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PREDICTIVE MODELLING FOR SUSTAINABLE AND RESILIENT SYSTEMS ACROSS PARAMETRIC AND UNCERTAIN CONDITIONS

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ABSTRACT

Addressing climate change and the transition towards sustainability requires both anticipating the evolution of environmental systems (e.g., desertification, wildfires, water resources, …) and designing engineering systems that minimise environmental impact while remaining efficient and resilient throughout their lifetime (e.g., electric mobility, renewable energy, …). Despite their different nature and objectives, these two challenges share a fundamental need: predicting the behaviour of complex systems to support reliable decisions on design, operation, mitigation, and adaptation.

The behaviour of these systems often depends on many parameters, interacting processes, potentially involving multiple physics and scales, and uncertain conditions that may evolve over time, posing significant scientific challenges. Available knowledge is typically distributed across heterogeneous sources, including high-fidelity simulations, simplified physical and data-driven models, and experimental observations, each with their own accuracy, credibility, and cost. This calls for innovative methods to explore high-dimensional parameter spaces, propagate uncertainties, and enable many-query applications while making parsimonious use of available resources.

This invited session focuses on computational methodologies for predictive modelling, with particular attention to scalability and the environmental footprint of the modelling process itself. Parametric surrogates, reduced-order methods, physics-informed and data-driven approaches, and multi-fidelity strategies provide complementary means of integrating models and observations to construct predictive representations. Beyond accuracy, ensuring reliability requires both quantitative assessments, such as error estimates and model calibration, and the ability to capture qualitative changes in system behaviour, including bifurcations and transitions between solution branches. These capabilities support robust optimisation and control, as well as adaptive modelling and monitoring, helping decisions remain reliable in different scenarios, under uncertainty, and as new information becomes available.

The session aims to connect methodological advances with environmental and engineering applications, translating predictive modelling into informed decisions, with the goal of reducing the environmental impact of the systems under analysis, while also limiting the computational footprint of the modelling methods themselves.