# Large Eddy Simulation of radioactive pollutant dispersion over an open field for time-dependent dose assessment

PUBLIC VERSION

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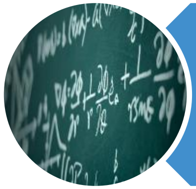
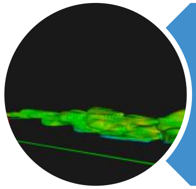
BVS-ABR Scientific Meeting
Brussels, September 19, 2014

# Content

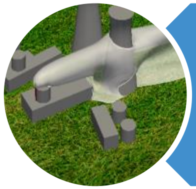
Introduction



Transport model



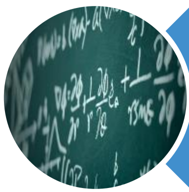
Case study



Ongoing research

# Content

Introduction



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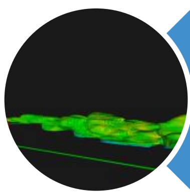

Case study

Ongoing research

# Personal background

- Master in Mechanical Engineering (2010)
- Master in Nuclear Engineering (2011)
- PhD program (2011-pres)

60 years of **experience** in nuclear research and technology

Most **recent** knowledge and development

**Innovative** projects

Availability of **large and unique nuclear installations**

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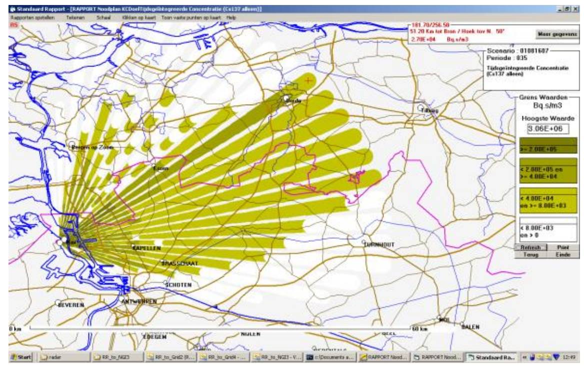
# SCK•CEN Academy
# 4 tracks

Manages all education and training activities – in the broadest sense:

1. Guidance young researchers
   - Thesis (PhD, Master, Bachelor level), post-docs, internships, educational visits
2. Organization of courses
   - Contribution to academic learning
   - Customized training for professionals
3. Policy support
   - Framework programs, H2020, expert groups of IAEA, OECD, …
4. Research transdisciplinary aspects
   - Scientific/technical + context! (ethical, economical, political, …)

# Accurate modeling results in effective countermeasures



Release of radioactive pollutants

- Controlled release
- Explosion
- Fire

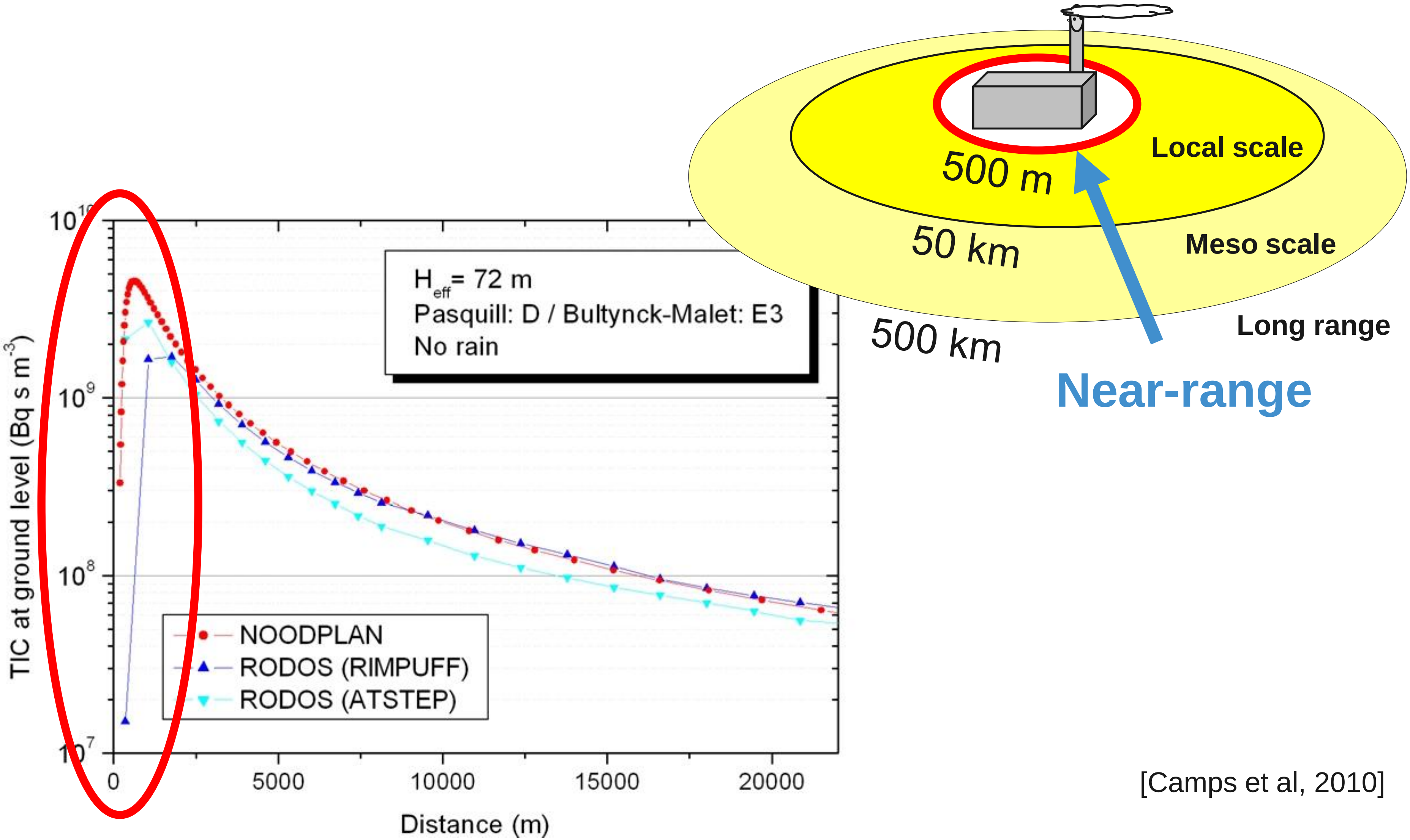
Dispersion simulation & dose estimation

- Link measurements to source term

Countermeasures

- Sheltering
- Evacuate
- Iodine intake

# Existing models not conclusive for the near-range




[Camps et al, 2010]

# Several applications for this model

- **Licensing phase**
  - Building configuration of new installations
- **Preparedness phase**
  - Positioning of monitoring stations
  - Drawing of evacuation routes
- **Response phase**
  - Source term estimation
  - Intervention planning

# Several applications for this model

- Account for
  - Complex air flow (~buildings, vegetation)

    → **Computation fluid dynamics (CFD)**
  - Variability due to atmospheric effects

    → **Large Eddy Simulation (LES) turbulence modeling**

**At the near-range, can we use instantaneous or time-averaged gamma dose rate measurements to estimate the skin dose rate or inhalation dose rate?**

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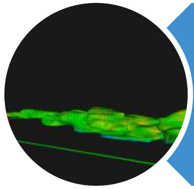
Transport model



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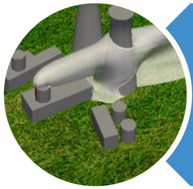


Ongoing research

- Time-dependent advection-diffusion with radioactive decay

$$\boxed{\frac{\partial c}{\partial t}} + \boxed{\nabla \cdot (\boldsymbol{u}c)} = \boxed{\nabla \cdot \frac{\nu_{sgs}}{Sc_{sgs}} \nabla c} - \boxed{\lambda c} + \boxed{S}$$

Turbulent diffusion

Source term

Convection

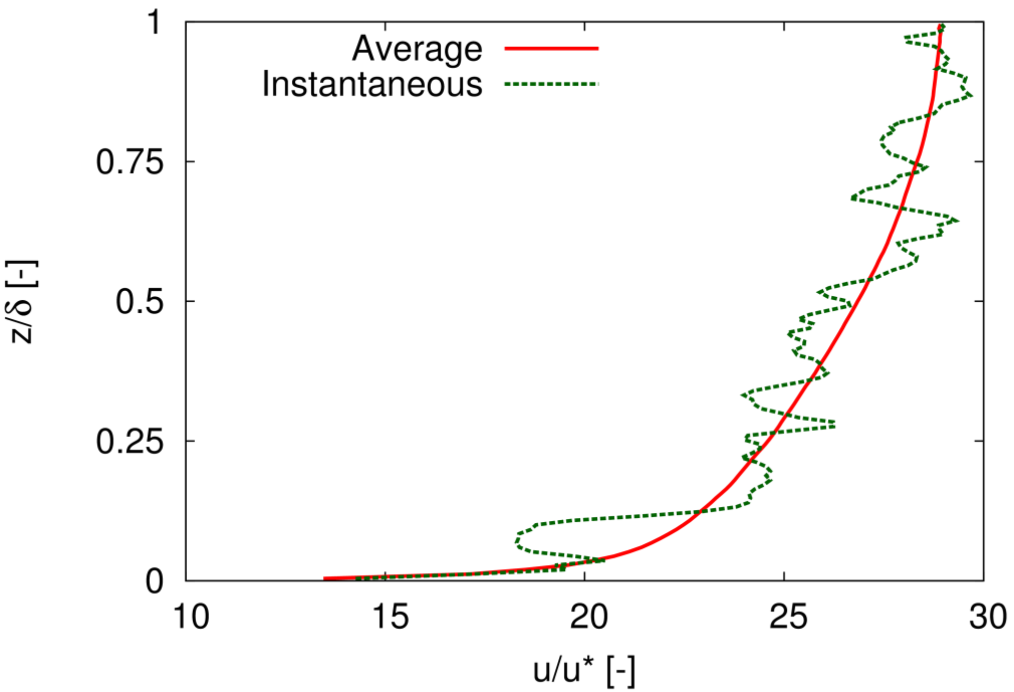
Local time derivative

Radioactive decay

- Assumptions
  - Neutral conditions
  - Non-reactive gas
  - No buoyancy or deposition

# CFD simulation of atmospheric boundary layer

- LES turbulence modeling
  - Lagrangian scale-dependent dynamic model [Bou-Zeid et al, 2005]
  - Resolve large scales of the flow field → $\boldsymbol{u}$
  - Model small scales → $\nu_{sgs}$




**No need for temporal meteorological wind field data**

- Gamma dose rate
  - Point-kernel method with buildup factors [Slade, 1968]

$$\dot{d}_{\gamma,x_0} \sim \phi(x_0, t)$$

Beta dose rate

- Range of $\beta$ particles in air = limited [Berger et al., 2000]
- Local cloud ~ infinite cloud

$$\dot{d}_{\beta,x_0} \sim c$$

Note: also inhalation dose rate ~ concentration [Slade, 1968]

# Content

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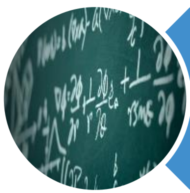

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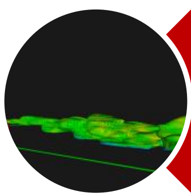
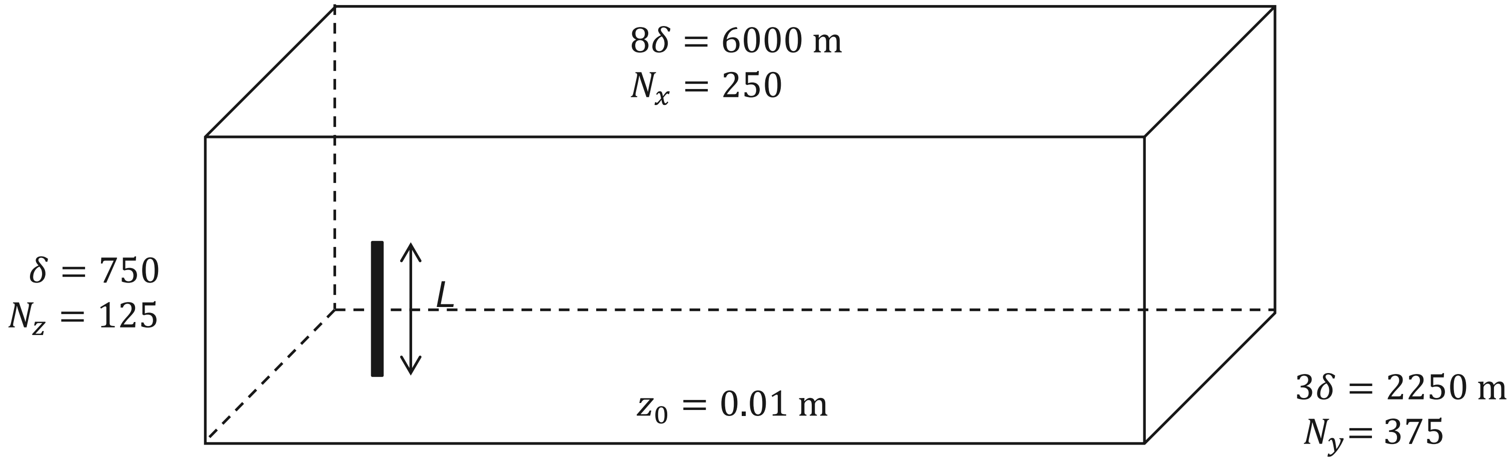


Case study

Ongoing research

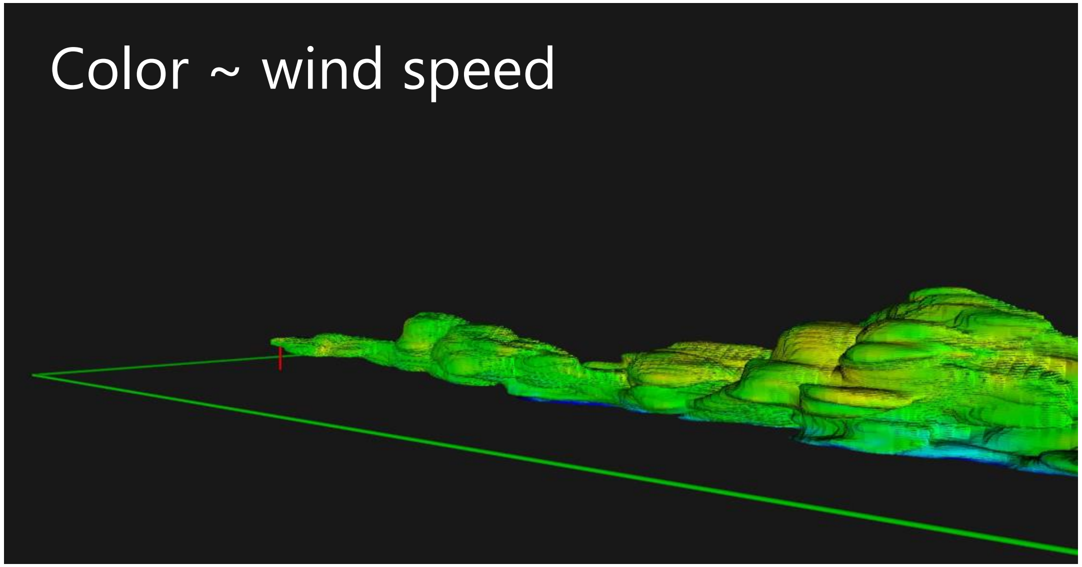
# Computational set-up

- Domain

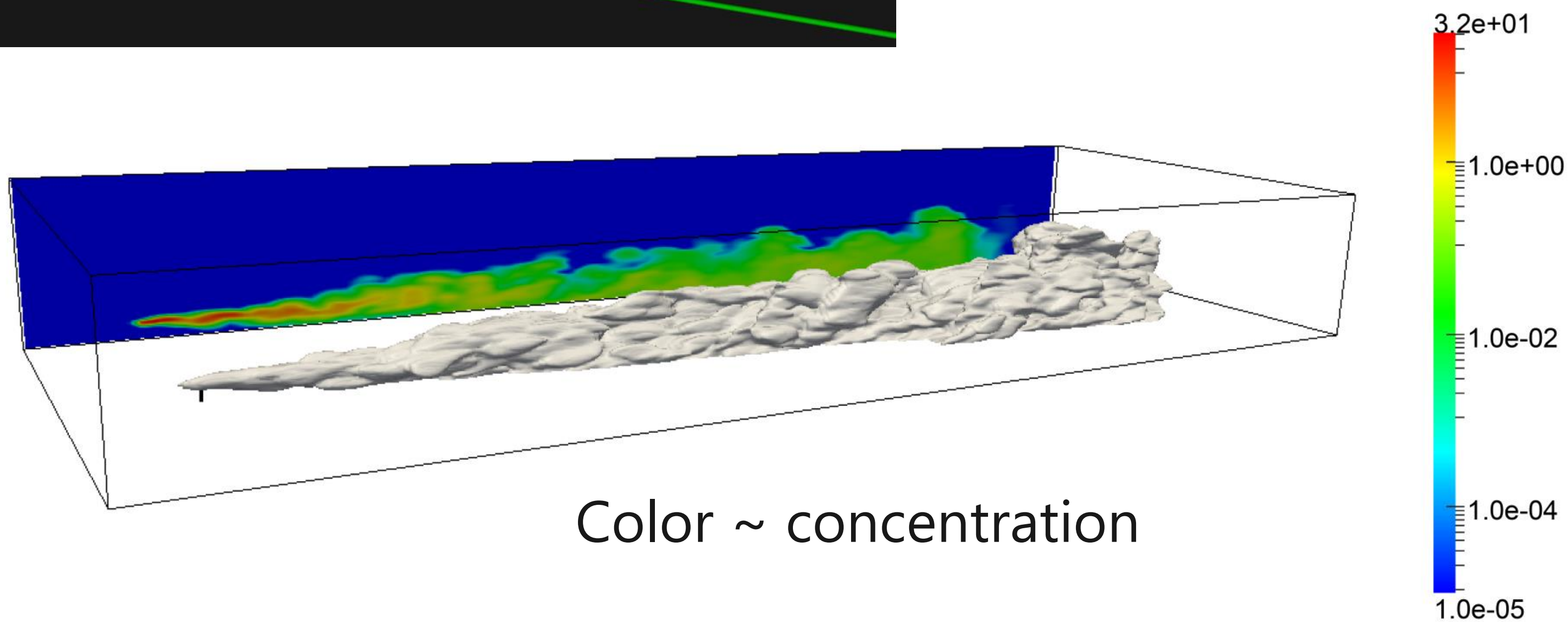



- Pollutants
  - Xe-133
  - Released from 75 m at constant rate
  - Observations at 1.5 m height
- Cluster setup
  - Vlaams Supercomputer Centrum (VSC)
  - 48 CPU
  - +- 4 week of computing

# Instantaneous concentration

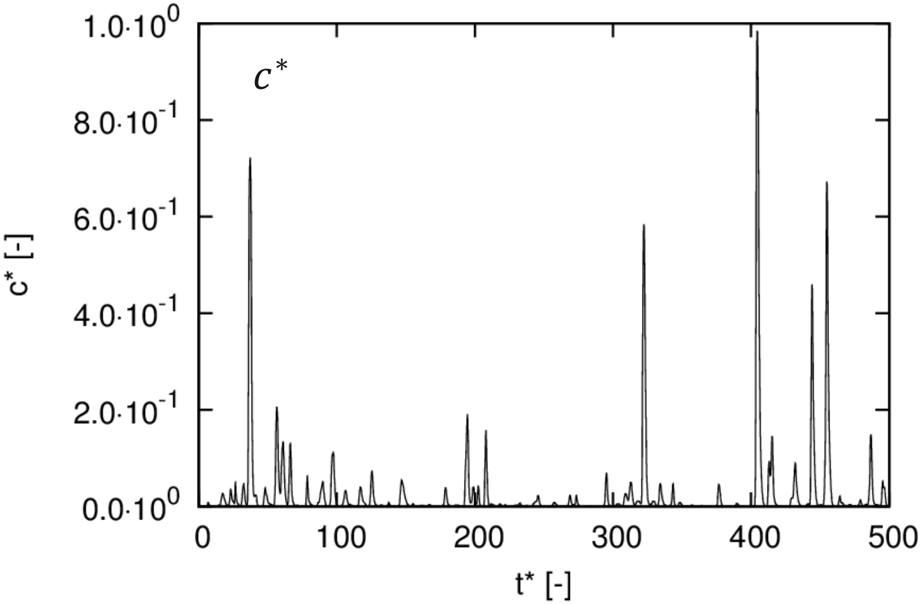


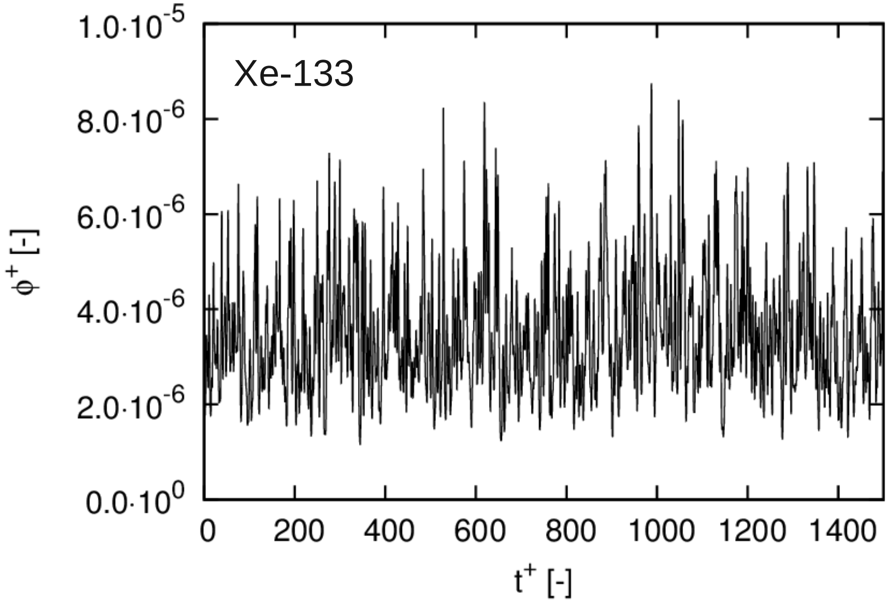

- Peak concentration near source
- Strong dilution with distance




Color ~ concentration

# Instantaneous observation at $x = 10L$




| Concentration (a) | Gamma fluence rate (b) |
|---|---|
| $c^* \approx 0$ most of the time | $\phi \neq 0$ |
| Large peaks at irregular time intervals | Noisy |

# Summary

- Large variation of the beta dose rate
- Limited variability of gamma dose rate
- Time-averaging does not help

**Gamma dose assessment at the near-range is not representative for the skin dose rate and inhalation dose rate**

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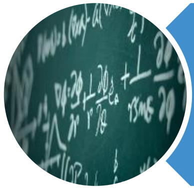

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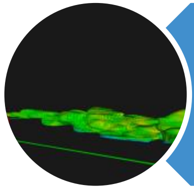
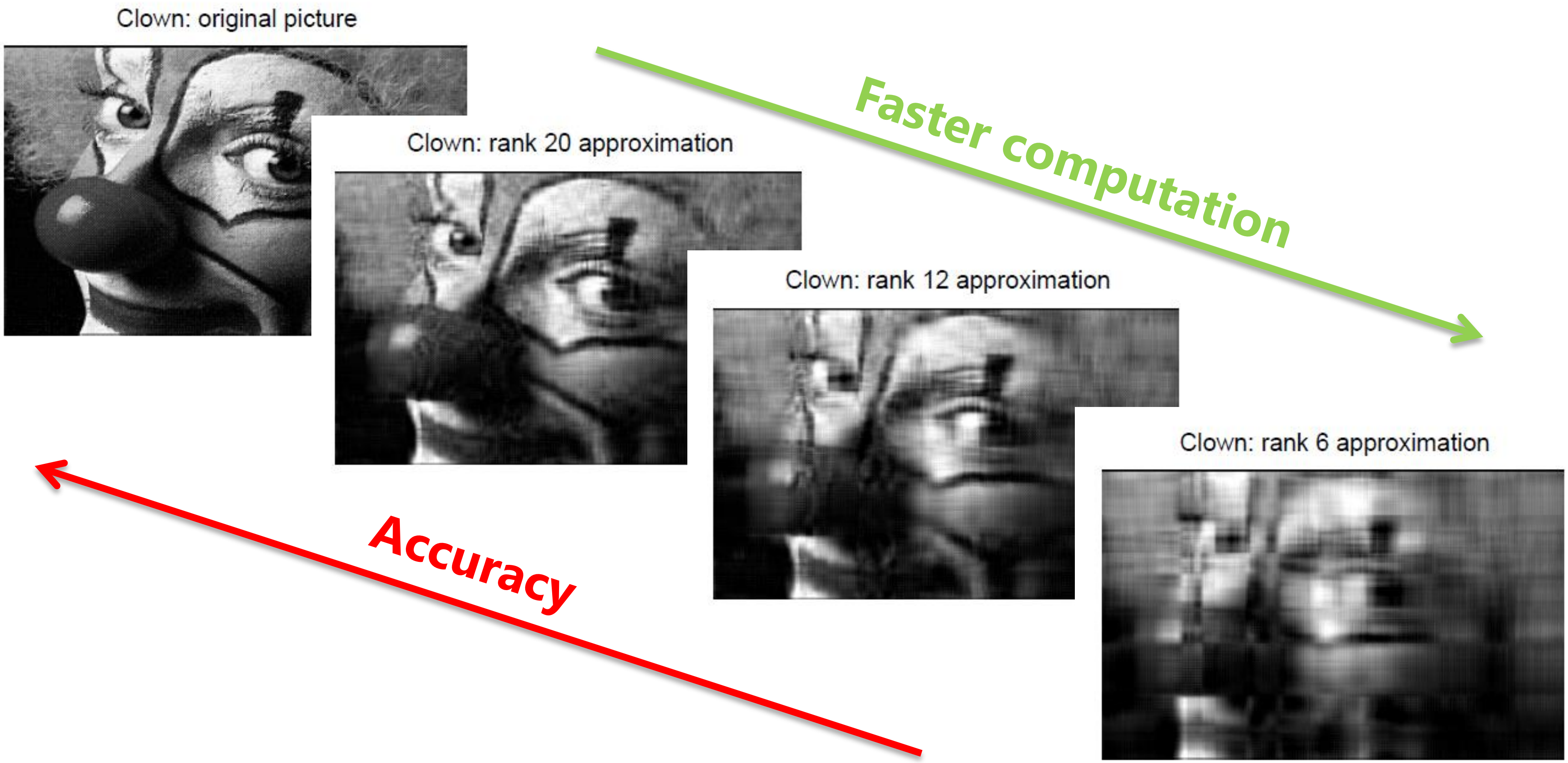


Case study

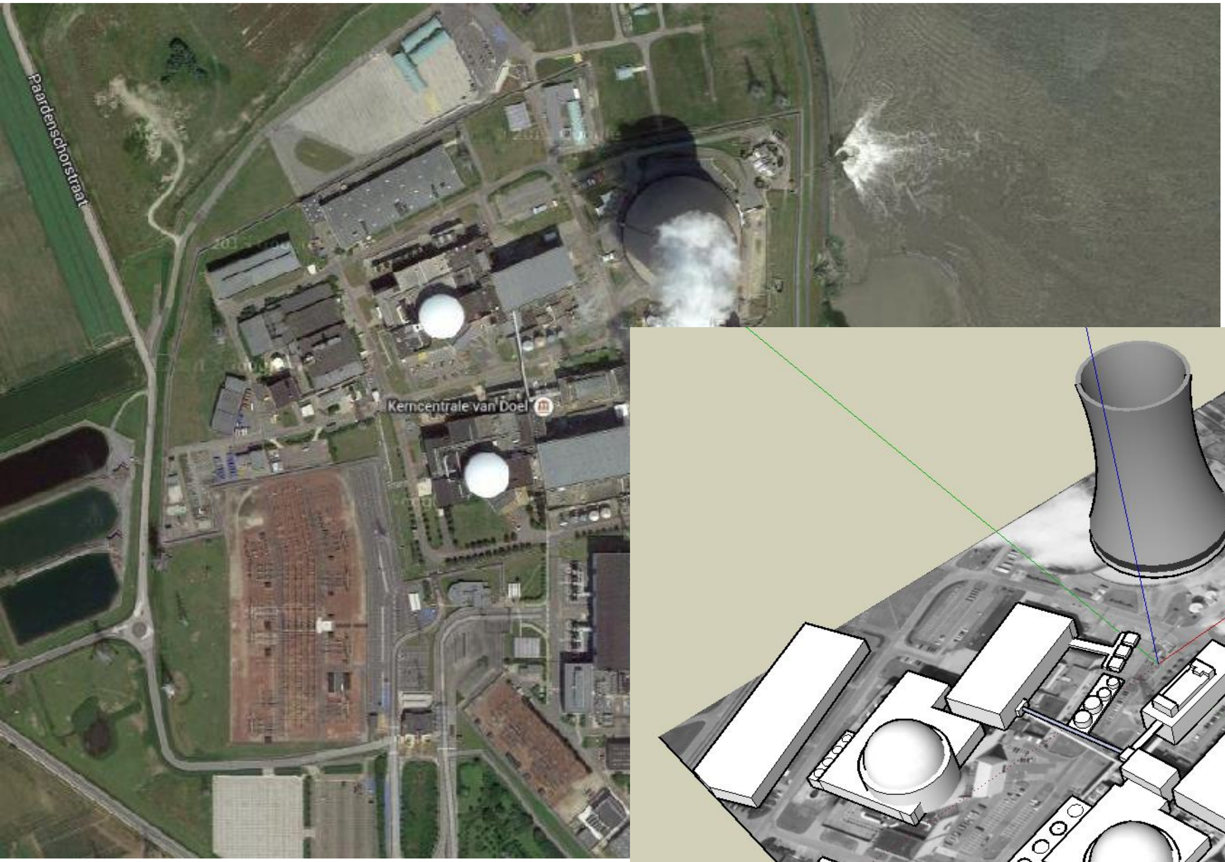
Ongoing research

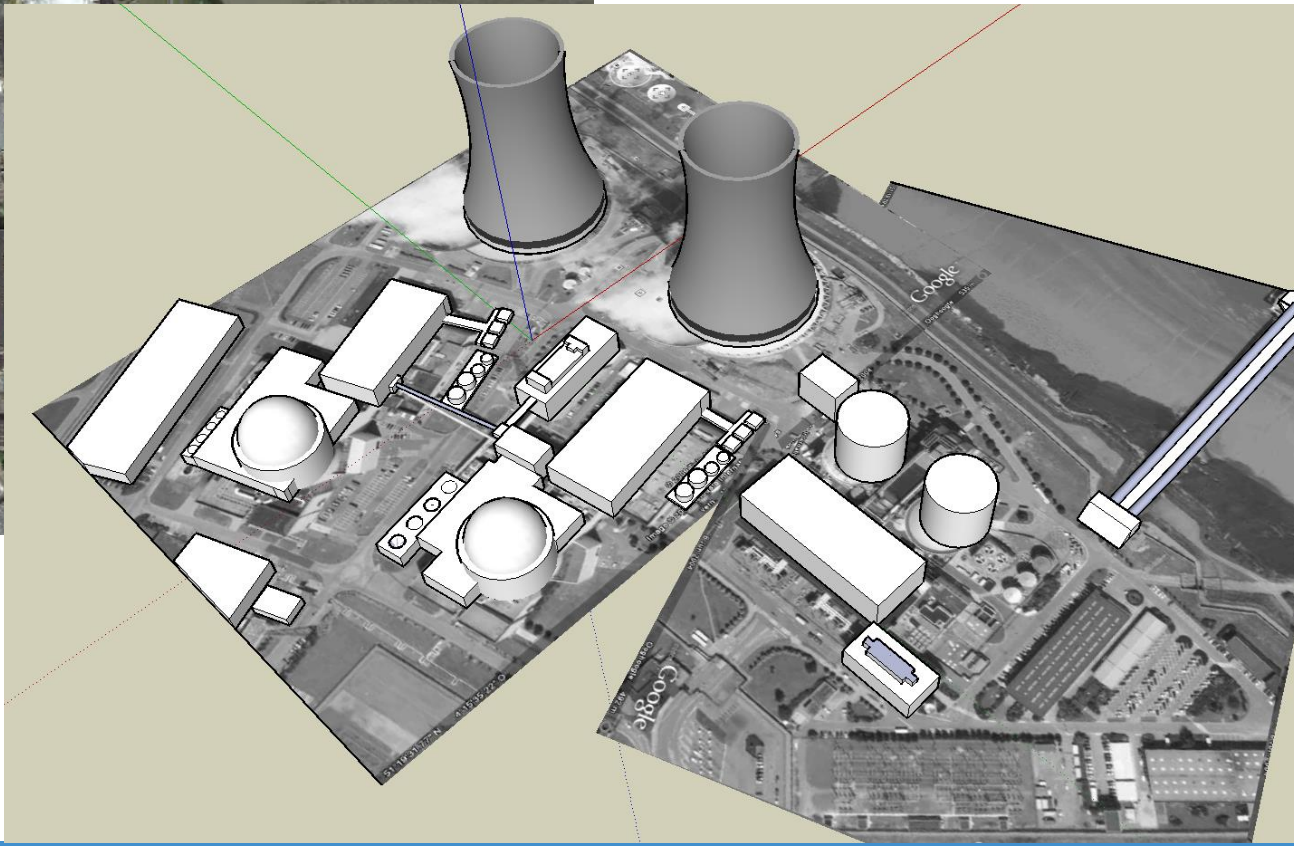
# Model reduction

- Very long simulation time
  - = Not suited for emergency response phase



# Case study: Doel Nuclear Power Station



# Release from Doel 3

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