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The assessment of doses after a radiological release

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International Experts' Meeting on Assessment and Prognosis in Response to a Nuclear or Radiological Emergency, IAEA 20 - 24 April 2015

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This presentation discusses…

- assessment of the doses received by members of the public in the event of a radiological incident (accident or deliberate release)
- the reasons for undertaking a dose assessment, and the different requirements of various assessment types
- lessons learnt from the accident at the Fukushima Daiichi Nuclear Power Plant
- what key uncertainties are associated with assessments
- future research priorities

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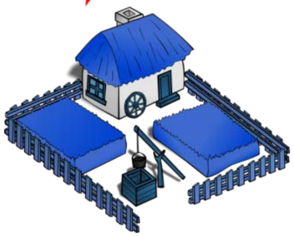
Assessments are undertaken for different reasons

- assessments in early emergency phase - to inform health protection decisions on emergency actions



- assessments in the emergency & post-emergency phases – to determine need for longer term measures

  recovery or longer-term food restrictions

- health-related assessments in post-emergency phase – comparison with medical observations, planning medical surveillance, input to epidemiological studies, public reassurance

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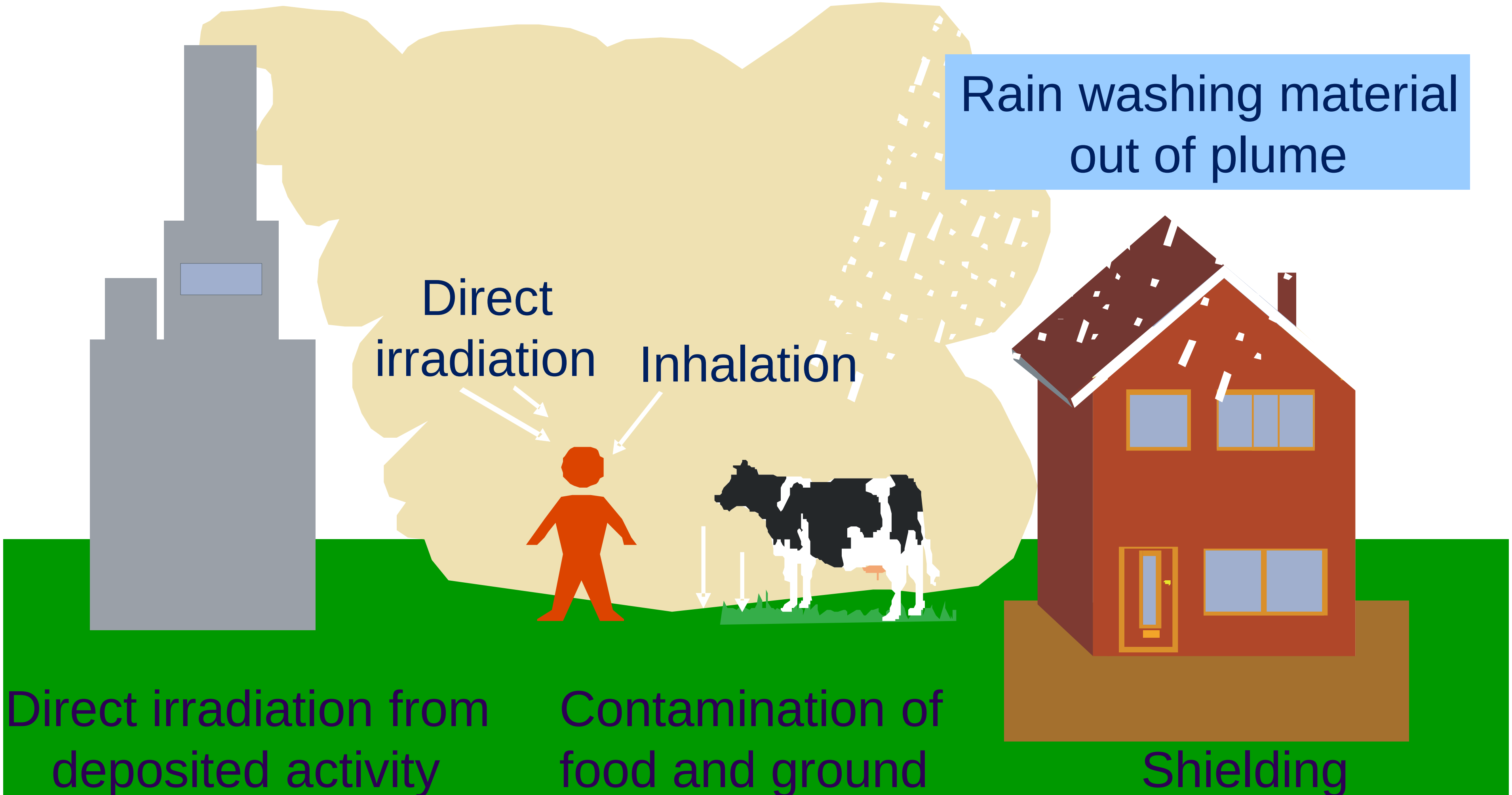
Exposure pathways - atmospheric



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Fukushima Daiichi 11 March 2011

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Fukushima dose assessments

- WHO (WHO, 2012)
- UNSCEAR (UNSCEAR, 2014)
- Key radionuclides: ^{131}I, ^{134}Cs and ^{137}Cs
- Key exposure pathways: external irradiation from deposited material, inhalation and, in most locations distant from the release point, the ingestion of food
- Doses delivered in the early days following the accident were a significant proportion of the first year’s dose
- But countermeasures significantly reduced the possible doses

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Geographic variability of dose

- Recent Public Health England assessment
- Used estimated source term, Lagrangian dispersion modelling and World Meteorological Office weather data
- Focused on geographic irregularity in doses, the impact of the meteorological conditions, and variability in dose as a function of radionuclide and exposure pathway

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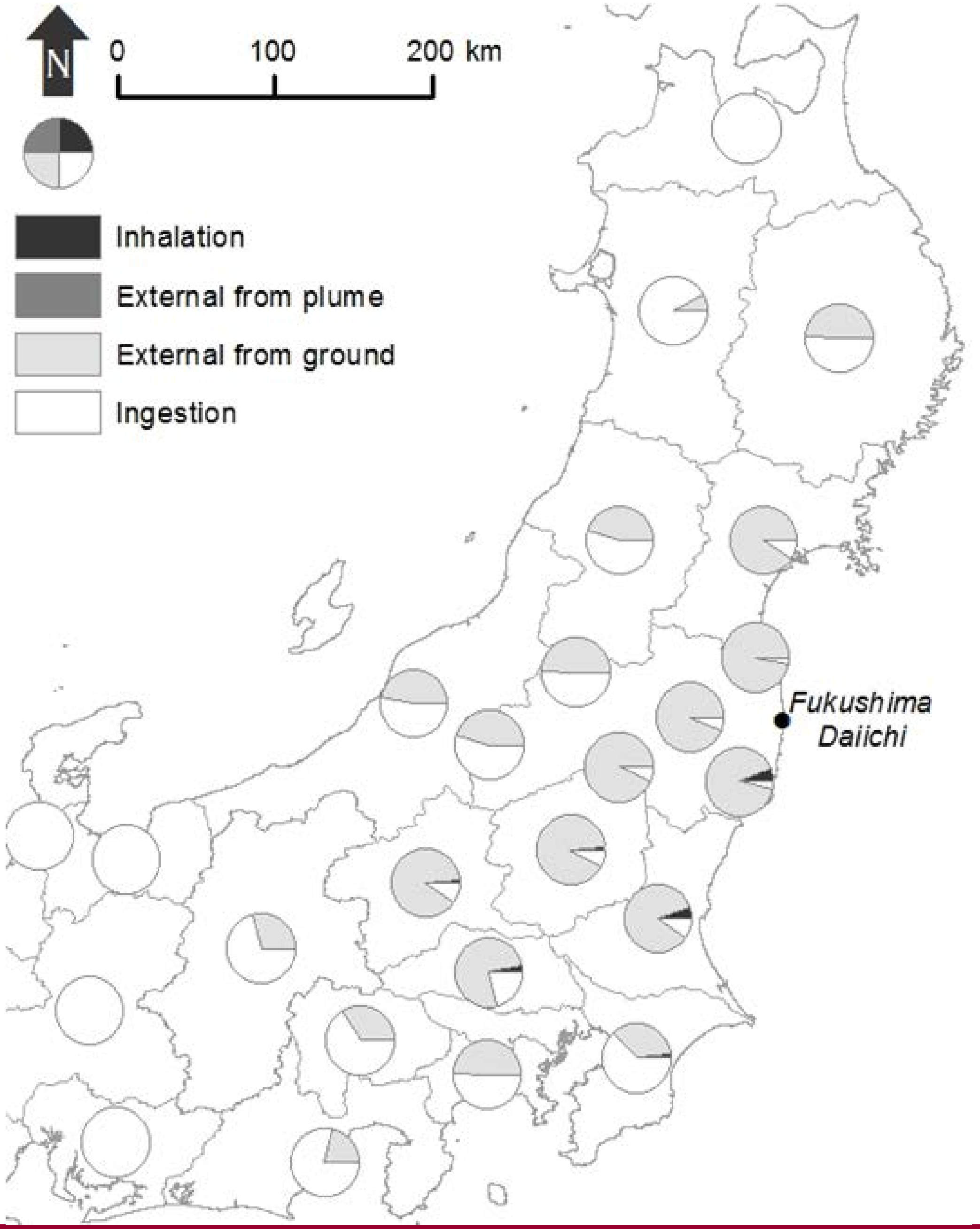
Geographical variability of the contributing exposure pathways to the estimated lifetime effective dose to an infant:

Mostly external close to release and mostly ingestion further away



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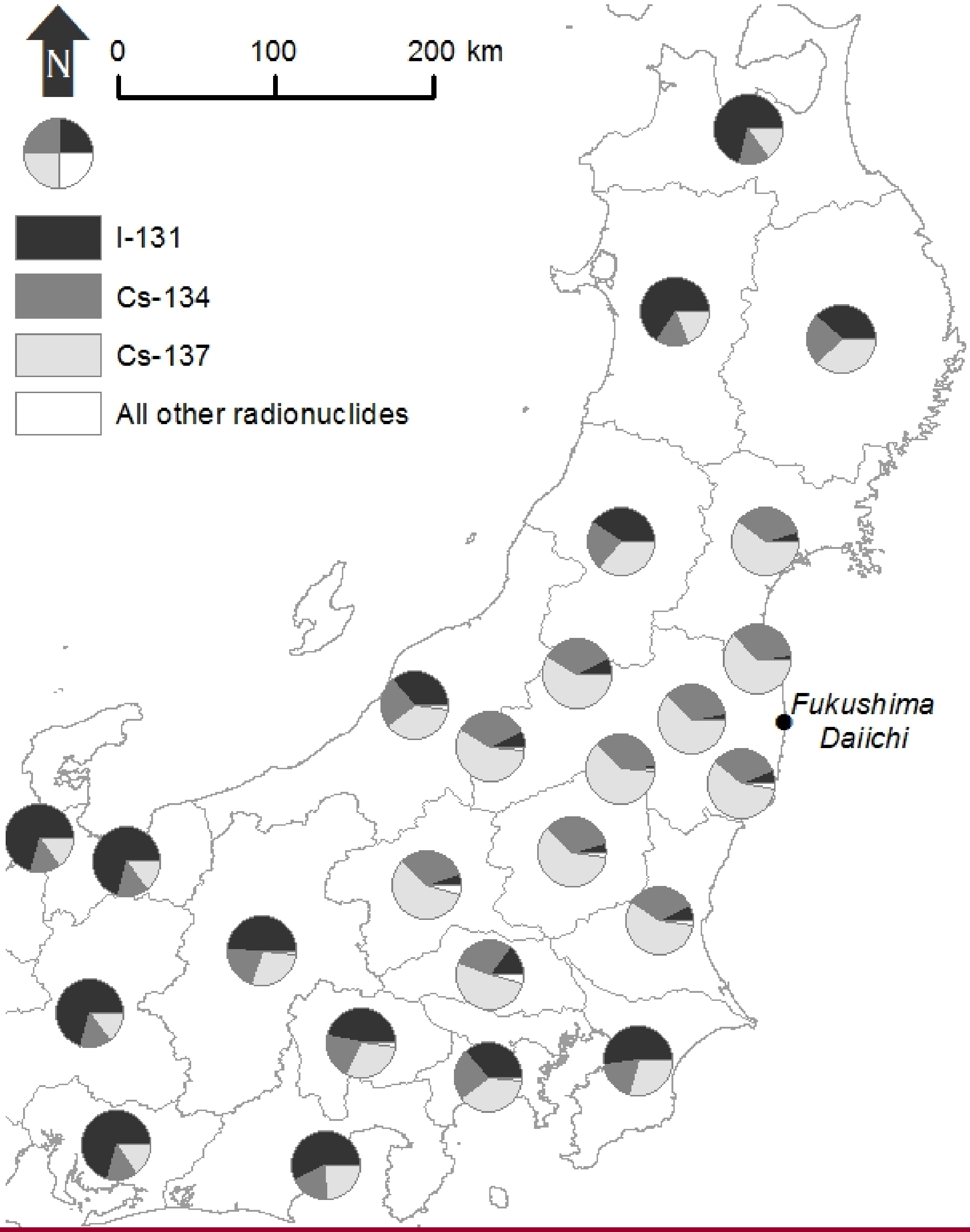
Geographical variability of the contributing nuclides to the estimated lifetime effective dose to an infant:

Mostly caesium nuclides closer to the release (external) and ^{131}I further away (ingestion)



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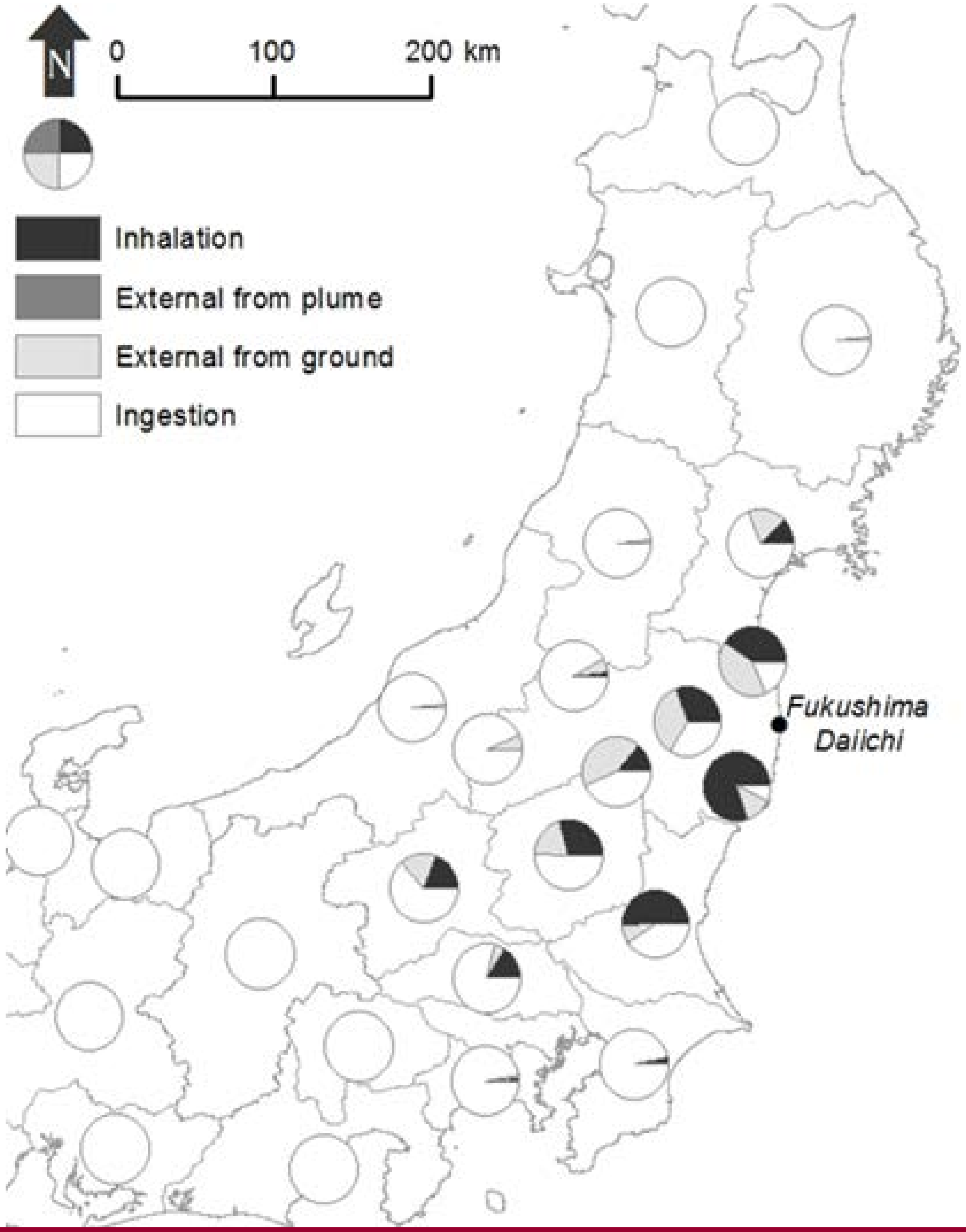
Geographical variability of the contributing exposure pathways to the estimated 1st year thyroid dose to an infant:

Mostly inhalation doses closer to the release and ingestion further away

Differences due to met conditions during the release - some areas little rain, others significant rain



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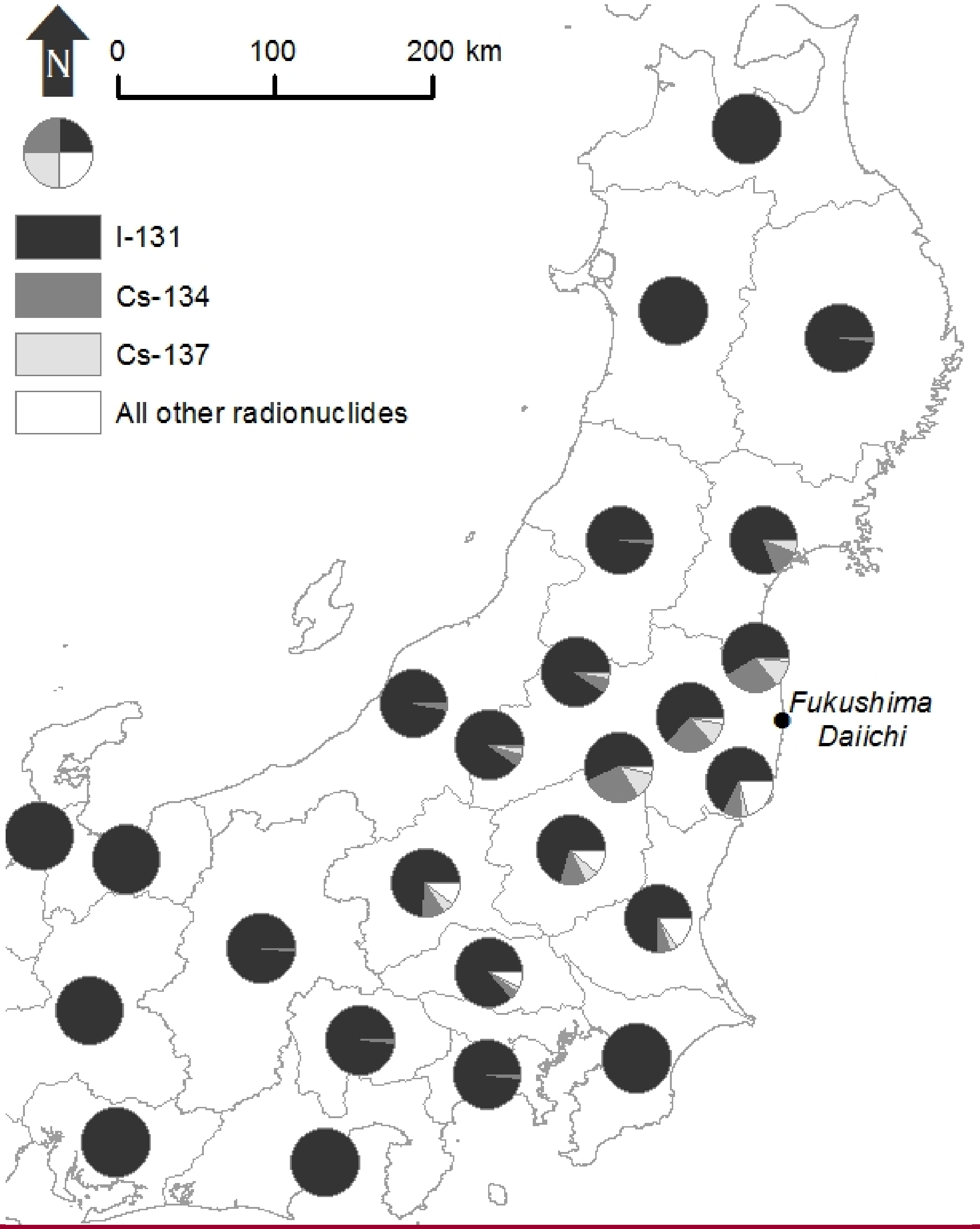
Geographical variability of the contributing radionuclides to the estimated 1st year thyroid dose to an infant:

Predominantly ^{131}I but caesium radionuclides contribute to thyroid doses in regions to the west of the release



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Geographic variability of dose

- Shows impact of met conditions on dose (especially wind direction and deposition)
- But measurements of all significant radionuclides in all significant mediums not readily achieved (for example, full spatial and temporal coverage)
- Dose assessments based on dispersion modelling contribute to better understanding of the picture
- The ideal …. to effectively and rapidly unify monitoring and modelling?

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Early emergency assessments

- Large releases of radioactivity require rapid decisions, possibly over large areas
- Emphasis on major health protection decisions rather than on detailed and comprehensive understanding
- Lack of knowledge but still a need to estimate doses and protective actions – while aware of key uncertainties

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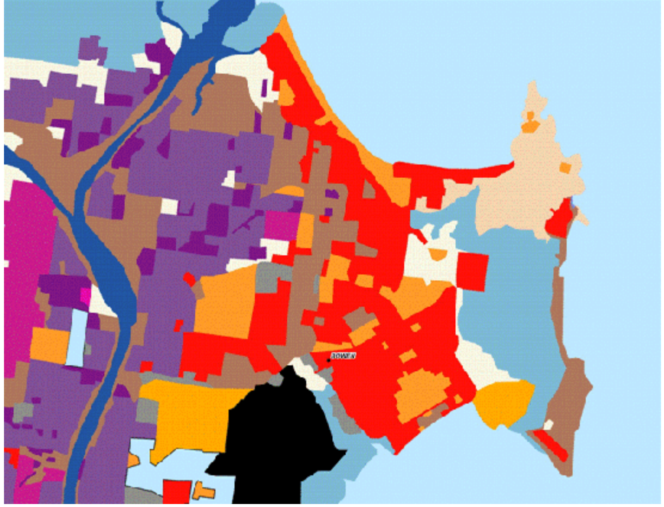
Post-emergency assessments



Need

- spatial and temporal environmental concentration maps
- modelling still required (for example, to predict very early concentrations, to predict to future times and to locations where measurements have not been taken)
- reconstruction of population activity and movements
- knowledge of actual countermeasures

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Later assessments

- Other parameters needed eg inhalation rates, occupancy times for different building types, factors for the reduction of external irradiation indoors, appropriate dose coefficients (for inhalation and ingestion)
- Limitations with measurement information:
  - Snapshot at a particular time (eg in-vivo measurements reflect only intakes up to the time of the measurement, or activity decayed)
  - Doesn’t provide information about activity elsewhere
  - Individuals have varying history of location movements and habits/metabolism
  - All measurements are uncertain

Other types of radiological emergency

- Deliberate releases or broken/exposed sources may be radiological emergencies off-site
- Similar considerations apply, but …
  - Impact may be more localised
  - Radionuclides may be different
  - May be delayed detection or very limited measurement information available quickly

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Other types of radiological emergency

- Assessment techniques may need to be more flexible to address the specific situation
- Monitoring will be key to reducing uncertainty and increasing knowledge
- Protection principles same as any radiological incident:
  - urgent protection for people at greatest risk
  - aim to avoid “serious deterministic injuries”
  - weigh up benefits of countermeasures against harm

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Implications of uncertainties in dose assessments

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Implications of uncertainties in dose assessments

Uncertainties in emergency assessments

- decisions for protection purposes require estimates of projected dose across the affected area
- … which require estimates of activity concentrations in air and deposited activity on the ground
- estimates should include all that is currently known about the nature of the emergency and ….
- … **just as importantly**, what potentially significant information is not yet known

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Uncertainties in assessments include …

- what has been released (amounts and radionuclides)
- what the time distribution of the release has been and how this may continue
- features of the release (for example, particle size and release energy)
- what influence the weather has had in the affected area
- future weather – there may be several alternative predictions

Uncertainties in assessments

- decisions on protective actions must be taken despite lack of knowledge
- but uncertainty in early estimates of dose must be counterbalanced by the known health risks associated with early emergency countermeasures
- in particular the risk associated with evacuation - the rapid evacuation of large numbers of people has the potential to cause more health injuries than exposure to radiation from remaining in sheltering, and should be justified by the severity of the situation
- need to be able to explain the uncertainty to decision-makers

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Presenting uncertain information to decision-makers

- work in the UK (Warwick University, UK Met Office, PHE)
- to develop techniques for presenting uncertainty to decision-makers, focusing on radiological emergencies
- particular focus is uncertainty in dispersion and deposition processes due to weather
- workshop of government experts and agencies held in Sept 2014
- work now in progress on alternative methods of presentation
- UK Government Chief Scientists involved in next workshop (Sept 2015)

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Presenting uncertain information

Source term possibilities – size, height, duration, nuclides, energies, particle sizes, chemical form ….

Weather possibilities

		1	2	3	4	5	6	7	8
1									
2									
3									
4									
5									

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Presenting uncertain information

Source term possibilities – size, height, duration, nuclides, energies, particle sizes, chemical form ….

		1	2	3	4	5	6	7	8
		0.1	0.09	0.1	**0.3**	0.01	0.1	**0.2**	0.1
1	0.05								
2	0.25								
3	**0.5**								
4	0.1								
5	0.1								

Weather possibilities

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Weather possibilities

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		0.1	0.09	0.1	**0.3**	0.01	0.1	**0.2**	0.1
1	0.05	0.005	0.0045	0.005	0.015	0.0005	0.005	0.01	0.005
2	0.25	0.025	0.0225	0.025	0.075	0.0025	0.025	0.05	0.025
3	**0.5**	0.05	0.045	0.05	0.15	0.005	0.05	0.1	0.05
4	0.1	0.01	0.009	0.01	0.03	0.001	0.01	0.02	0.01
5	0.1	0.01	0.009	0.01	0.03	0.001	0.01	0.02	0.01

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3	**0.5**	0.05	0.045	0.05	**0.15**	0.005	0.05	**0.1**	0.05
4	0.1	0.01	0.009	0.01	0.03	0.001	0.01	0.02	0.01
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Weather possibilities

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Presenting uncertain information

Source term possibili… n,
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Likely scenarios

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Weather possibilities

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Presenting uncertain information

Source term possibiliti… n, nuclides, energies, particle sizes, chemical form ….

Likely scenarios

Worst case scenario

Weather possibilities

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4	0.1	0.01	0.009	**0.01**	0.03	0.001	0.01	0.02	0.01
5	0.1	0.01	0.009	0.01	0.03	0.001	0.01	0.02	0.01

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Presenting uncertain information

Source term possibiliti... n, ... , energies, particle sizes, chemical form ….

Likely scenarios

Bad but not 'worst' scenario

Worst case scenario

Weather possibilities

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Presenting uncertain information

Source term possibiliti n,
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4	0.1	0.01	0.009	**0.01**	0.03	0.001	0.01	0.02	0.01
5	0.1	0.01	0.009	0.01	0.03	0.001	0.01	0.02	0.01

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Conclusions….

- The purpose of the dose assessment has a major bearing on what is required in terms of information needs
- Measurements are very unlikely to be a sufficient basis for a dose assessment
- Much of the total dose arising from an accident is likely to be delivered in the first days, when measurements may be scarce
- Direct measurements of people are useful but require interpretation
- The best approach to dose assessment is to use a combination of different methods and data, recognising uncertainties

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Gaps and future work

- Enhancing the value of monitoring data eg maximum information from gamma dose measurements
- Developing additional resources to estimate source terms based on, for example, plant conditions
- Further enhancement of tools which rapidly combine and interface the results of monitoring with the use of real-time modelling of dispersion and deposition processes based on fine resolution meteorological information
- Development of systems which show what is not fully known at each point (eg alternative release durations & weathers)
- International intercomparison of key features of major assessment tools, so that the reasons for differences between early dose estimates are to some extent at least understood

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Final thought

Every radiological accident is different

Important not to focus overmuch on the lessons learnt from the last accident, but rather on the cumulation of experience over decades, as the next accident may well be very different from the last