Near-range Gaussian plume modelling for γ dose rate reconstruction

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Introduction

When it comes to nuclear or radiological emergency planning or actual emergencies, atmospheric dispersion modelling is an indispensable tool for impact studies.

Many radionuclides emit γ radiation (0.1–10 MeV photons). If such γ emitters are suspended in a plume, radiation is measured at ground level. On-site dosimetry (e.g. TELERAD) can thus be used to quantify dispersion.

Objectives

Our goal is to demonstrate that, using our dispersion model, we can obtain results consistent with measured meteo, source and dose rate.

The longer-term aim of this PhD project is to improve near-range modelling by actively using env. observations

Dispersion model

The atmospheric dispersion model used in this study consists of the following main elements:

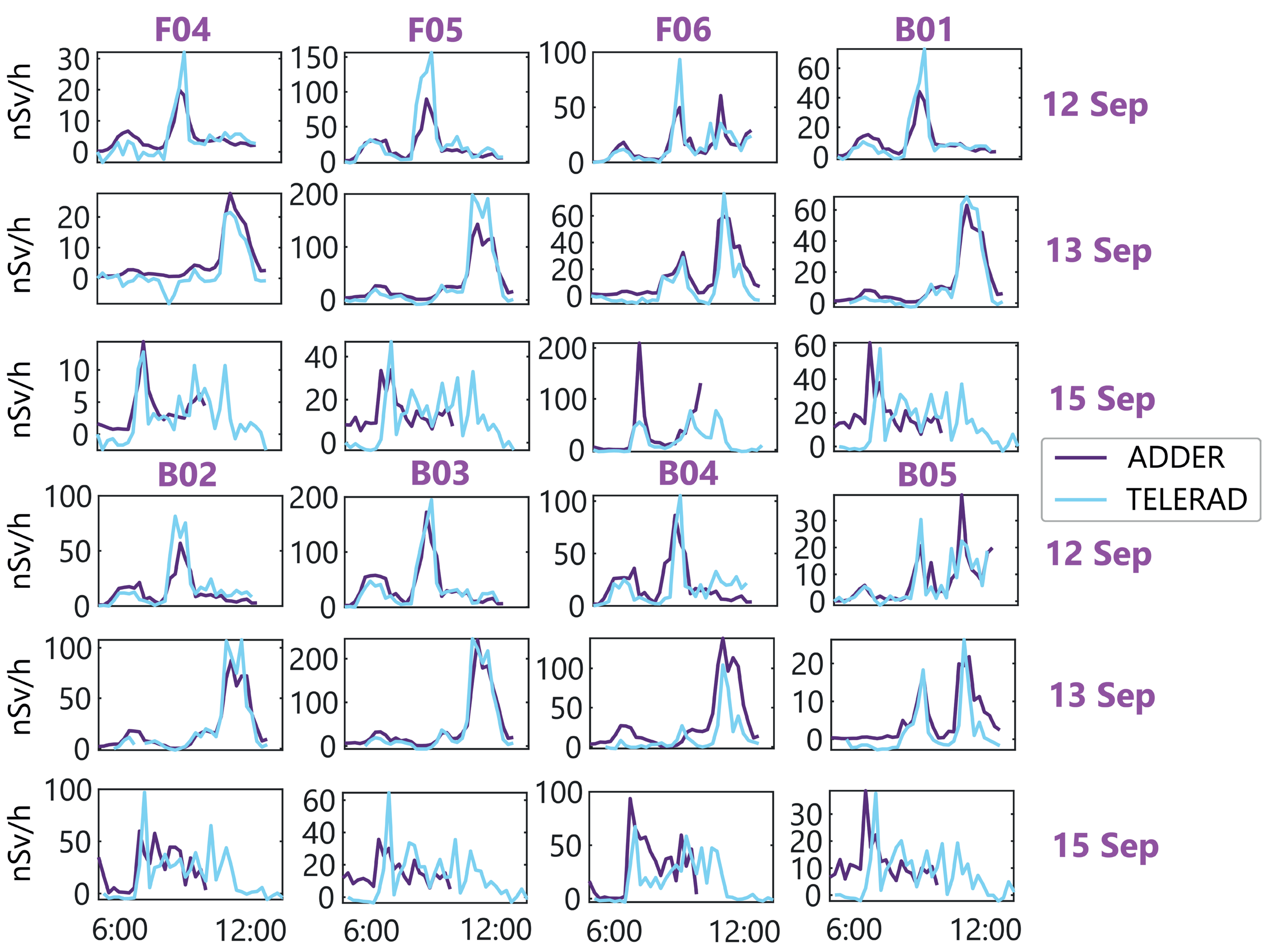
- 3D-resolved bigaussian plume
- ground and boundary layer reflection
- Site dispersion parametrisation (Bultynck & Malet, 1972)
- buoyant plume rise (Briggs, 1971)
- cloud-integrated dose rate (Healy & Baker, 1968)

$$\frac{\partial}{\partial t} H^*(10) = \sum_{\gamma} C_\gamma I_\gamma \left[\frac{\mu_{\mathrm{en}} K E_\gamma}{4\pi\rho} \iiint \frac{B(\mu r)\exp[-\mu r]}{r^2} \chi(\mathbf{r}')\mathrm{d}\mathbf{r}' \right]$$

Python code available

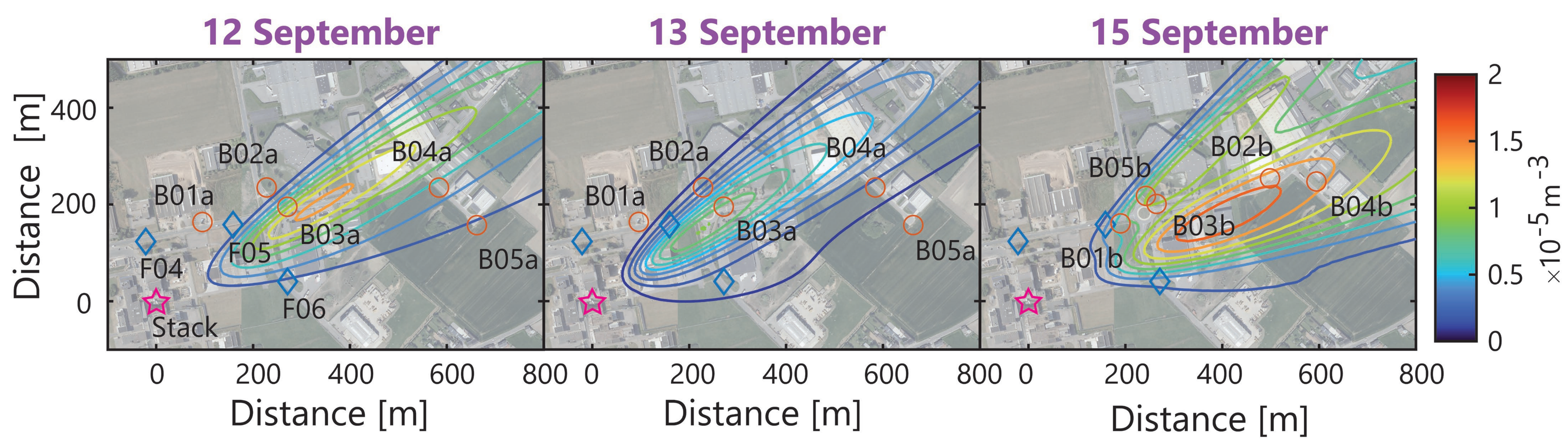
Our code, Atmospheric Dispersion and Dose Equivalent Rates or simply ADDER, can be found online on Gitlab. Scan the QR code to the right or surf to:
https://gitlab.com/jpfr95/ADDER

Application to routine emission



$\dot{H}^*(10)$ of a xenon plume was measured using fixed (F) and mobile (B) TELERAD stations at IRE in 2017 (Camps et al, 2019). Online source term (15-min rep.) and meteo (30-m, 10-min rep.) were also monitored. Stability (stable to neutral) was determined off-site. For the IRE case, ADDER was able to reproduce the measured $\dot{H}^*(10)$. In another case, BR1, ADDER underestimates $\dot{H}^*(10)$ by a factor four in keeping with Bijloos et al (2020)*

◀ **Figure 1** Measured $H^*(10)$ versus ADDER simulations on all three days for all detectors.
Figure 2 ▶ Footprint of a unit release on all three days imposed on a map of the area.



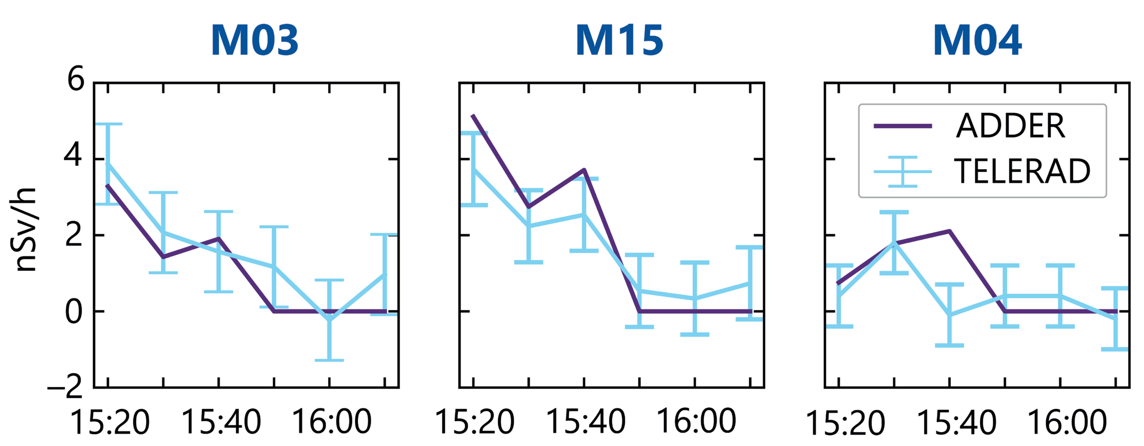
*For details, refer to the Extended Abstract or ask me about it!

Application to a new dataset (Frankemölle et al, 2022)

An incident at BR2 caused the release of radioactive selenium-75 to the atmosphere in 2019. During impact analysis, a rich dataset was obtained. Frankemölle et al (2022) have shown this dataset to be largely consistent.

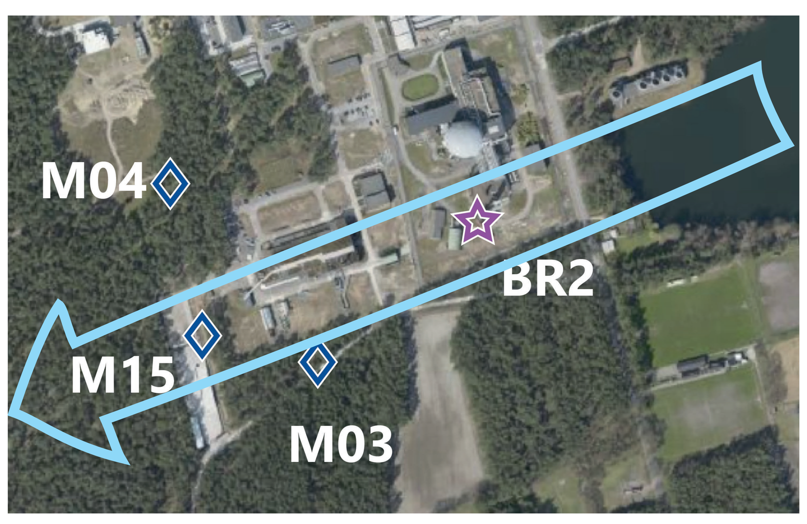
Additionally, meteo, source term, dose rate, deposition and concentration data are now publicly available. Below, we show that TELERAD-measured $\dot{H}^*(10)$ is well-reproduced by ADDER.

10.5281/zenodo.7019239



◀ **Figure 3** Background-subtracted H*(10) at three different detectors. Measurements in blue match simulations in orange very nicely. Error bars indicate 95% confidence interval of the average background.

Figure 4 ▶ Locations of the four detectors and of the BR2 stack. Distances between all three detectors are approximately 300 m. The wind was blowing from ENE at around 6.3 m/s. The atmosphere was slightly unstable. Stack height is 60 m, gas outflow rate of 150,000 m^3/h and assumed temperature of 15°C.



Conclusion and outlook

With ADDER, we can reconstruct γ dose rates using available meteo and stack data.

The next question is if we can also get adequate results in case of missing or wrong data. We are looking into data assimilation or Bayesian inference schemes to find out.

Briggs, G.A. in Englund, H. M. and W. T. Beery (eds.), *Proceedings of the Second International Clean Air Congress, Academic Press, New York*, 1029-1032 (1971) | Bijloos, G. et al, *J. Environ. Radioact.* **225**, 106445 (2020) | Bultynck, H. and Malet, L.M., *Tellus*, **24**, 455-477 (1972) | Camps et al, *5th NERIS Workshop, Roskilde, Denmark,3–5 April* (2019) | Frankemölle, J.P.K.W, et al, *J. Environ. Radioact.*, in print (2022). | Healy, J.W. and R.E. Baker in Slade, D. H. (ed.), *Meteorology and atomic energy*, 301-377 (1968).