CIThARA WP3: AI-based long-range surrogate atmospheric dispersion modelling and advanced inverse modelling

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Context: CIThARA 1st specific objective (SO-1)

- To develop and validate AI-driven modelling methodologies for:
  - rapid forecast of radiological consequences related to atmospheric dispersion and deposition of radionuclides
    - In near ranges – complicated geometries
    - In medium and far range – spatial- and time-varying meteorological fields
  - fast localisation and quantification of unknown sources of radionuclides emissions in the medium and far ranges
  - inclusion of different types of uncertainties in the above processes

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Context: Inverse modelling

- Estimate source parameter vector that best explains observations... taking into account the combined measurement and model uncertainties
- Model uncertainties can have a profound impact on inverse modelling & are hard to quantify (typically done using ensembles but computationally demanding)
- How to combine different types of observations in a statistically sound way?

- ➢ adjoint modelling (if available and relatively few observations)
  fast & accurate
- ➢ forward modelling
  accurate but can be computationally demanding
- ➢ forward modelling using surrogate model
  fast [?!], accurate?

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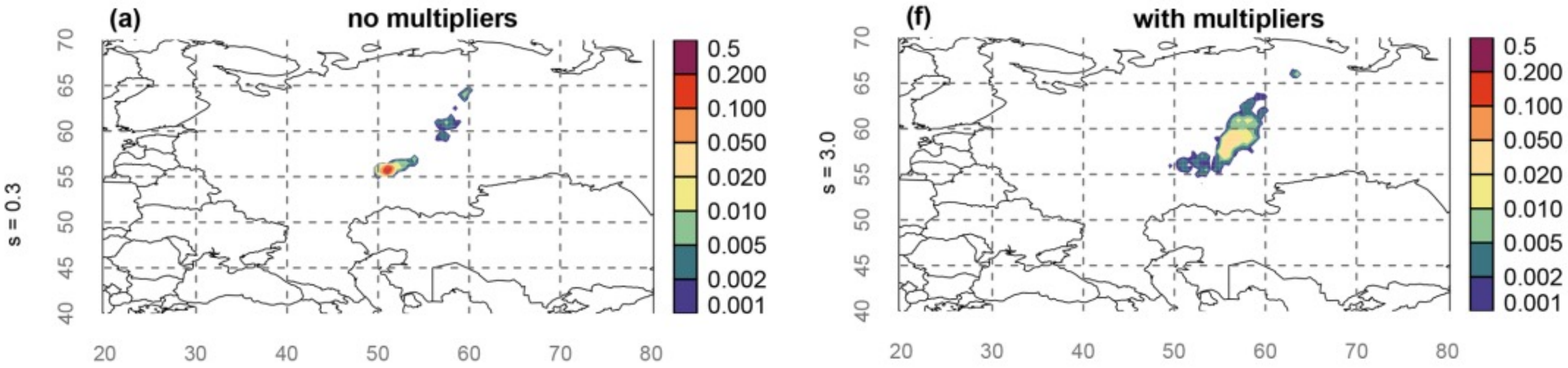
Context: Model uncertainty can have a profound impact on event analysis and reconstruction



Source location inference assuming low model+measurement uncertainty (left) and high model+measurement uncertainty (right) for the same observations and the same ATM output
(De Meutter et al., 2021)

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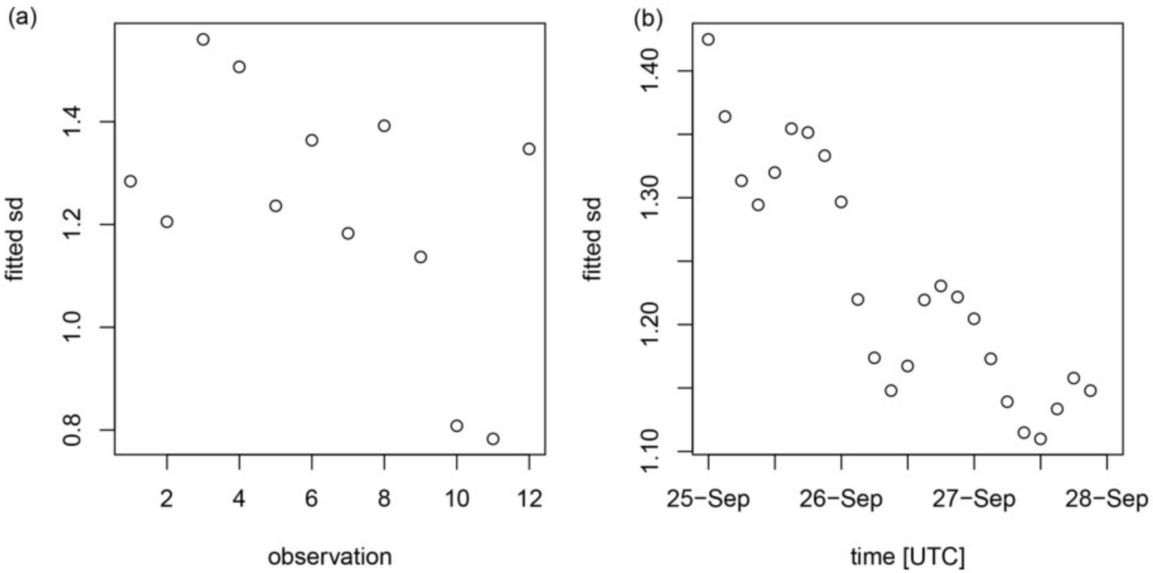
Context: Model uncertainties are hard to quantify



Meteorological uncertainty varies in space and time
(De Meutter et al., 2021)

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WP3 overview (Lead SCK CEN; Partners ASNR, BfS, ISS, MET, NCBJ, NCSRD)

Surrogate modelling will be developed to quickly evaluate long-range atmospheric dispersion of radionuclides. The speed-up from the surrogate model compared to traditional physics-based models will subsequently be used for computationally demanding applications:

1. uncertainty quantification
2. inverse modelling, where a large number of unknown source parameter configurations need to be evaluated

Two tasks:

T3.1 AI-based long-range surrogate atmospheric dispersion modelling – development, training and validation (lead: NCBJ)

T3.2 AI-enhanced advanced inverse modelling (lead: BfS)

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T3.1 AI-based long-range surrogate atmospheric dispersion modelling – development, training and validation

- The objective is to create surrogate models for atmospheric dispersion of radionuclides
- Due to the relatively small number of relevant real-world observations, training and validation will be performed using physics-based model output only
- Use case: hypothetical release from the Zaporizhzhia nuclear power plant following war-related damage
- Focus initially on noble gases, later also iodine and aerosols
- The necessary input for the surrogate model will be assessed as part of the project
- The surrogate model should output hourly activity concentrations in the lowest ~O(100 m), [dose rate maps] and total deposition if applicable

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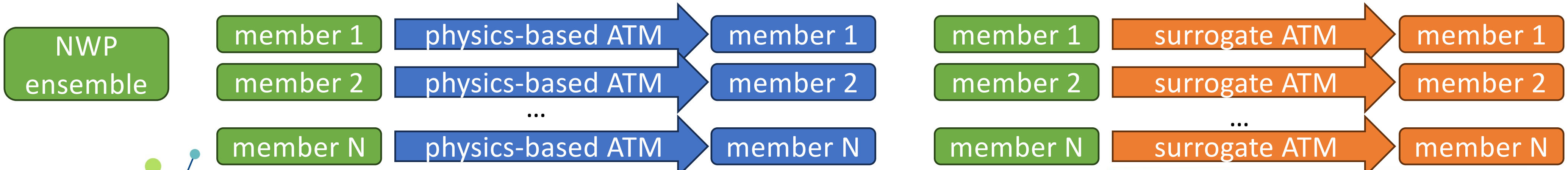
T3.1 AI-based long-range surrogate atmospheric dispersion modelling – development, training and validation

A few research questions:

- What is computationally possible in terms of simulation lead time / output domain size?
- Once trained, will the surrogate model work for other nuclear facilities within [/ beyond] Europe?
- Can it propagate uncertainty from an NWP ensemble similar to physics-based models?
- …



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T3.2 AI-enhanced advanced inverse modelling

Existing state-of-the-art inverse modelling algorithms will be adapted to

1. take into account model uncertainty and
2. take into account multiple sources of observations in a consistent way

… using the surrogate models from T3.1

T3.2 AI-enhanced advanced inverse modelling

Definition of scenarios and calculation of synthetic data

- Synthetic observational data, nuclide-specific activity concentrations and gamma dose rates, will be generated using physics-based models.
- Results from WP2 will be used to assist in generating synthetic observation data derived from citizen input.

Inverse modelling using surrogate modelling and ensembles

- Inverse modeling using nuclide-specific activity concentration data.
- In-depth exploration of meteorological uncertainty aspects within inverse modelling.

Advanced inverse modelling using surrogate modelling and citizen measurements

- Inverse modelling for more complex compositions of the nuclide vector using synthetic gamma dose rate measurements and simulated citizen measurements, considering variation in quality.
- Explore identification of the source term composition.

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Thank you for your attention

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