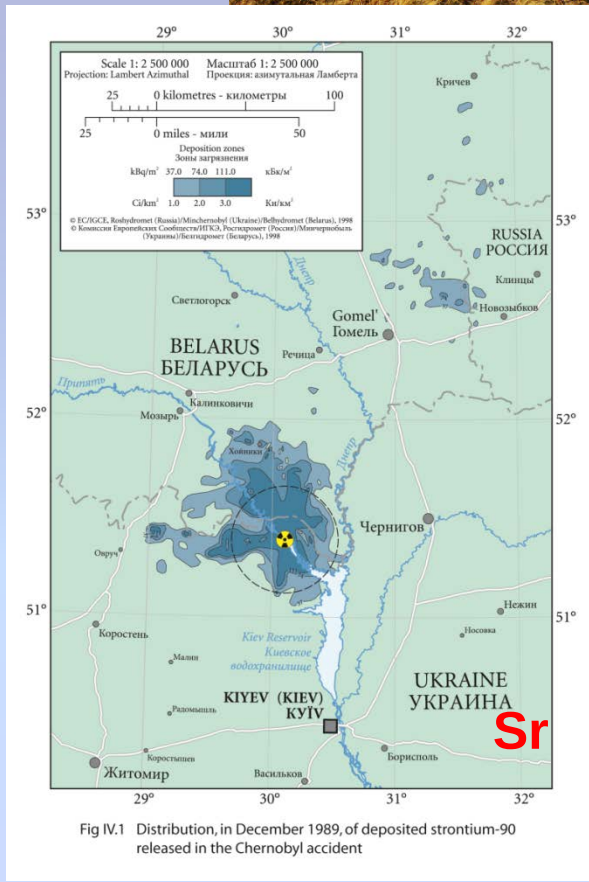

Fig IV.1 Distribution, in December 1989, of deposited strontium-90 released in the Chernobyl accident

Ukraine, Belarus and European Russia received ^{137}Cs deposition above 10^6 Bq m^{-2} with elevated depositon of Pu nuclides and ^{90}Sr. Northern europe and areas of elevated topography in many EU countries received radiocaesium deposition in the 10^4 -10^5 Bq m^{-2} region. Response was disparate.

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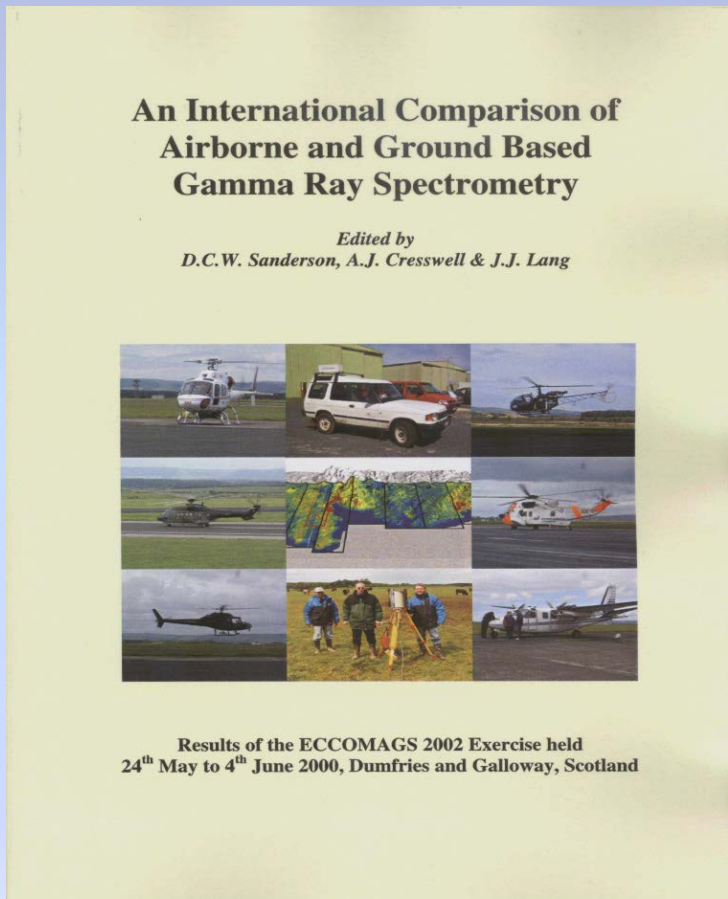
EU projects on emergency management and restoration of contaminated environments

- Framework V
  - SAMEN and MOSES thematic clusters
    - **EUR 21927 Publication "Off-site Nuclear Emergency Management and Restoration of Contaminated Environments" 2007, ISBN 92 79 04498-2**
    - Projects within cluster : ASTRID, DAONEM, DSSNET, ECCOMAGS, ENSEMBLE, EVATECH, FARMING, MODEM, RODOS Migration, SAGE, STERPS, STRATEGY
    - Pertinent to recovery phases
      - ECCOMAGS (International validation and comparabiliity of mobile gamma spectrometry)
      - FARMING (Food and Agriculture Restoration Management involving Networked groups)
      - SAGE (Strategies and Guidance for Establishing a Practical Radiation Protection Culture in Case of Long-term contamination after a Nuclear Accident) http://www.ec-sage.net/
      - STRATEGY (Sustainable Restoration and Long Term Management of Contaminated Rural, Urban and Industrial Ecosystems)



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EU projects on emergency management and restoration of contaminated environments

- Framework VI
  - **EURANOS: European approach to nuclear and radiological emergency management and rehabilitation strategies (2004-2009)**
  - http://www.euranos.fzk.de/
  - Outputs include manuals on management of Agricultural systems and inhabited areas following radiological incidents
- Framework VII
  - **NERIS : European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery**
  - http://www.eu-neris.net/, http://resy5.fzk.de/NERIS-TP/
  - **DETECT – project to optimise radiation monitoring methods and strategies for nuclear or radiological emergences in Europe**
  - http://detect.sckcen.be/

Generic Handbook for Assisting in the Management of Contaminated Inhabited Areas in Europe Following a Radiological Emergency

Part I: Decision-making Framework

V 1 . 0

Activity number: CAT1RTD04
Deliverable number: D12C1R04

EURANOS

EURANOS(CAT1)-TN(07)-02

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  - **DETECT – project to optimise radiation monitoring methods and strategies for nuclear or radiological emergences in Europe**
  - http://detect.sckcen.be/

Generic handbook for assisting in the management of contaminated food production systems in Europe following a radiological emergency

Version 2

Activity number: CAT1RTD03
Deliverablenumber: D7C1R3

EURANOS

European approach to nuclear and radiological emergency management and rehabilitation strategies

Nuclear Fission / Radiation Protection *Integrated Project FI6R-CT-2004-508843*

EURANOS(CAT1)-TN(09)-01

1

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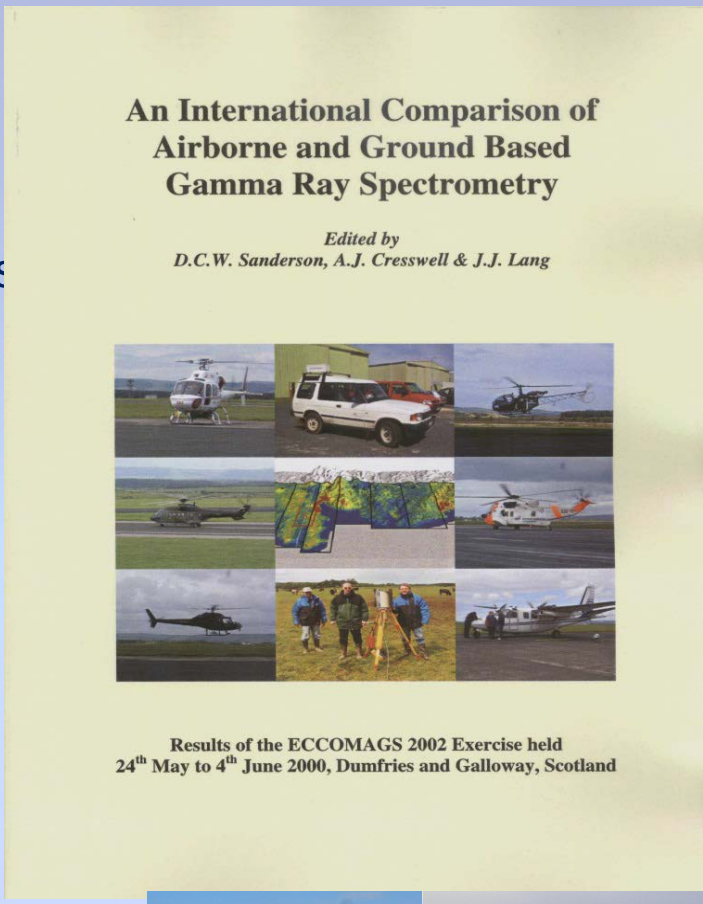
ECCOMAGS

- Protocols for dose rate and radionuclide deposition mapping using AGS
- Exercise design documentation
- Unique data base of airborne & ground based measurements
- Exercise report – 387p book published
- Journal articles
- European Capability for AGS *Radiation Protection Dosimetry*
- *Vol. 73, Nos 1–4, pp. 213–218 (1997)*
- European Bibliography *Journal of Environmental Radioactivity*
- *53 (2001) 411-422*
- International validation of deposition and dose rate determination under conditions of cooperative trials *Radiation Protection Dosimetry (2004), Vol. 109, Nos 1-2, pp. 119-125*



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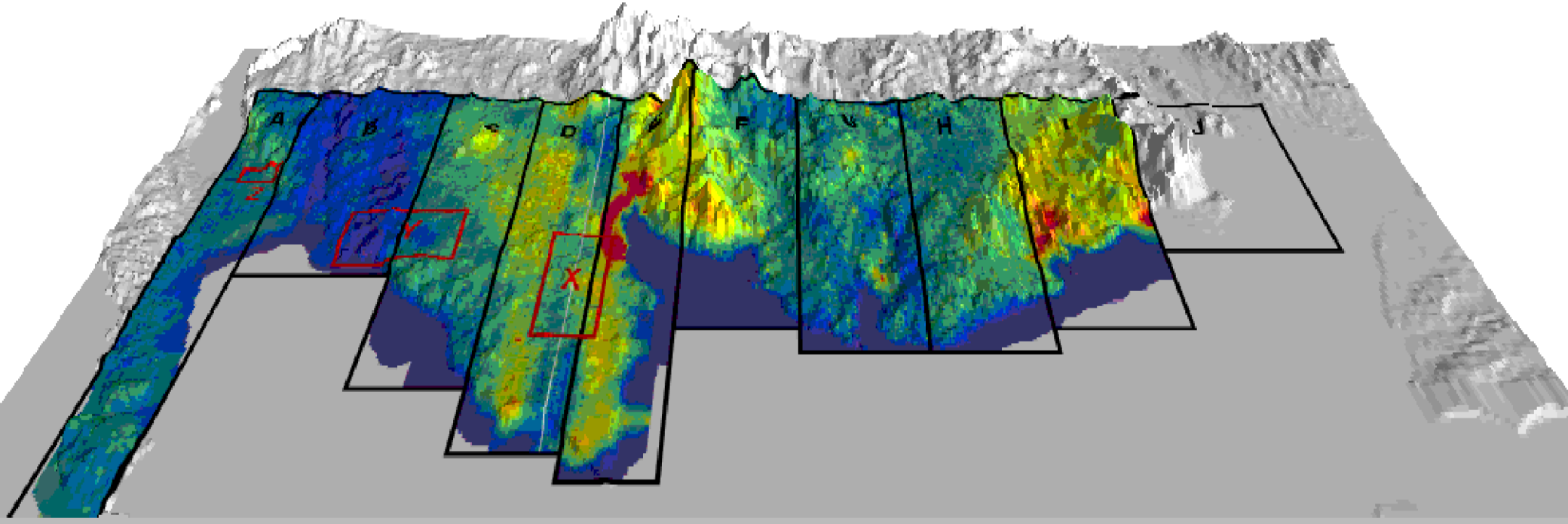
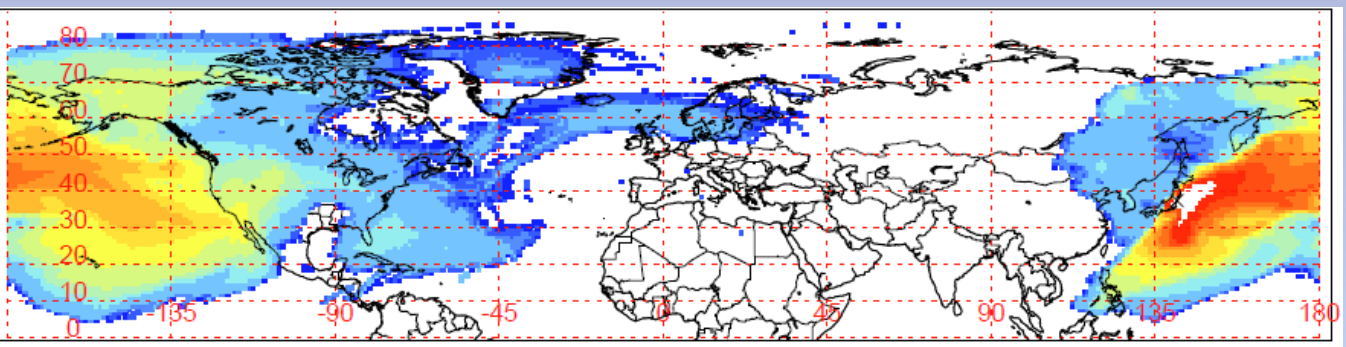
^{137}Cs Map with terrain model

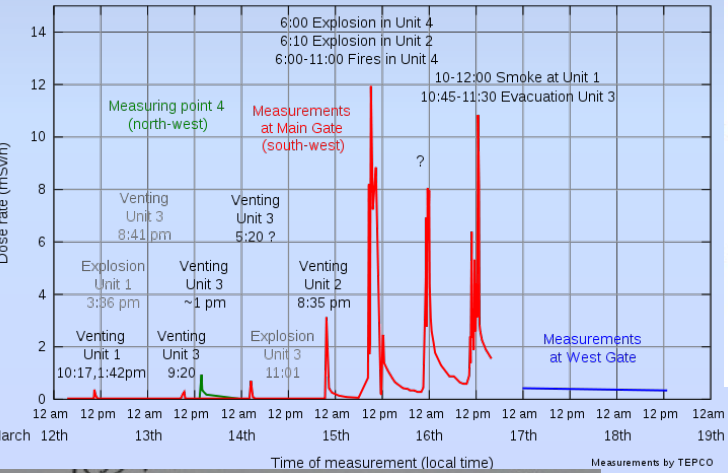
ECCOMAGS exercise composite mapping task 2002

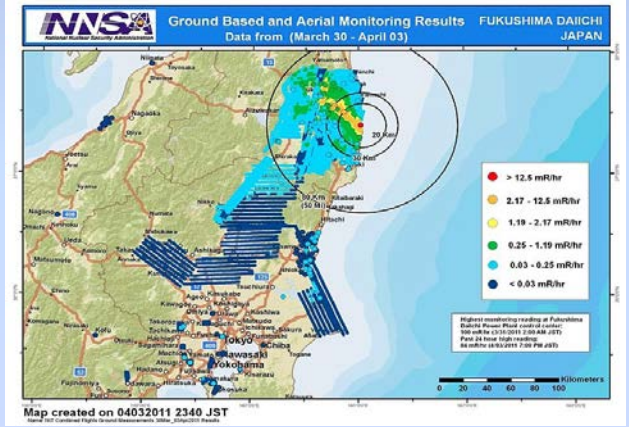
90x40 km area; 69000 spectra; data acquired in 3 days, published on-line within a week

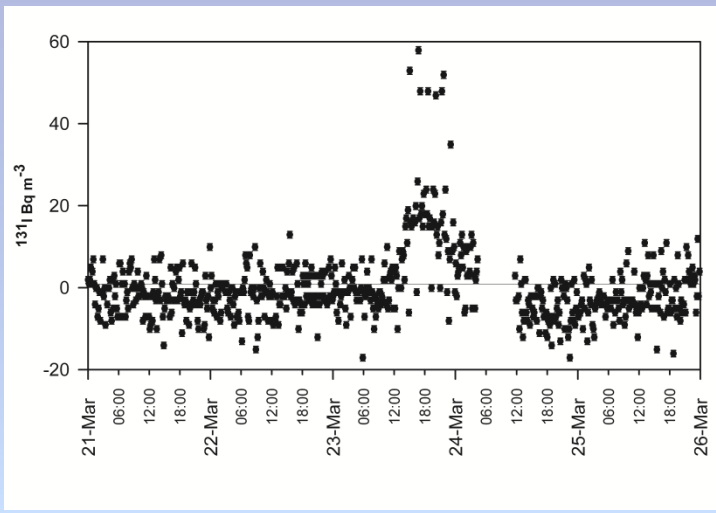


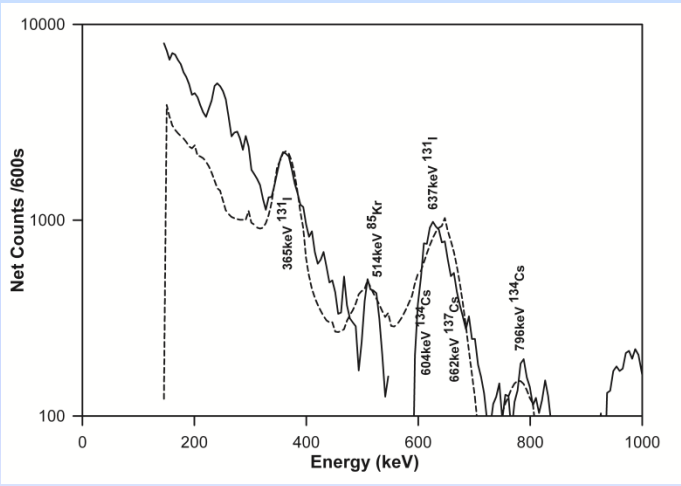
Can radiometrics help target remediation in Japan?

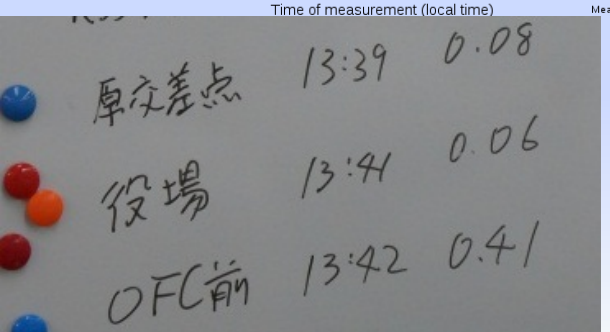












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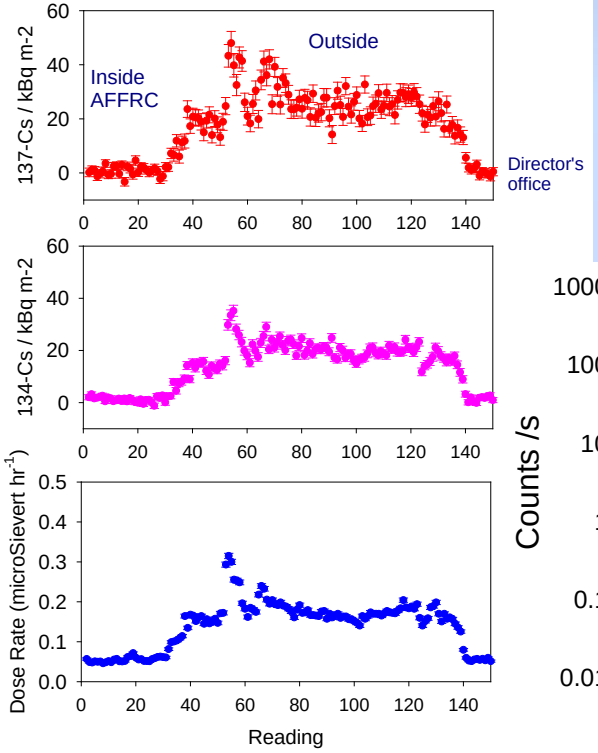
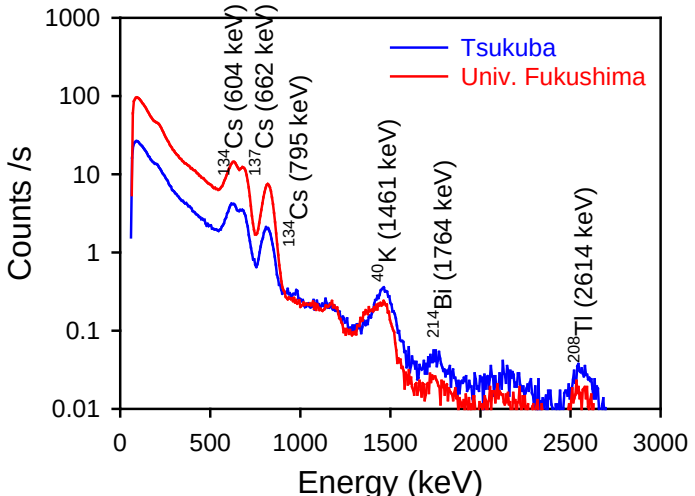
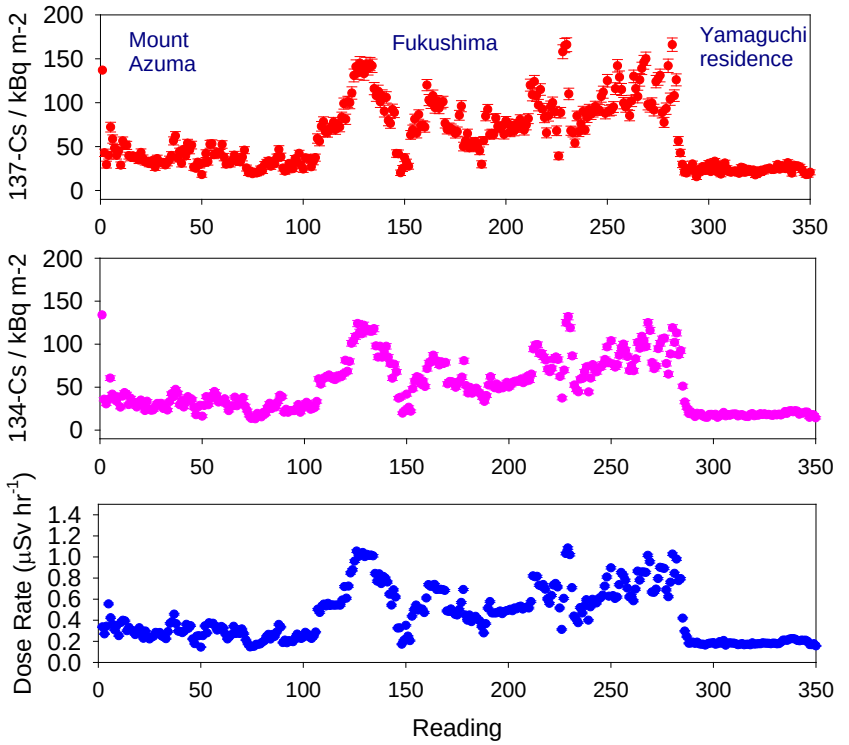
Exploratory backpack measurements made in Tsukuba and Fukushima in March 2012

- Short trial surveys in Tsukuba, Fukushima City, University of Fukushima, Research Institutes, and during a car-borne visit to the exclusion zone.
- Relatively simple spectrum (134Cs and 137Cs + K,U,Th)
- Activity level are consistent with national maps







Fukushima University Kanayagawa Campus
6th March 2012

^{134}Cs (kBq m^{-2})

> 130.0
120.0 – 130.0
110.0 – 120.0
100.0 – 110.0
90.0 – 100.0
80.0 – 90.0
70.0 – 80.0
60.0 – 70.0
50.0 – 60.0
40.0 – 50.0
30.0 – 40.0
20.0 – 30.0
10.0 – 20.0
< 10.0

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Maps show the patchy nature of deposition

Can we use this to target remediation?

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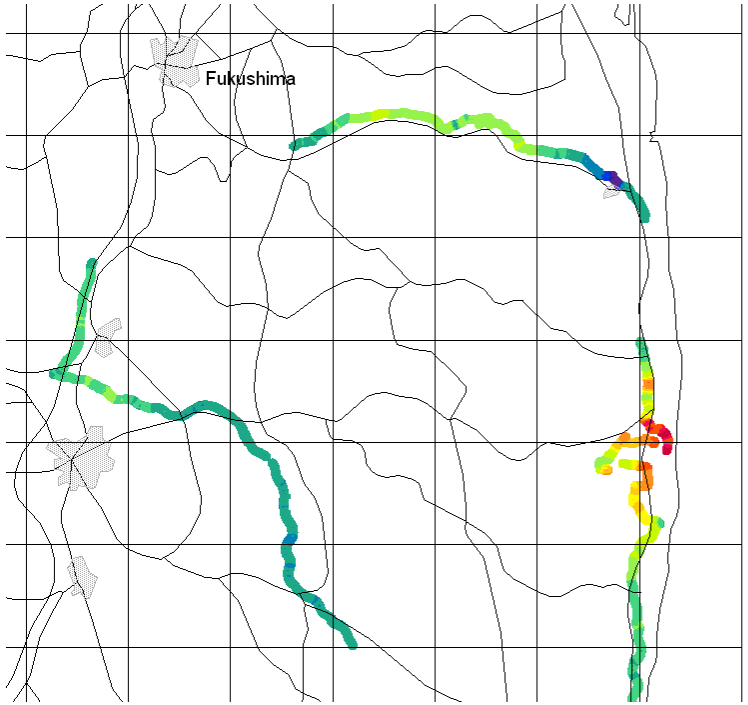
7th March 2012 Road Trip



^{137}Cs (kBq m^{-2})

> 3052.70
1863.80 – 3052.70
1137.92 – 1863.80
694.75 – 1137.92
424.17 – 694.75
258.97 – 424.17
158.11 – 258.97
96.53 – 158.11
58.94 – 96.53
35.98 – 58.94
21.97 – 35.98
13.41 – 21.97
8.19 – 13.41
< 8.19

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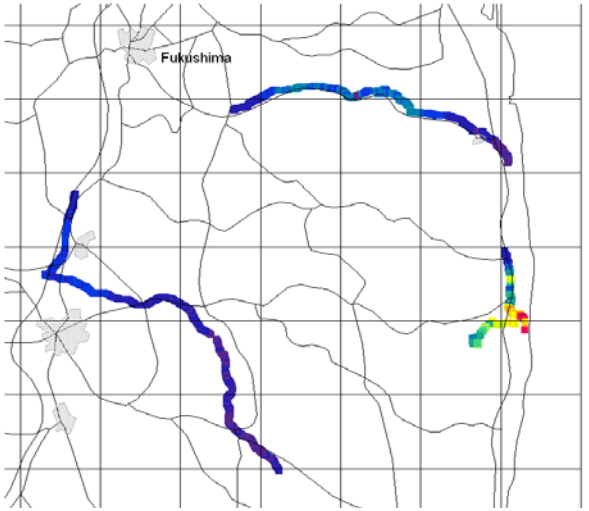

Gamma Dose Rate (μGy h^{-1})

> 150.22
90.27 – 150.22
54.24 – 90.27
32.59 – 54.24
19.58 – 32.59
11.77 – 19.58
7.07 – 11.77
4.25 – 7.07
2.55 – 4.25
1.53 – 2.55
0.92 – 1.53
0.55 – 0.92
0.33 – 0.55
< 0.33

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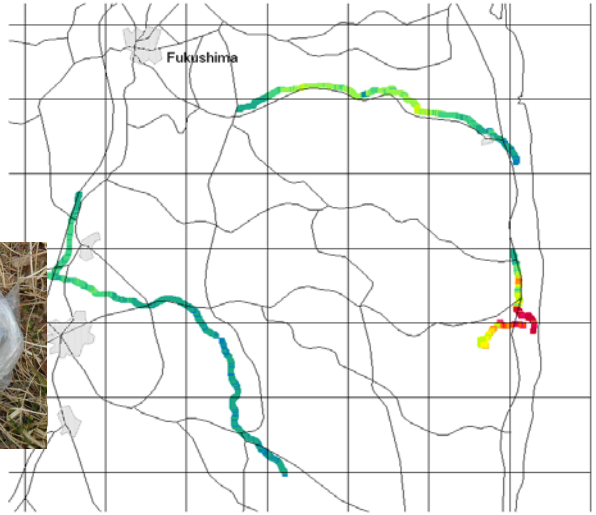

^{134}Cs (kBq m^{-2})

> 3052.70
1863.80 – 3052.70
1137.92 – 1863.80
694.75 – 1137.92
424.17 – 694.75
258.97 – 424.17
158.11 – 258.97
96.53 – 158.11
58.94 – 96.53
35.98 – 58.94
21.97 – 35.98
13.41 – 21.97
8.19 – 13.41
< 8.19

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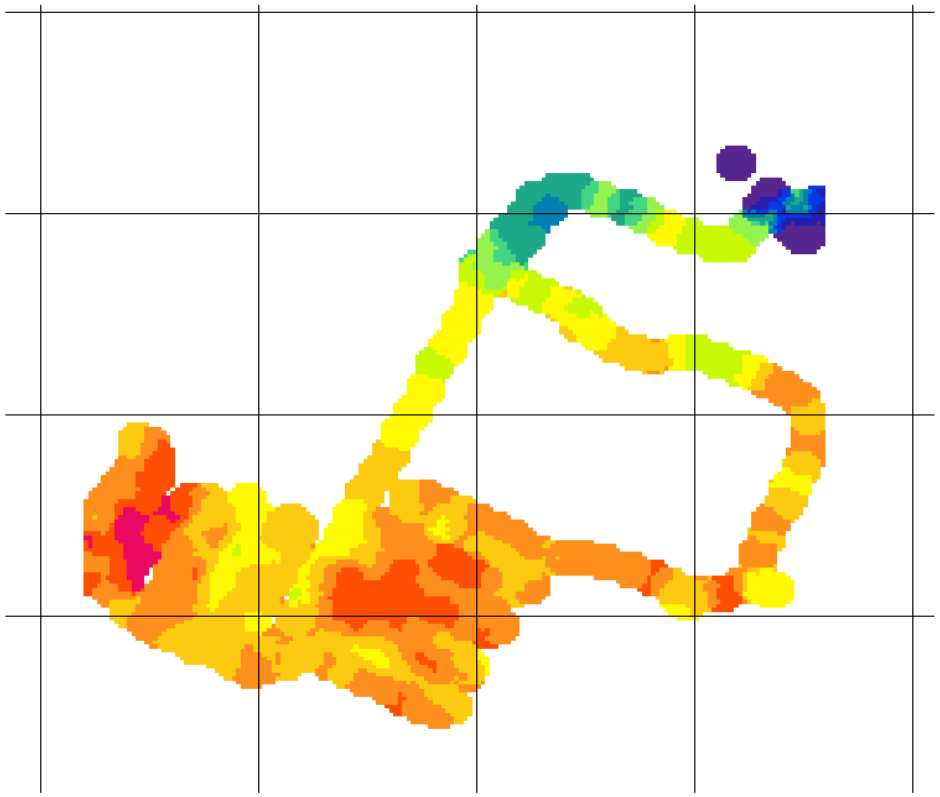
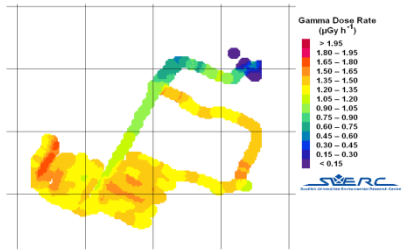
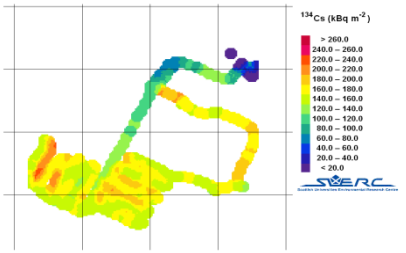
8th March 2012
Fukushima Prefecture Fruit Tree Research Institute



Do radiometric data from experimental orchards help to understand the pathways and impacts of fruit cultivation in the presence radiocaesium?

Can we use this to evaluate solutions?





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Apportionment of dose rate

Conversion to dose rate for:

- natural specific activity – established SUERC coefficients from dating work
- radiocaesium activity per unit area – ICRU53, 1.4 g cm^{-2} mass depth

The charts show the relative proportions of dose rates due to individual nuclides

- Can we use this type of information to set and evaluate targets for remediation ?

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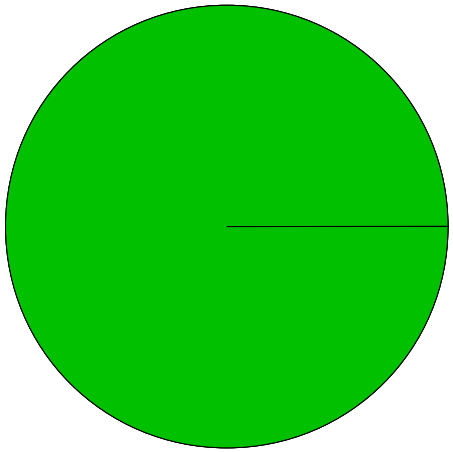
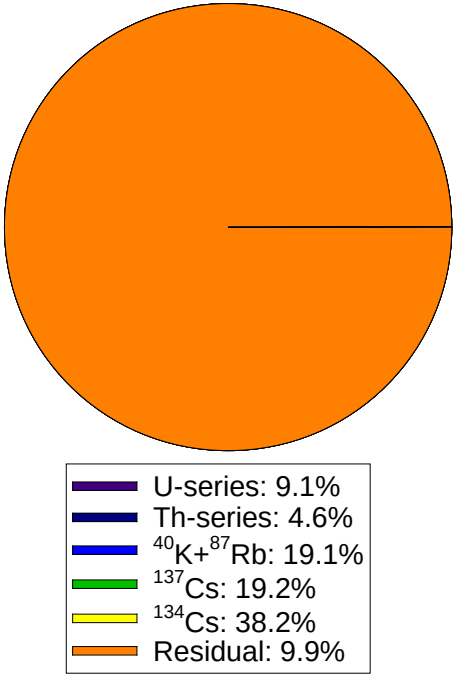
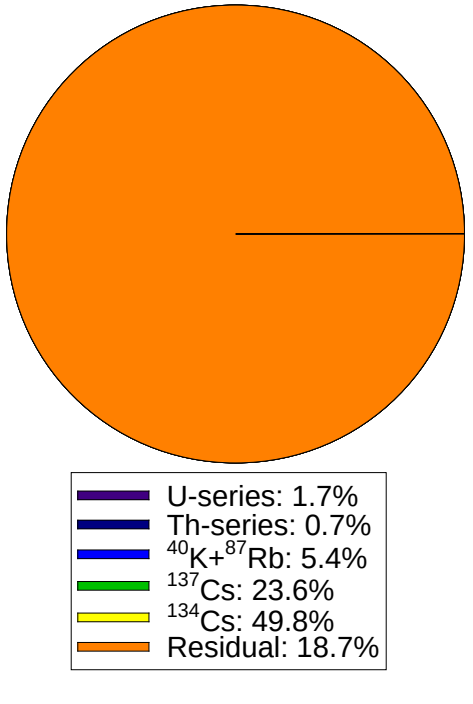


Tsukuba



University of Fukushima



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Summary and conclusions

- Radiometrics has developed significantly since the early nuclear accidents
  - - today there are versatile systems capable of deployment from a wide variety of platforms, and able to produce real-time, quantitative data for dose rate and deposition

Past nuclear accidents have had profound impacts on nuclear regulation, nuclear safety, and more recently on development of modern approaches to decision making and adoption of appropriate social policies in affected areas

- UK and EU experience is available to help with the situation in Japan
- UK experience of site remediation is largely focussed on the decommissioning programme, and to recovery of particulate activity from coastal zonesI

In respect of linking radiometrics to remediation in Japan there may be useful opportunities for conducting detail local mapping of affected areas both to target, and to evaluate remedial actions

- Mapping provides immediate visual indicators and has potential benefit for public communication
- Measurements of change are important in highlighting redistributional effects, and to record natural amelioration
- Dose rate apportionment also has important potential

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