



AI-Driven Urban Flood Resilience: Integrating Earth Observation and Architectural Innovation

AURORa

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Abstract

Urban areas face increasing flood risks due to climate change and rapid urbanization, yet current assessment and planning methods often remain fragmented. This project proposes an integrated framework that combines multi-sensor Earth observation, hydrodynamic modeling, urban digital twins, and AI to analyze and improve urban flood resilience. Key components include:

- (1) enhancing flood detection by linking EO observations with digital twins
- (2) quantifying resilience through an AI-based surrogate hydrodynamic model
- (3) generating high-quality what-if digital-twin scenarios
- (4) automating scenario creation using representative learning

The system will be calibrated and validated using major flood events from Germany (2021), Brazil (2024), and Spain (2024), ensuring robustness and transferability across cities. This integrated approach aims to support faster, more reliable, and cost-efficient planning for flood-resilient urban design.

Overall Motivation and Goals

Existing practices focusing on urban flooding, from EO-based flood mapping to hydrodynamic simulations, still operate largely in isolation. This fragmentation makes it difficult for cities to translate disparate datasets into coherent, actionable strategies for resilience planning. In addition, scenario development for future flood events is often slow, resource-intensive, and heavily dependent on expert knowledge, limiting its scalability and operational usefulness.

AURORa aims to address these gaps by establishing an integrated analytical framework that unifies EO observations, digital twins, hydrodynamic modelling, and AI-driven analysis. The overarching goal is to provide cities with a holistic, data-driven system that uncovers the causal relationships driving urban flood dynamics, evaluates resilience under varying conditions, and generates reliable what-if scenarios at scale. Ultimately, the project seeks to enable more proactive, faster, and cost-efficient decision-making for designing flood-resilient urban environments.

To achieve this vision, the project is structured around four core research goals:

- (1) Uncovering Flood Causation in Built Environments Through AI and Earth Observation Towards Resilient Cities
- (2) Quantification of Flood Resilience using a DL-based Surrogate Model derived from Numeric Hydrological–Hydrodynamic Flood Simulation
- (3) Digital Twinning, AI-Based Scenario Generation and Visualization
- (4) Compositional and Controllable Generative Models

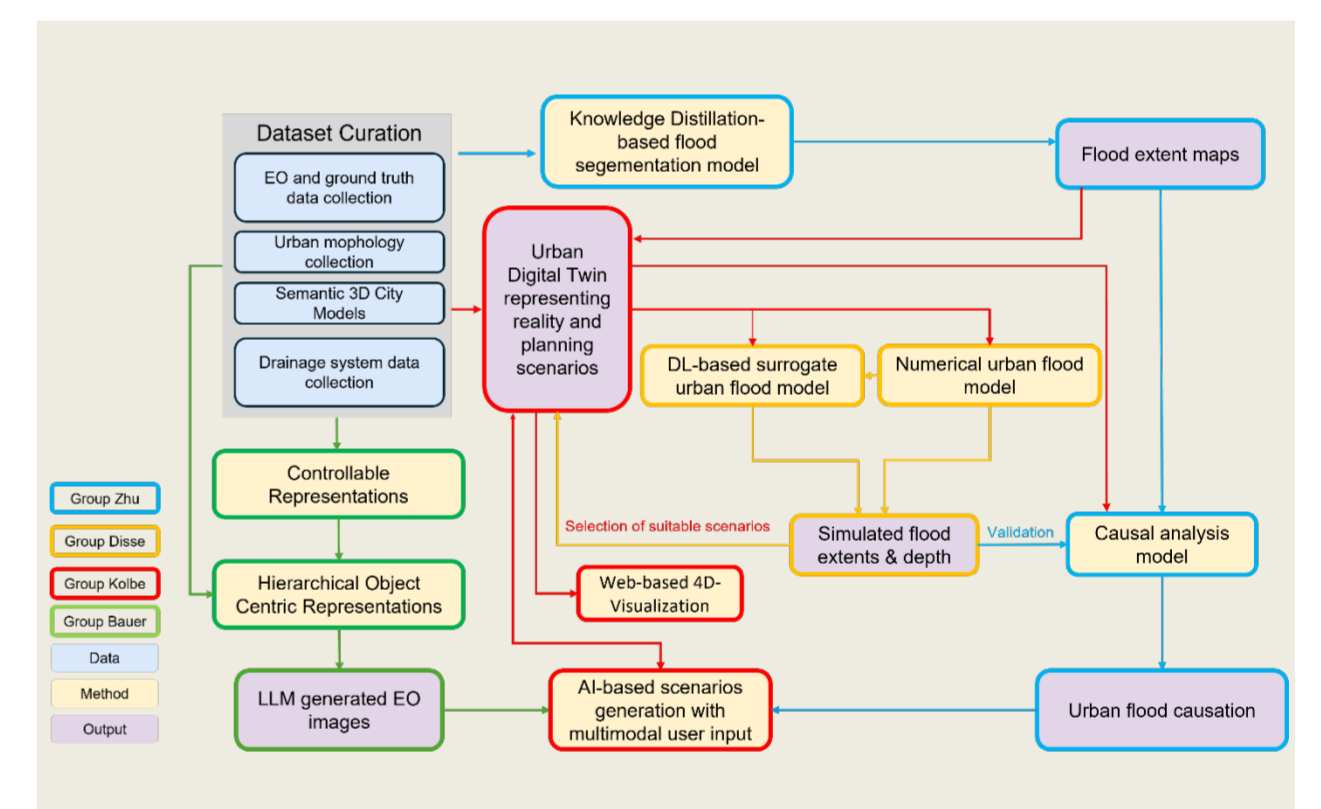


Image 2: Proposed workflow of AURORa Project.

Overall Methods

The AURORa project employs an integrated workflow combining EO data, hydrodynamic modelling, digital twins, causal analysis and AI. The methods are organized into four layers:

- **Data Integration:** EO data, 3D urban models, and infrastructure information are harmonized within a unified digital-twin environment.
- **Physical & Causal Modelling:** Hydrological–hydrodynamic simulations provide physically consistent flood states, while causal inference methods link observed flooding patterns with built-environment and infrastructure factors to reveal underlying drivers of urban flood impacts.
- **AI Modelling:** Representation learning and surrogate models capture links between EO observations, built environments, and flood dynamics, enabling rapid data-driven flood prediction.
- **Scenario Generation & Resilience Assessment:** AI-driven generative methods produce what-if scenarios by altering hazards or urban layouts, while resilience metrics integrate hazard, exposure, and vulnerability.

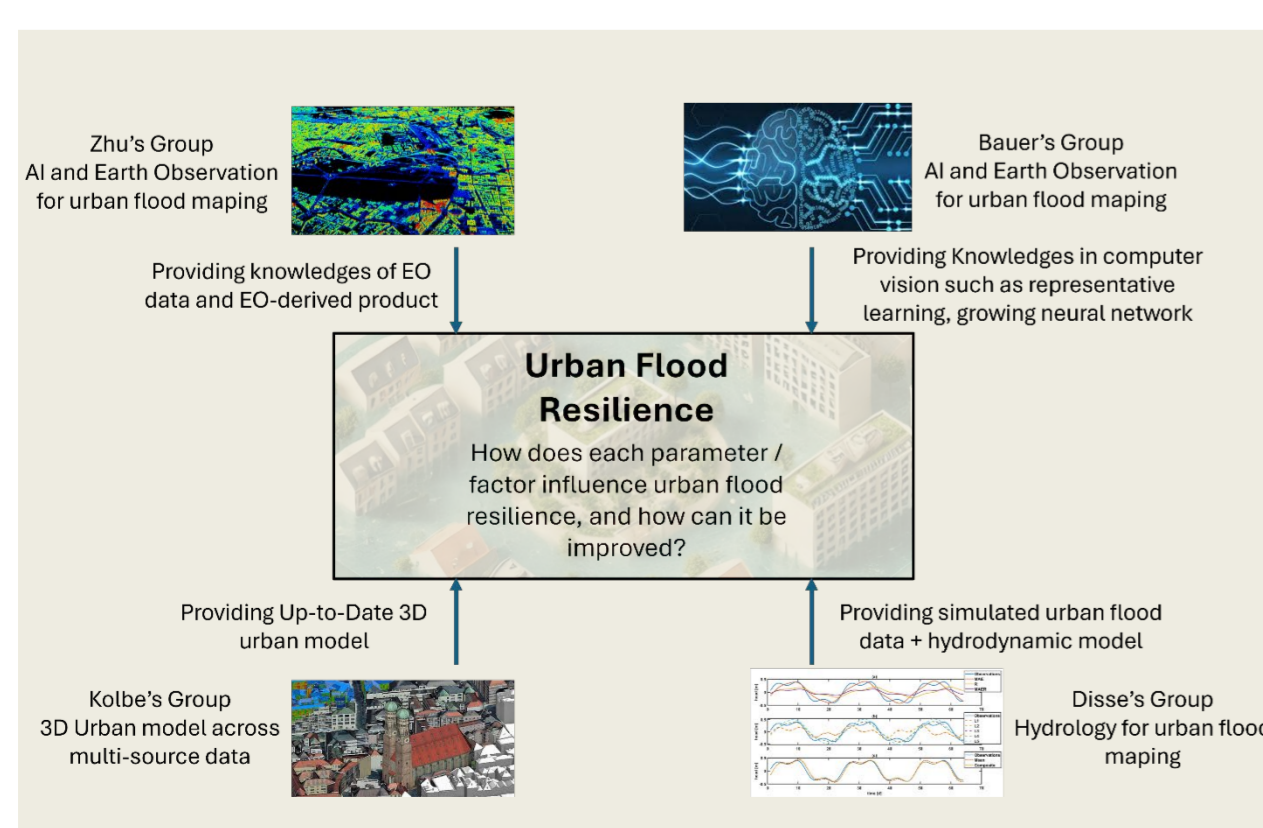


Image 1: Conceptual overview of an interdisciplinary framework for advancing urban flood resilience using Earth Observation, hydrodynamic modeling, 3D urban model and AI-driven analysis.