PhD proposal — Using Statistical Emulators to Quantify and Understand Urban Climate Risks

NERC CDT UNRISK
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Overview

Cities face rising risk from heatwaves and flash floods. High-fidelity simulators capture these hazards in detail but are computationally expensive, limiting scenario exploration and uncertainty quantification. This PhD will develop multi-fidelity statistical emulators (Gaussian process families), cost-aware adaptive experimental design, and explainable AI methods to make urban climate simulators usable for large-scale UQ and decision support. Deliverables include validated emulators for flood and heat case studies, open-source code, and stakeholder briefs that translate uncertainty into action.

Role highlights — what you will do

- Develop and validate multi-fidelity emulators for urban climate and hydrodynamic simulators with calibrated predictive uncertainty.
- Design sequential/adaptive experimental strategies (cost-aware acquisition) to maximise information per simulation cost and choose fidelity adaptively.
- Integrate explainability and sensitivity analysis (global/local) to produce trustworthy, actionable explanations for decision makers.
- Apply methods to two or more urban case studies (heat and flood), co-produce outputs with stakeholders where possible, and release reproducible software.
- Publish results and present to academic and practitioner audiences.

Position & how to apply

- Fully funded NERC CDT UNRISK scholarship.
- Interdisciplinary training across climate science, data science and decision science; collaborations with Exeter and Toulouse.
- Opportunity to deliver research with direct policy and operational relevance for urban resilience.

• Full project details: unrisk-cdt.ac.uk/projects/using-statistical-emulators-to-quantify-and-understand-urban-climate-risks/
• Application guidance: unrisk-cdt.ac.uk/application-process/

Candidate profile — key skills and interests

Ideal applicants will be curious, motivated and keen to bridge computation with societal impact. Essential and desirable skills:

- **Essential:** STEM degree (statistics, mathematics, computer science, environmental modelling or related). Proficiency in scientific computing (Python, Java, R or equivalent). Foundations in optimisation, statistical learning and machine learning.
- **Desirable:** Experience with simulation models (hydrodynamic, climate or agent-based), geospatial data/GIS, Gaussian process libraries (e.g. GPyTorch) and Bayesian optimisation toolkits (BoTorch, Emukit).
- Interest in interdisciplinary, impact-led research connecting methods to urban resilience and decision making.

Research context & motivation

Urban systems concentrate people, infrastructure and services, making them highly vulnerable to climate extremes (heatwaves, flash floods) whose complex dynamics are captured by high-fidelity simulators (hydrodynamic, urban microclimate and agent-based models) but at computational costs that limit exhaustive scenario exploration, calibration and uncertainty quantification; surrogate modelling (emulation) therefore offers a practical route to scale analyses and support probabilistic risk estimates and decision support [2].

However, important challenges remain for urban-scale emulation: spatially and temporally resolved outputs (e.g. inundation maps, local temperature time series) are high-dimensional and often nonstationary so scalar surrogates transfer poorly; available simulation data are frequently heterogeneous and limited across fidelity levels, complicating budget allocation and emulator training; coupling emulators with agent-based decision layers (crisis cells, infrastructure operators) is underdeveloped; decision-relevant uncertainty metrics and interpretability (so outputs are usable by planners and crisis teams) are not well integrated into current acquisition and explanation methods; and robustness to nonstationarity and distribution shift under changing climates is an open problem [3].

References

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[2] M. Dunne, H. Mohammadi, P. Challenor, R. Borgo, T. Porphyre, I. Vernon, E. Firat, C. Turkay, T. Torsney-Weir, M. Goldstein, R. Reeve, H. Fang, and B. Swallow. Complex model calibration through emulation, a worked example for a stochastic epidemic model. *Epidemics*, 39:100574, 2022.

[3] M. Prédhumeau. Sustainable urban digital twins: Reducing, reusing, recycling models. In *19th International Conference on Computational Urban Planning and Urban Management*, 2025.