Use of drones in the assessment of uncommon exposure situations

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Lay-out

- Introduction: definitions/categorization of drones
- Type of radiological measurements/scenarios - benefits
- Altitude – speed – resolution - … : an optimization challenge
- Some of the UAV developments/UAV measurements at SCK•CEN:
  - Point source
  - Contamination
  - Radioactive plume
  - Unknown radiation exposure (first responders)
- Outlook

Drone definition/types and categories

- Drone or unmanned aerial vehicle (UAV):
  - Autonomously performs flight missions or
  - Tele-operated by pilot from ground
- Autonomy varies from:
  - Basic features: self levelling, position holding (GPS), altitude holding (barometer, dist. sensor)
  - Higher autonomy: automatic take-off and landing, path planning, obstacle avoidance

UAV

Heavier-than-air | Lighter-than-air

Wing type | Rotor type

Fixed-wing

Flying-wing

Flapping-wing

Helicopter

Quadru-copter

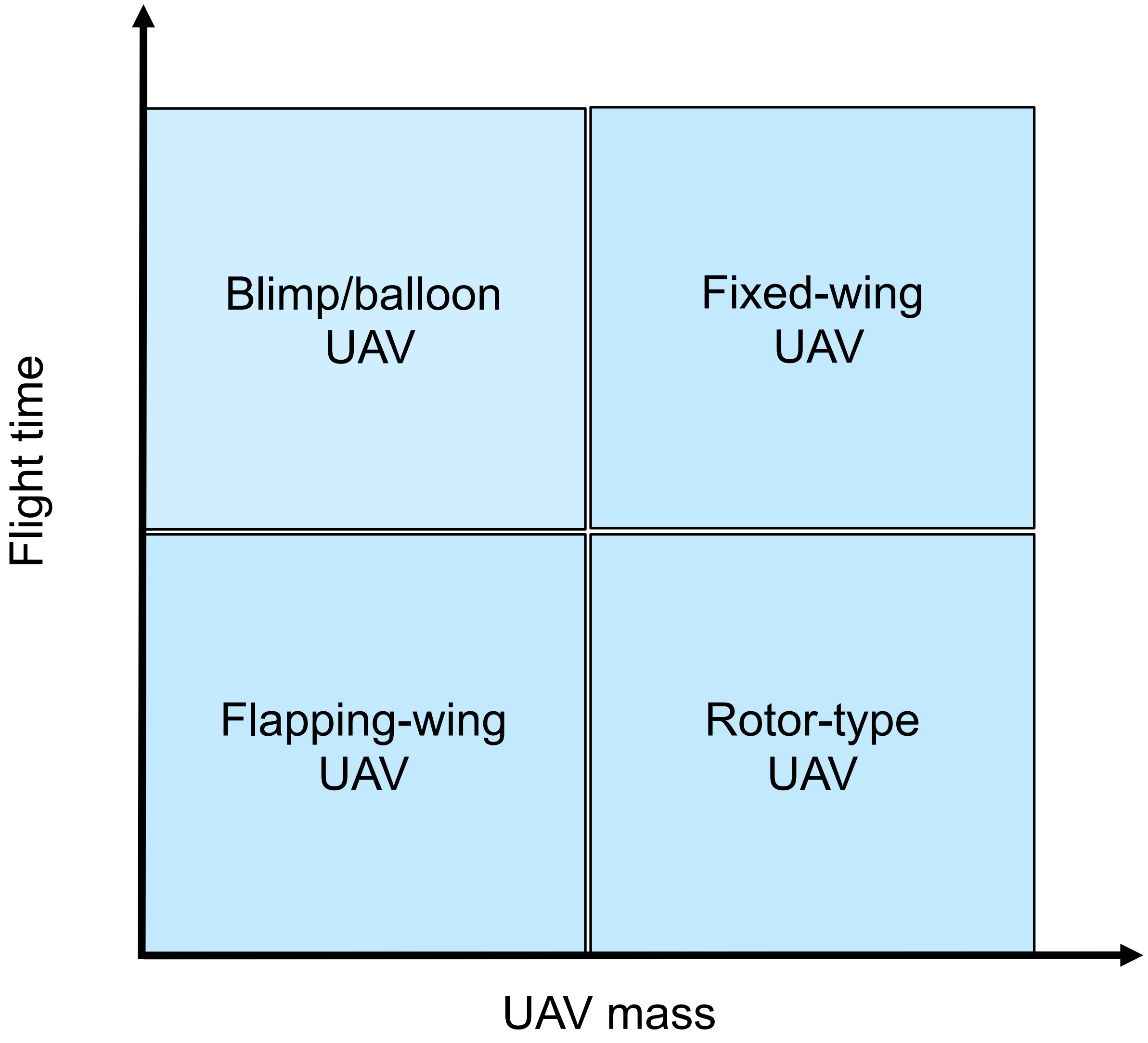
Hexacopter

Octocopter

Blimp

Balloon

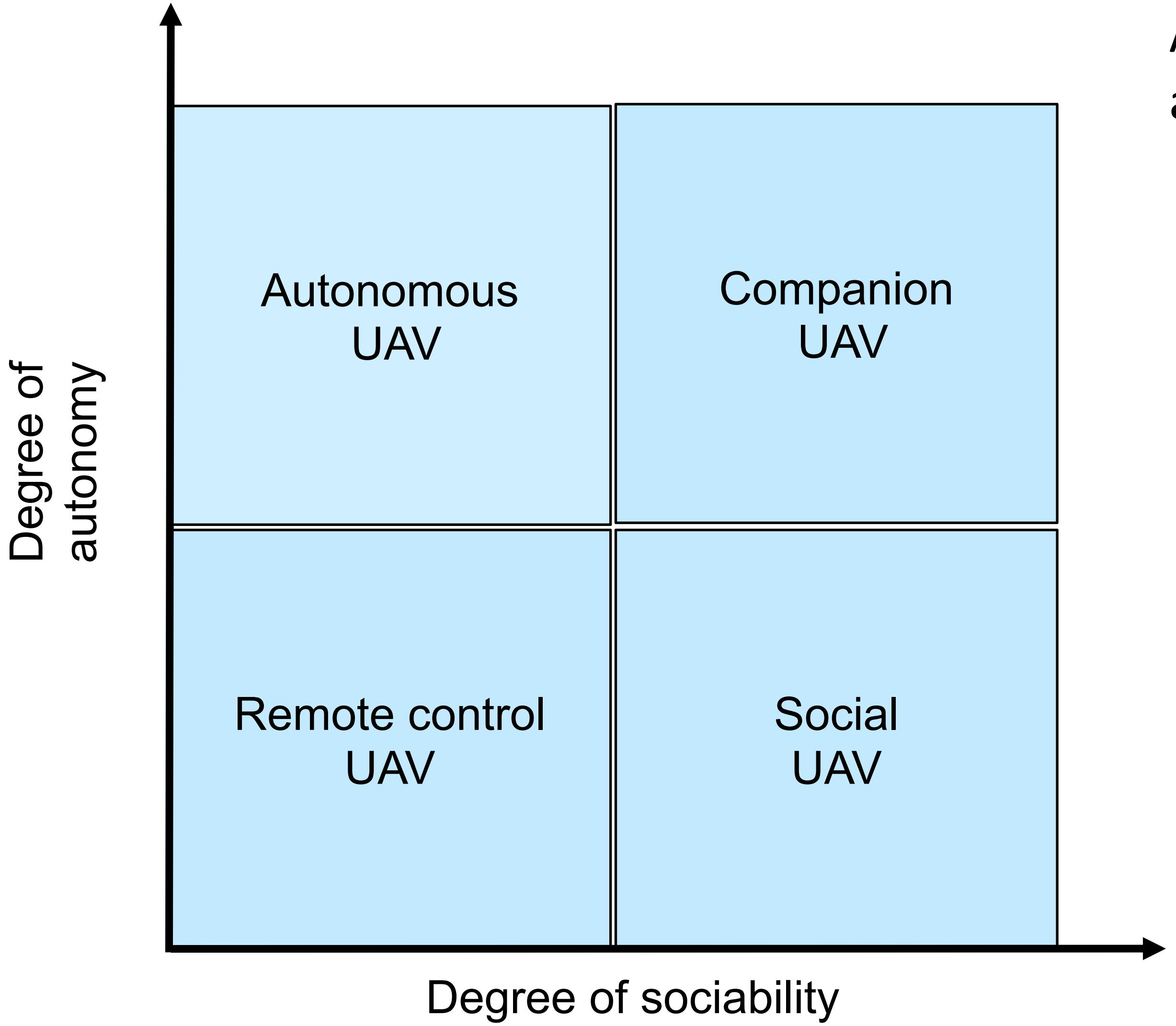
Categorization



A technical characterization based on UAV mass and flight-time

- For radiation measurements currently mainly Fixed-wing versus Rotor-type:
  - Fixed-wing:
    - High cruising velocity;
    - Long flight-time possible;
    - Need for launching/landing capabilities;
    - Screening large areas (cf. uranium exploration, mapping contamination in large-accident)
  - Rotor-type:
    - Relative low cruising velocity;
    - Easy to launch and hover;
    - Fly at lower altitudes (easier to avoid obstacles);
    - If batteries used: limited flight-time.

Categorization (2)



A characterization based on general way-of-use and potential use

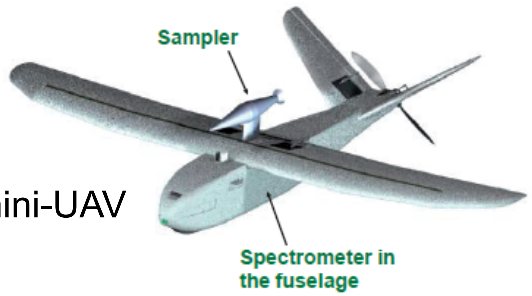
- Currently mainly remote control with limited autonomy
- Companion UAV: ultimate goal as a companion for a radiation expert/first responder?

Recent developments in aerial robotics: Liew et al., 2017

Type of radiological UAV measurements

Possible measurements:

- Direct measurement of gamma radiation:
  - Dose rate (GM, Plastic);
  - Spectroscopy (NaI, CsI, LaBr, CZT);
- Air-Sampling: easier on fixed wind (passive) compared to rotor-type (pump);



Patria MASS mini-UAV
STUK

- Use UAV for ors (TLDs or active dosimeters/ spectroscopic devices).

Different scenarios has been investigated (experimentally and theoretically) :

- Ground-level radiation:
  - Lost source(s);
  - Contamination, e.g. post accident; NORM sites;
  - Efficiency decontamination- remediation (E.g.; Fukushima);
- Airborne plumes;
- Low-level radiation anomalies (installations);
- Indoor applications;
- Surveys: combining radiological and visual images.

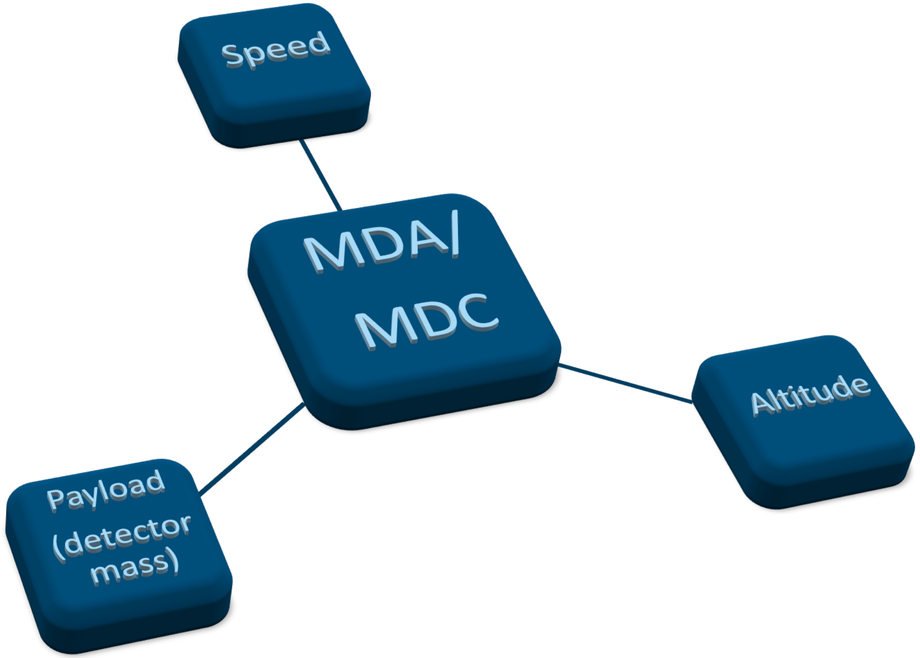
Literature review: see for example: D. Connor et; al Airborne radiation mapping: overview and application of current and future system – International Journal of Remote Sensing (2016) 37, no. 24, 5953-5987

Benefits, especially of small-size UAVs

- Take-off and landing at any location
- No dependence on road-network or problems with accessibility of location
- Safety for operator (ALARA): operator can stay in low radiation/background zone
- Low cost: cost of drone is often a fraction of cost spectroscopic detectors
- Small operation cost
- Contamination of aerial platform is not a major problem

Optimization challenge: speed – altitude – payload …

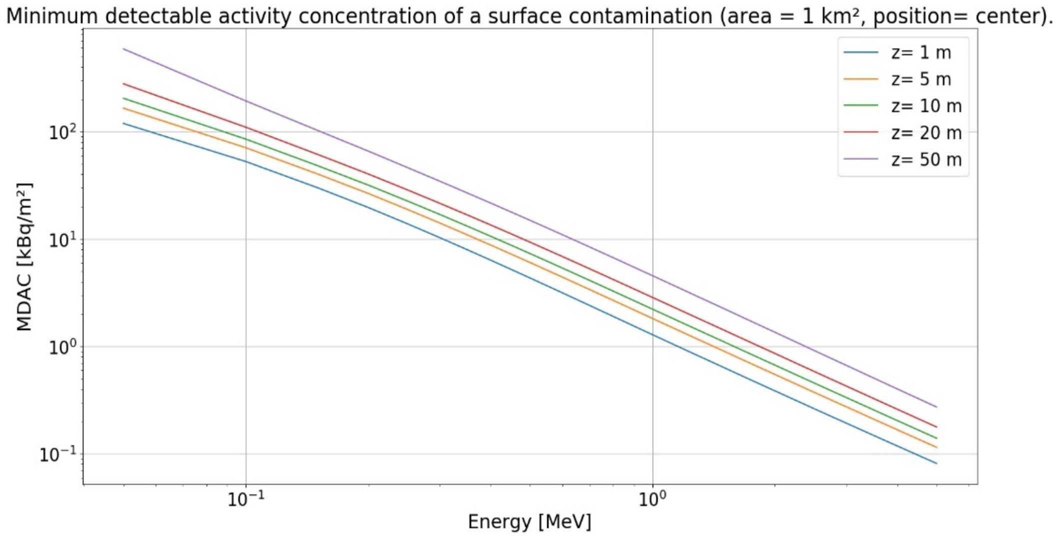
Interconnection of many parameters such as speed, altitude, detector efficiency, flight path which have influence on detection – no detection



Simple model allowing drone measurement calculations, currently implemented as a Python script for dose rate.

Dose rate from point source with activity C:

$$\dot{H}^*(10) = KH\, k\, \mu_{en} \frac{1}{1-g} E_\gamma\, \epsilon \frac{B}{4\,\pi\, r^2} e^{-\mu r}\, C$$



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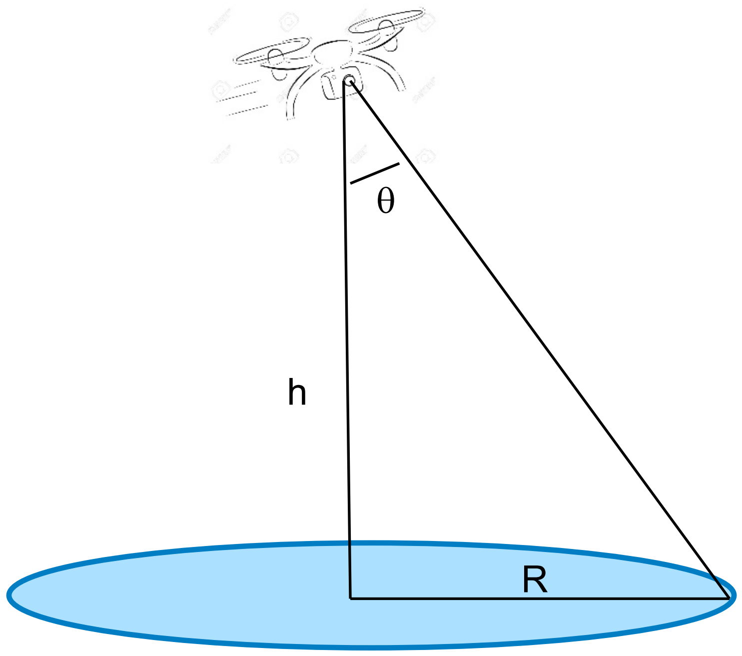
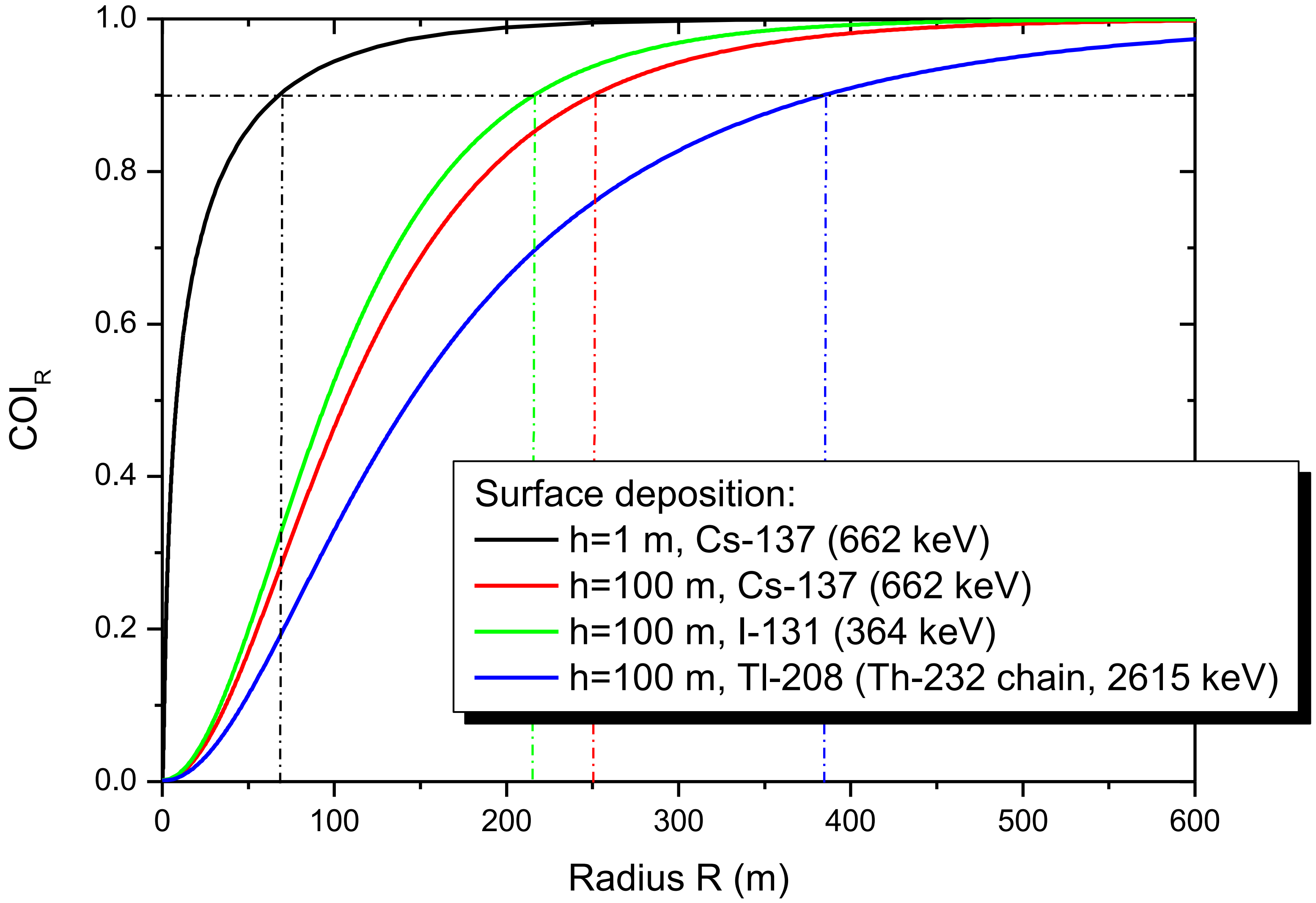
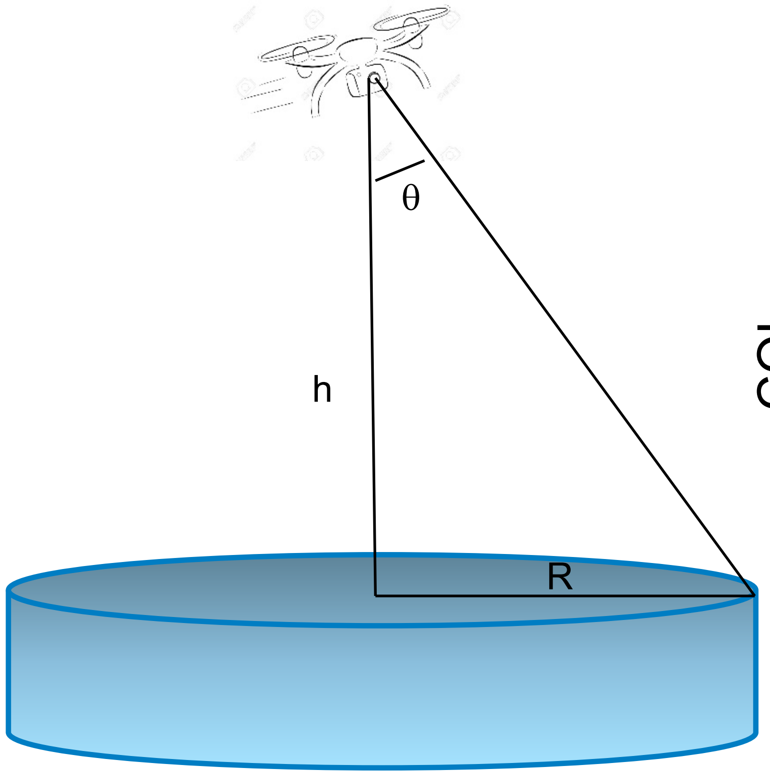
Homogenous contamination: circle of investigation



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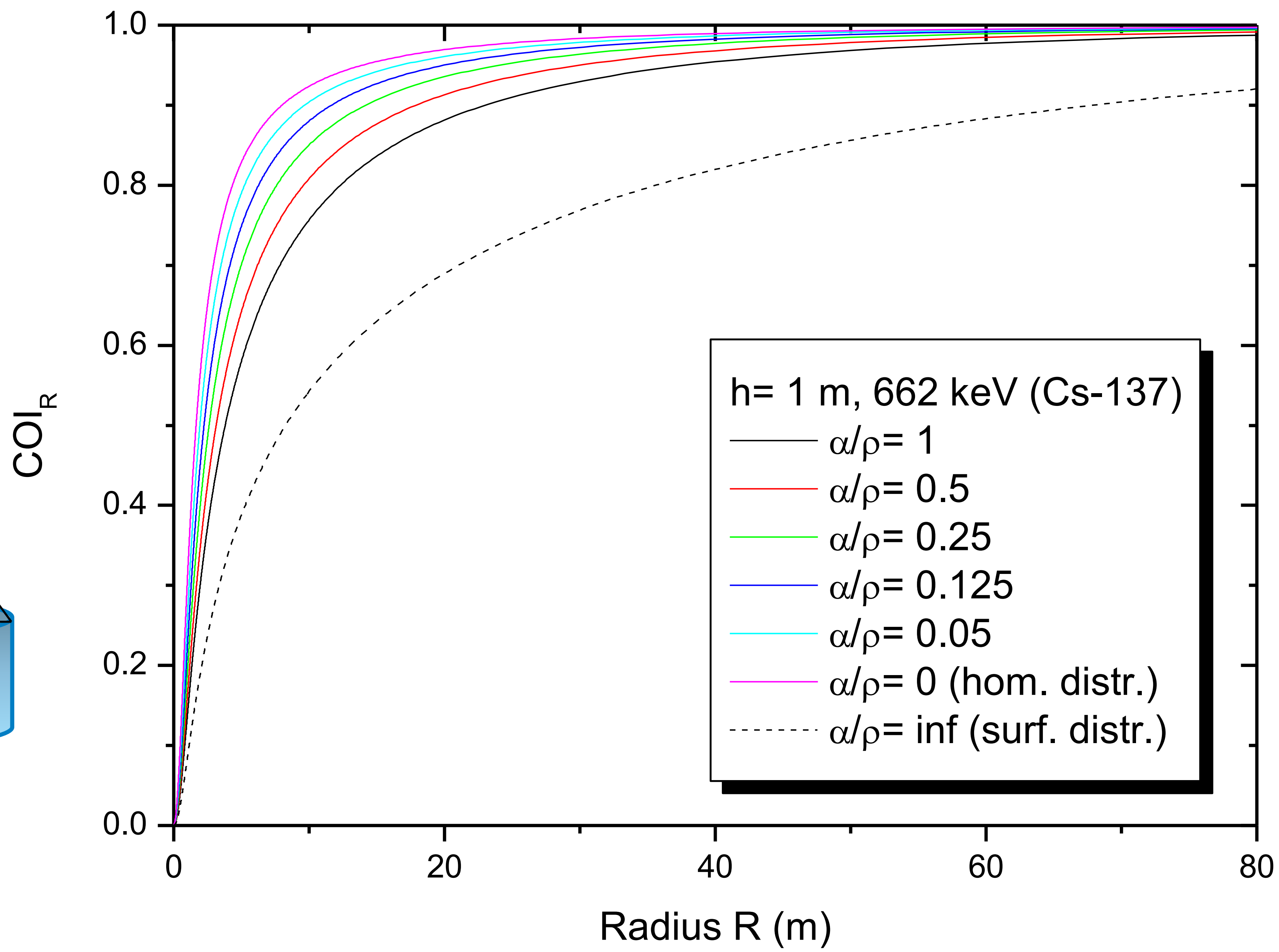
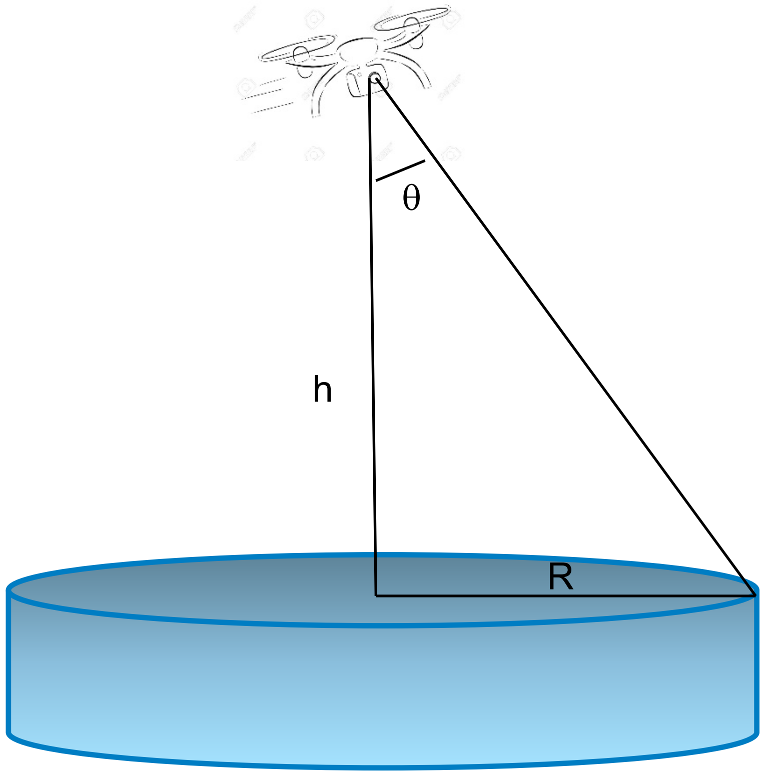

1.0
0.8
0.6
0.4
0.2
0.0
COI_R
0
20
40
60
80
Radius R (m)
h= 1 m, 662 keV (Cs-137)
α/ρ= 1
α/ρ= 0.5
α/ρ= 0.25
α/ρ= 0.125
α/ρ= 0.05
α/ρ= 0 (hom. distr.)
α/ρ= inf (surf. distr.)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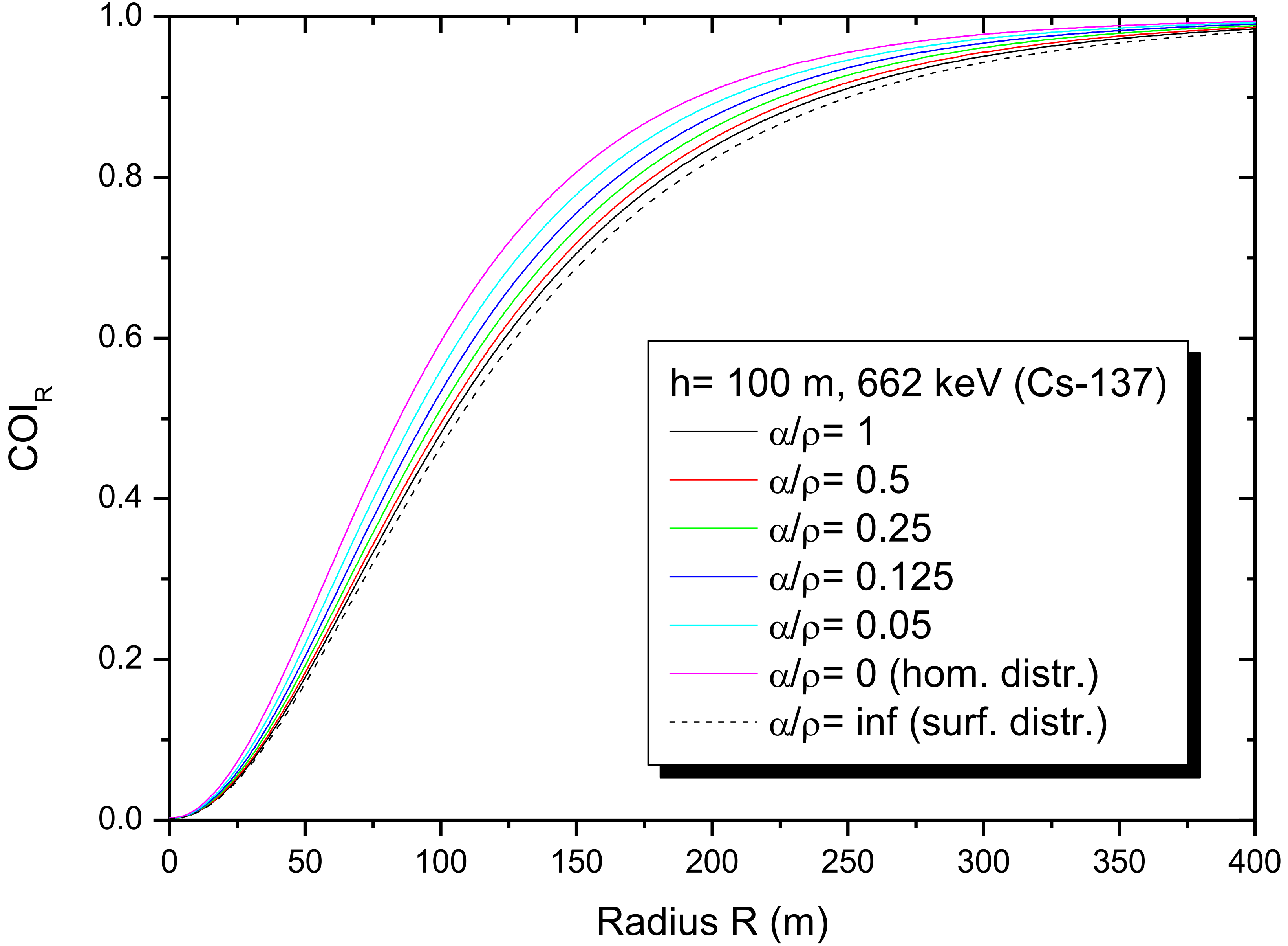
1.0
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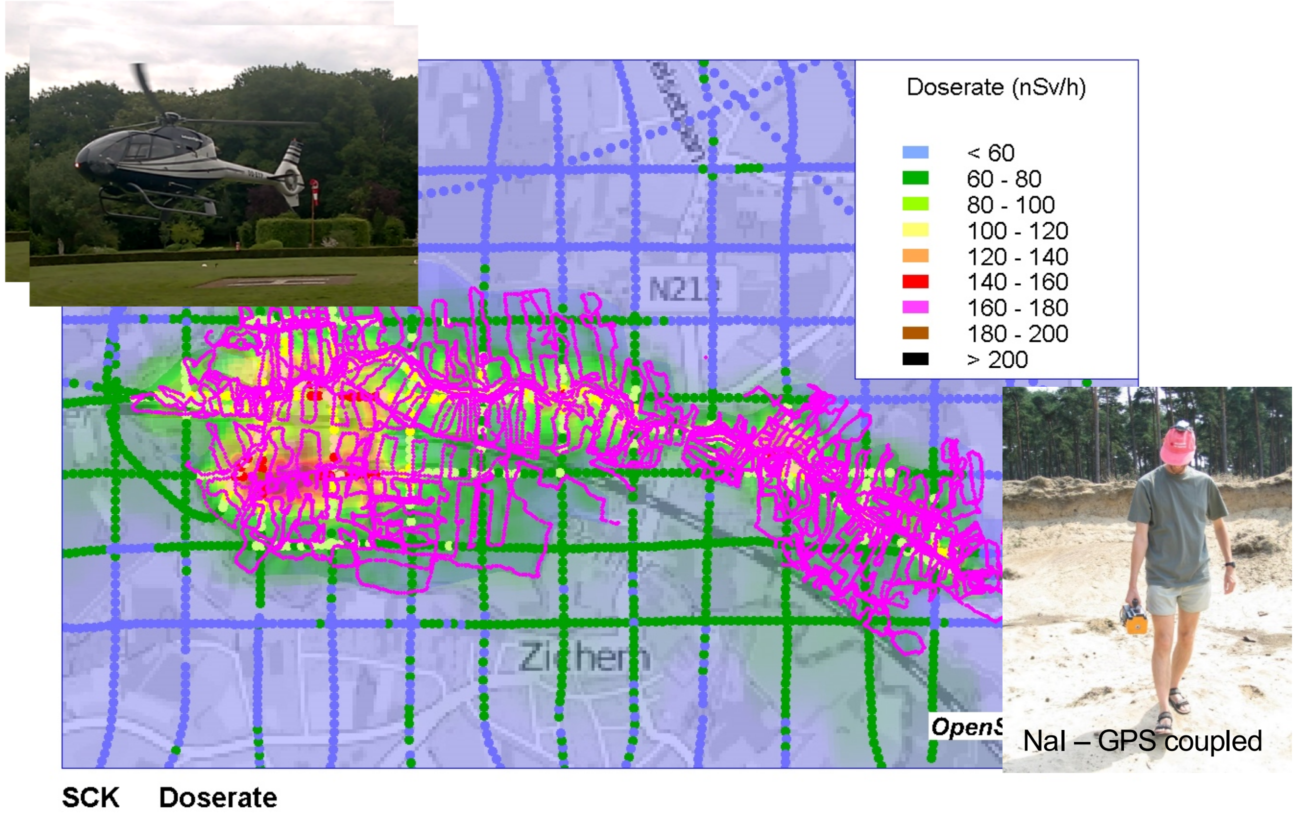
Effect of resolution:
example from mapping historic contamination

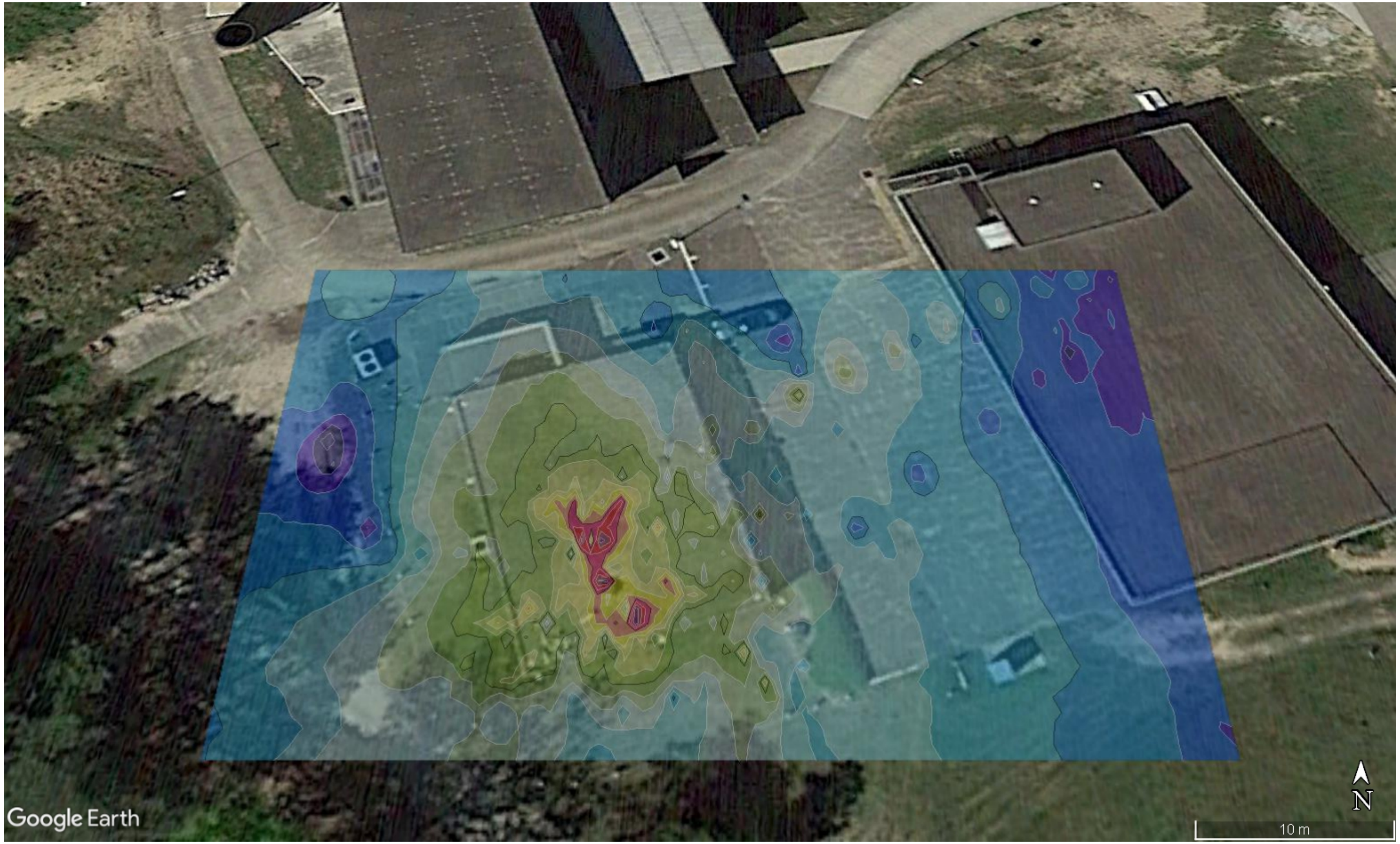


Historic Ra-226 contamination from liquid releases (originating from phosphate industry)

Developments at SCK•CEN

- Rotor-type drones (battery operated);
- 2 pilots trained and certified;
- 3 certified drones, typical payload < 2 kg;
- Radiological equipment currently used:
  - GM (dose rate);
  - CsI detector: 25.4 mm×25.4mm×51mm (Kromek);
  - CZT detector: 10 mmx10mmx10mm (Kromek);
- Tele-operated from ground, flight path planning currently on one drone;
- Direct communication of radiological results with ground station (own developments);
- Focus currently on better GPS positioning and altitude estimation (barometer, may-be laser in future);
- Collaboration with Civil Protection for demanding flights.

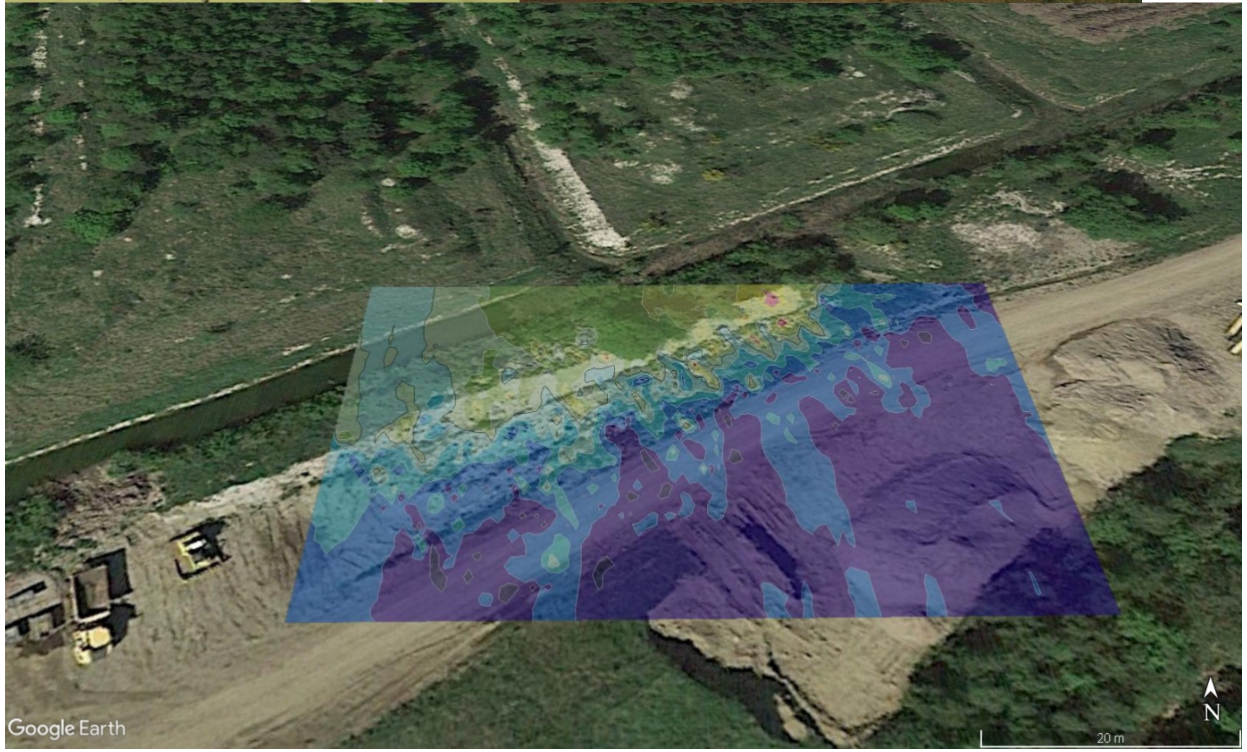
Point source: example inspection of buildings

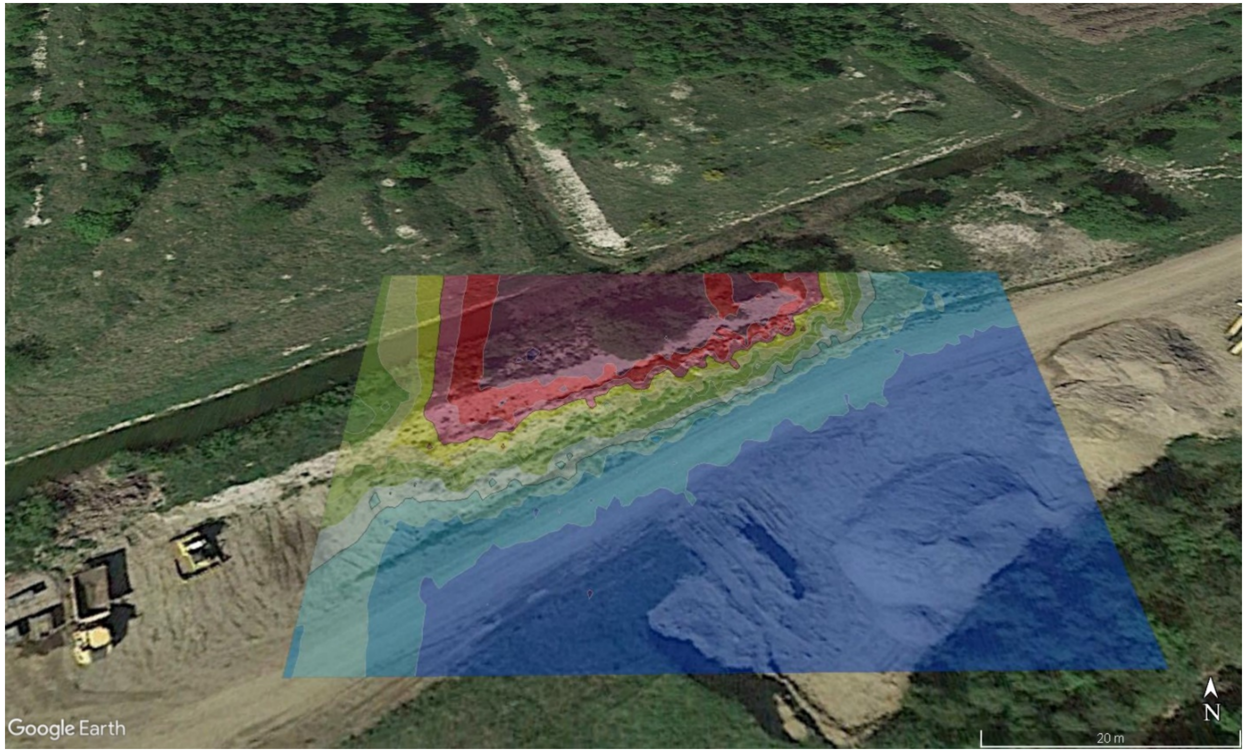


- Survey over a building
- Calibration and irradiation laboratory with limited roof shielding
- Use of GM
- Flight at +/- constant altitude (above ground)

Contamination mapping

Waste dump phosphate industry (Kepkensberg – radioecology observatory site – Ra-226)



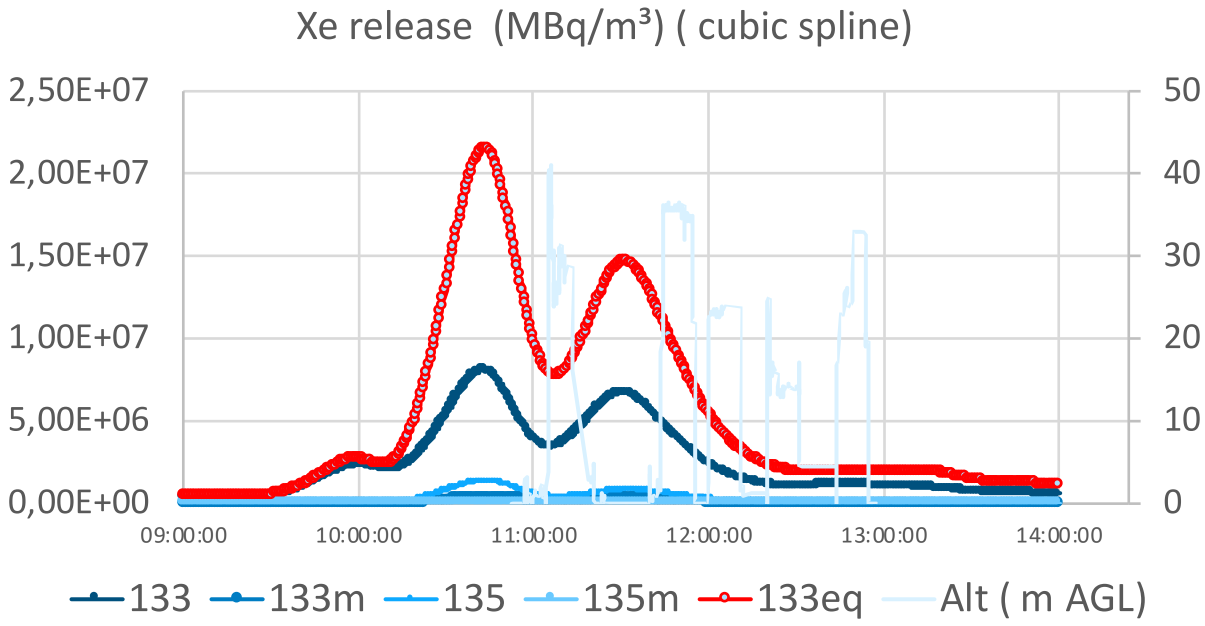


Drone survey (GM based) of part of the terrain at the interface contamination – no-contamination

Automess Ad-B (3”x3” Plastic detector) survey of same region (hand-held)

Radioactive plume

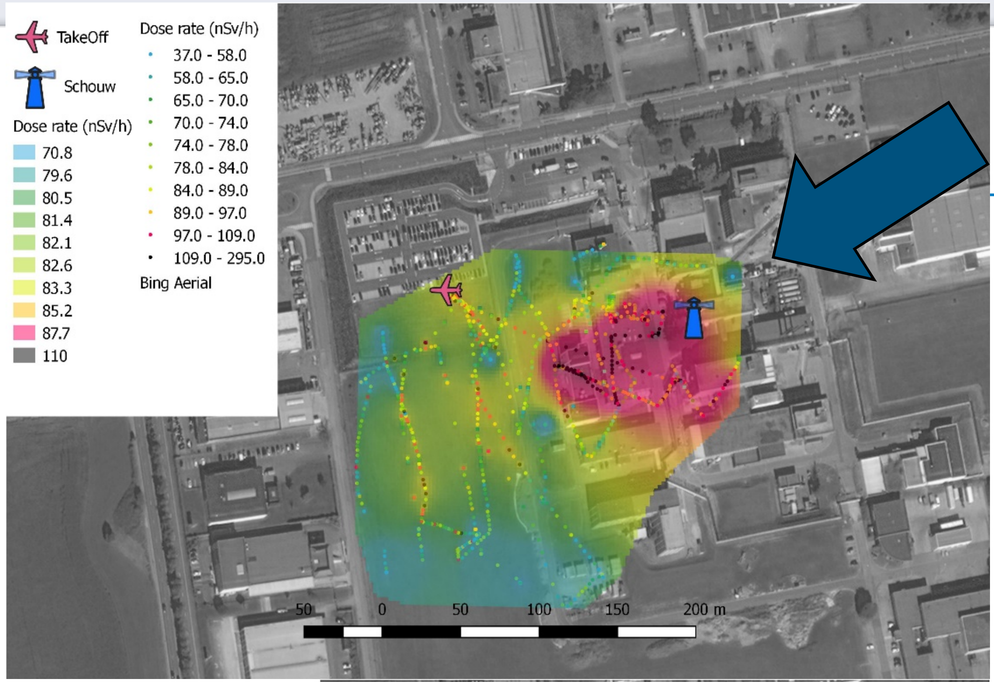
- Test flight near release stack (around 30 m high) at IRE facility during normal operation
- 15-minute resolution stack data on different radionuclides released

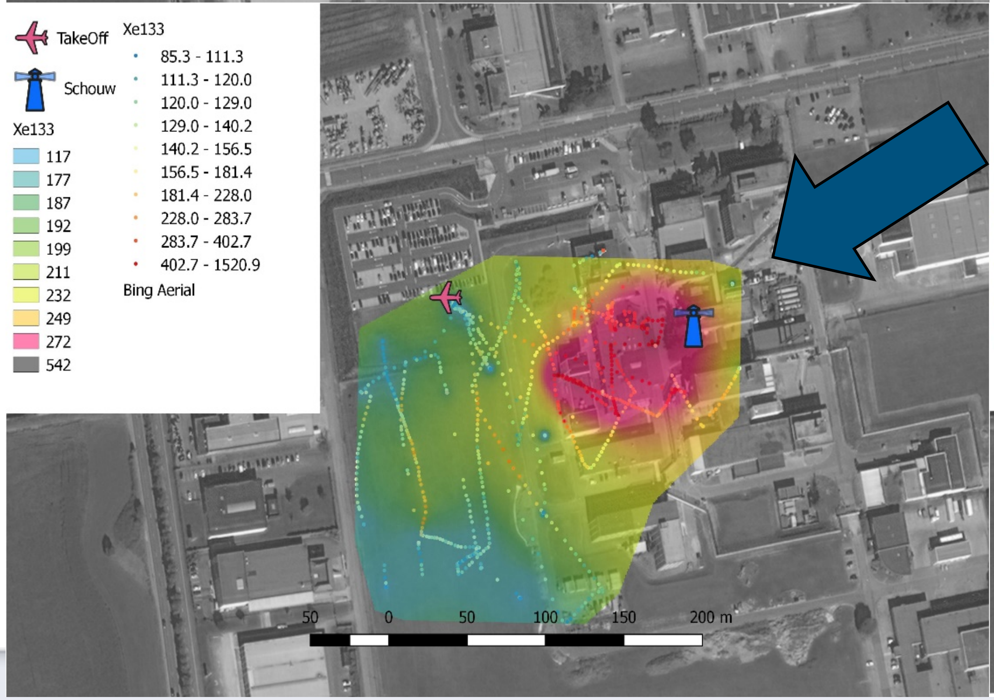


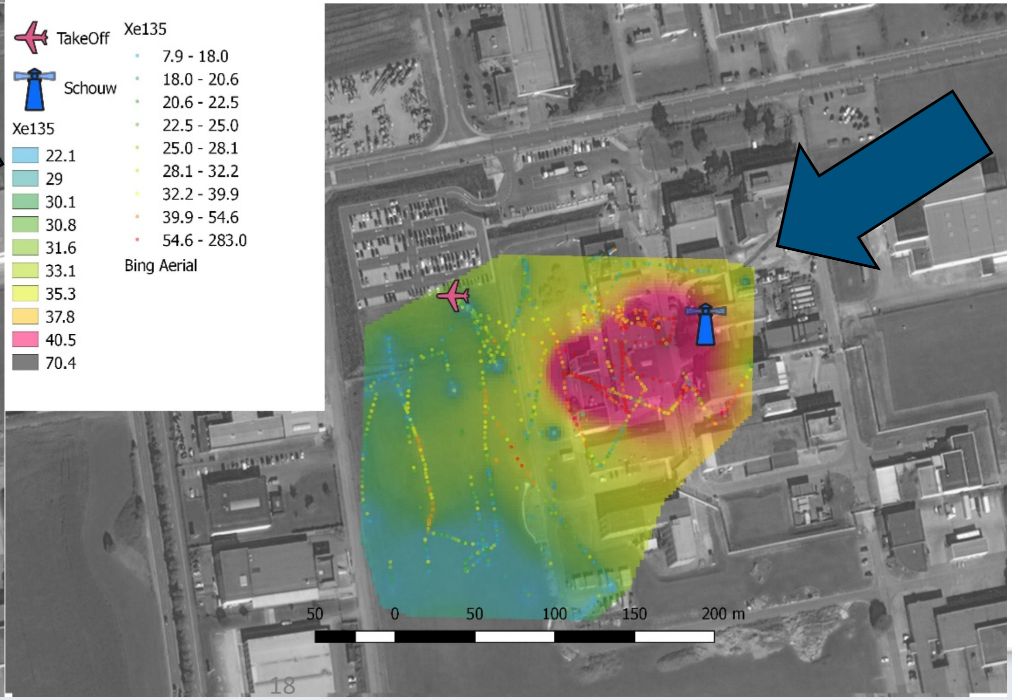
Stack Release Data, IRE (HPGe stack monitoring)

Radioactive plume

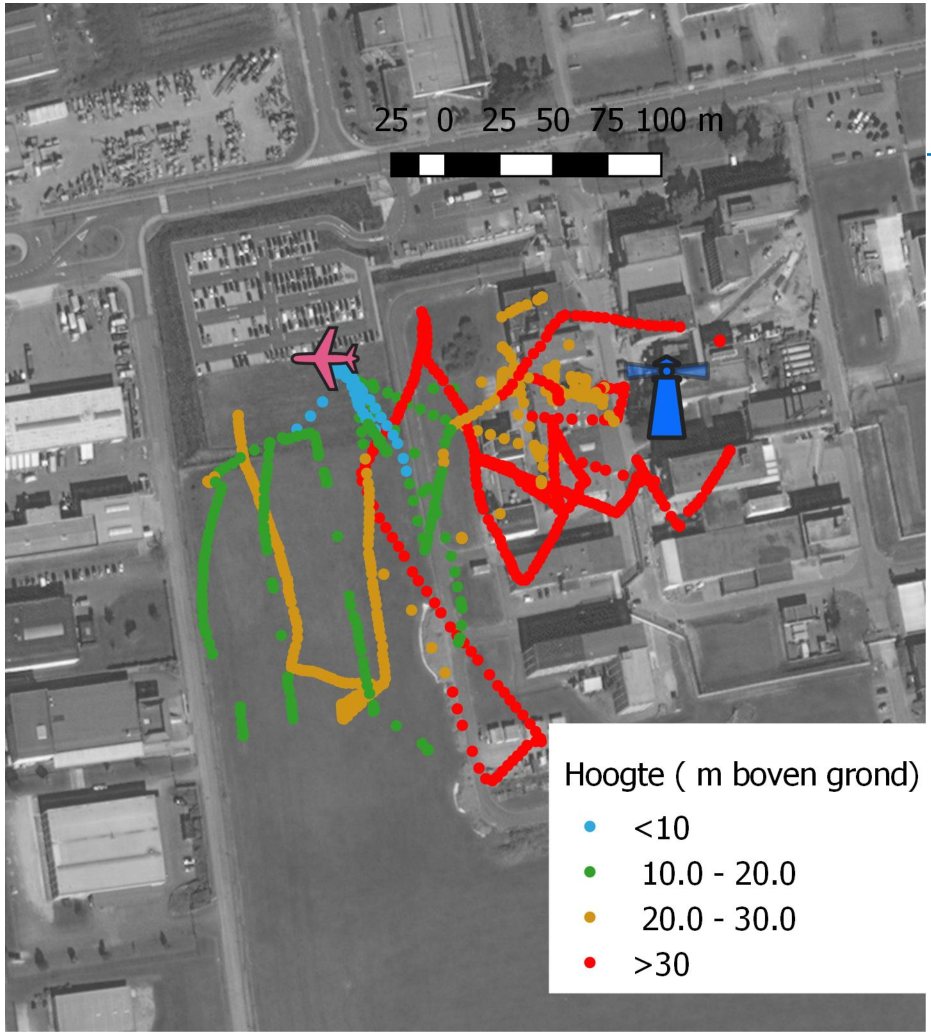
- Dose rate – Xe-133 and Xe-135 count rate during 5 short flights around release chimney
- Arrow gives on-site measured wind direction

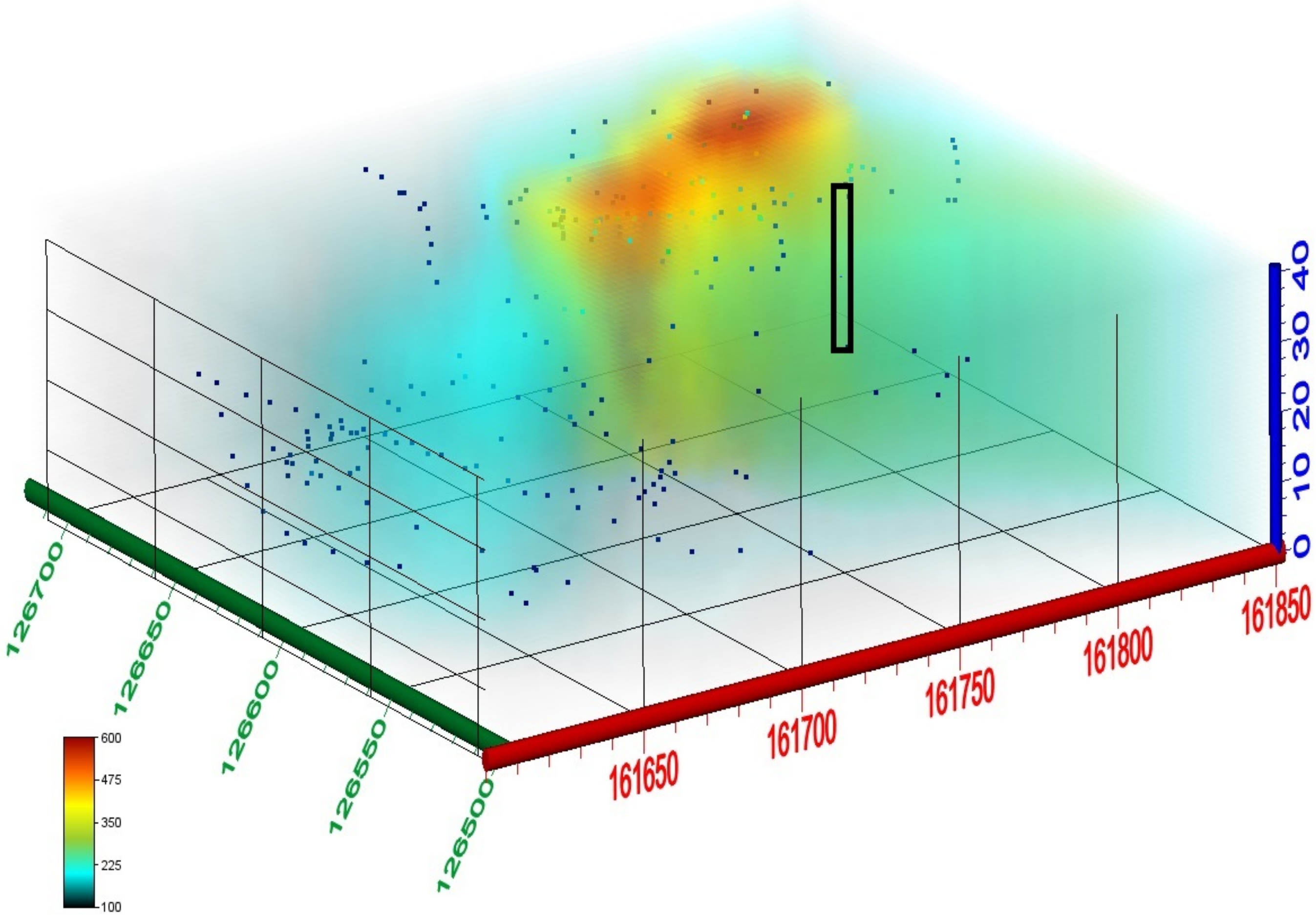






Plume reconstruction





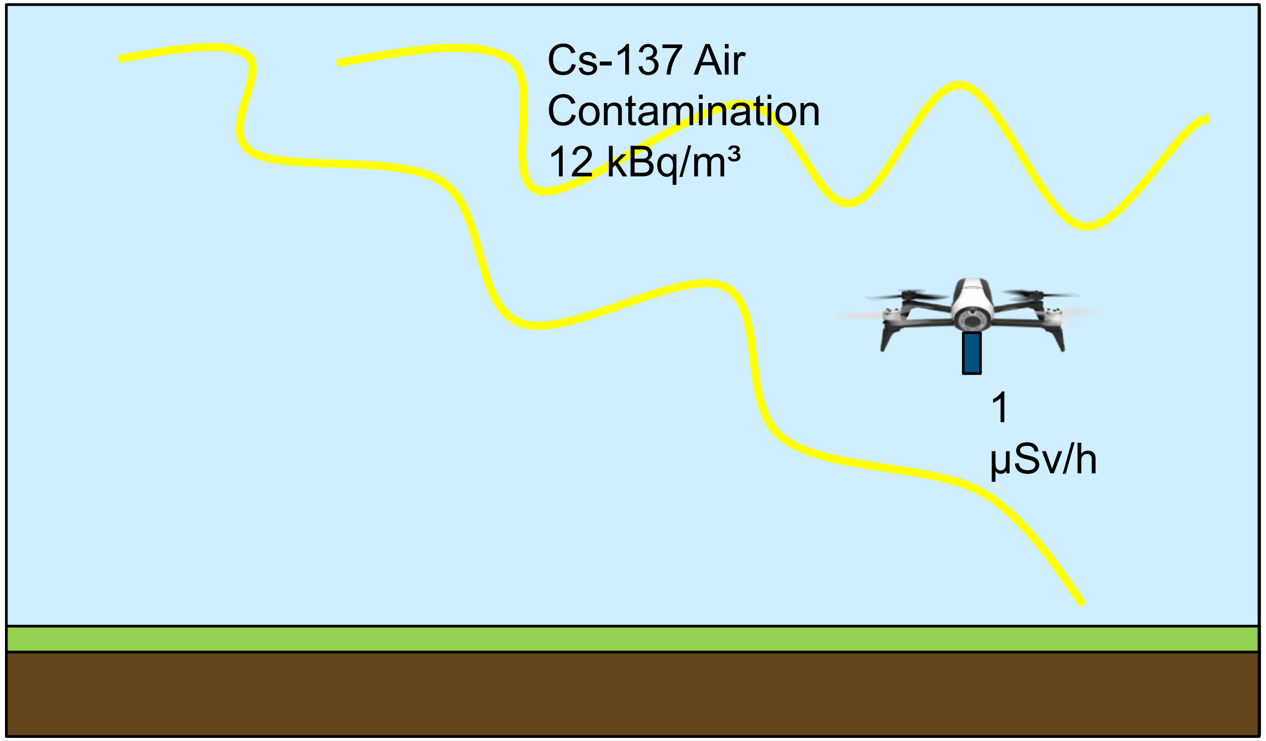
Plume reconstruction difficult due to large variation of source term during flight and limited 3-D coverage of region, however a downwash of plume seems to be present

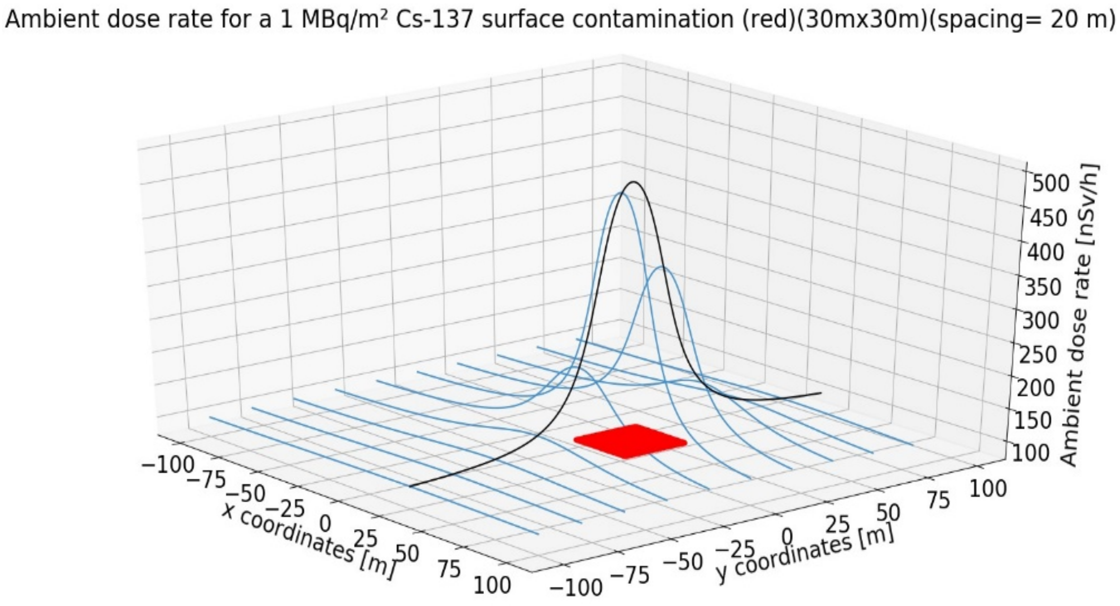
Unknown radiation exposure

How can drones help in the identification of unknown exposure situations

e.g. when first responders arrive at the scene

Scenario calculations → definition of flight paths allowing for discrimination between exposure pathways





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Outlook

- Most research directed towards rotor-type UAVs
- Not one optimal UAV solution for all radiological applications
- Most radiological UAV papers/studies deal today with a specific case: measurement of source, contamination, … or purely theoretical studies (source search algorithms, …): very important to explore potential use, pitfalls, (technological) challenges
- However, need for more systematic and quantitative studies (MDA, optimized flightpaths, …)
- Difficult to follow drone evolutions by radiation protection community

Thank you – questions?

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2/ EMPIR within the 16ENV04 PREPAREDNESS project: http://www.preparedness-empir.eu/