Institute of Hydraulic Engineering and Technical Hydromechanics (TU Dresden, IWD)
Institute of Urban and Industrial Water Management (TU Dresden, ISI)
Department of Environmental Informatics (Helmholtz Centre of Environmental Research Leipzig, ENV-INF)

Staggered Coupled Simulation of Urban Precipitation Events using BASEMENT, SWMM and OpenGeoSys

Lars Backhaus

8. BASEMENT User Meeting
January 26th 2023

Water related Planning and Realizations

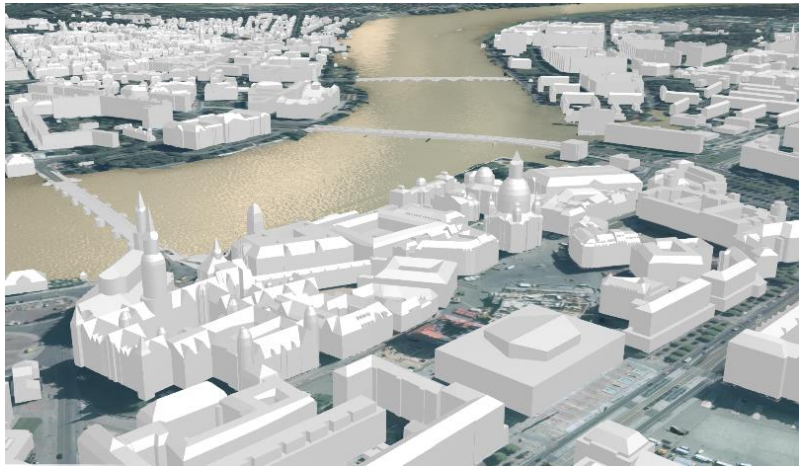
- Future problems of urban water management require a **combined effort** of varying actors: **public authorities, scientists, people**
- Necessity for a **unified, consistent and adaptive platform** for:
  - Data- and Scenario management (climate, city planning)
  - Process simulation (Hazard) und risk management (damage models)
  - User driven result exploration and visualization
  - Evaluation tools and decision making aids
- Additional focus on **knowledge transfer** and **communication**:
  - **Public authorities and decision makers** (Realization)
  - **Non-Experts** (Acceptance, Awareness)

Elbe Flooding 2002 (Photo: Heyer)

Ahr Flooding Aftermath 2021 (Photo: Stamm)

Research Project WetUrban

Goal:
Develop a modular, adaptive and extensible solution for analysis and management of the urban water balance and water-induced risks based on 3D semantic, digital city models.



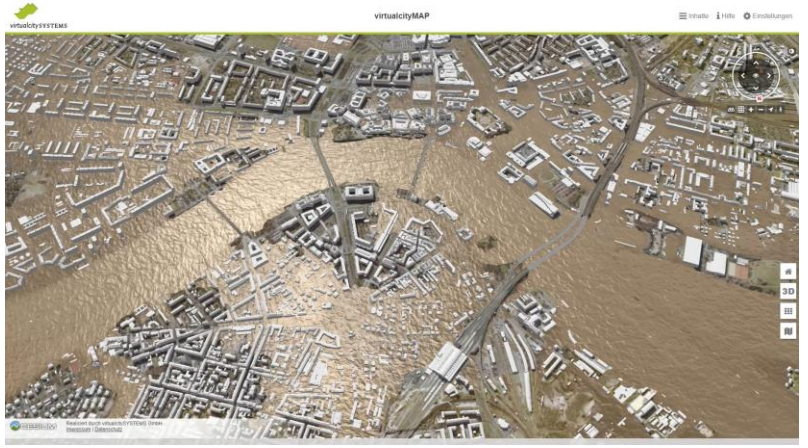
Research partners:

- Hydraulic Engineering & THM, Prof. J. Stamm
- Urban and Industrial Water Management, Prof. P. Krebs
- Environment Informatics, Prof. O. Kolditz

TECHNISCHE UNIVERSITÄT DRESDEN
UFZ HELMHOLTZ Zentrum für Umweltforschung

Processes

- Coupled simulation of **Surface-, Sewage- and Groundwater flows** in urban areas
- Modelling **varying water extremes** (floods and droughts)



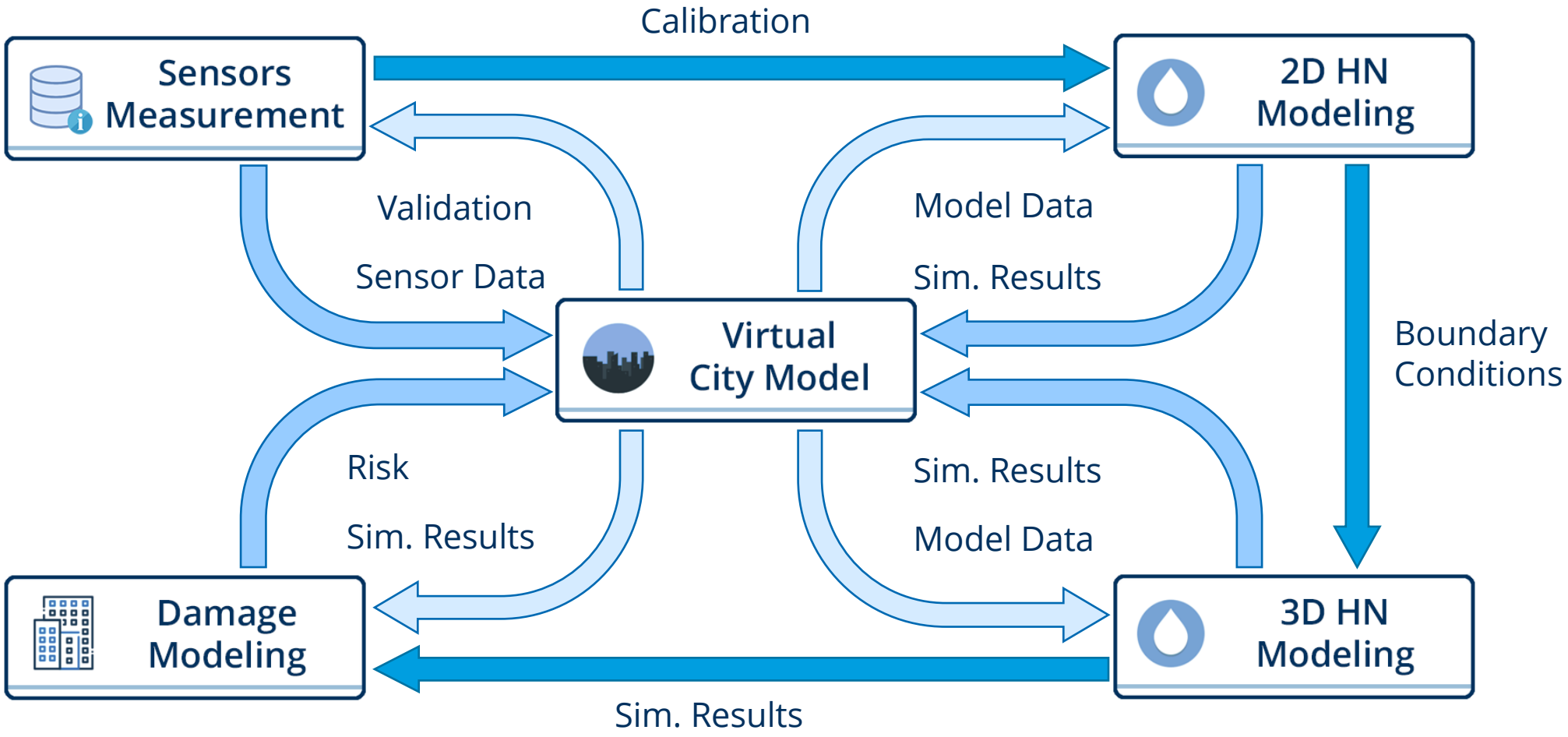
Practical relevance and Transfer:

- Demonstrator for the city of Dresden (extended catchment Lockwitzbach)
- Integration of relevant public actors (environment protection, city planners, city drainage)

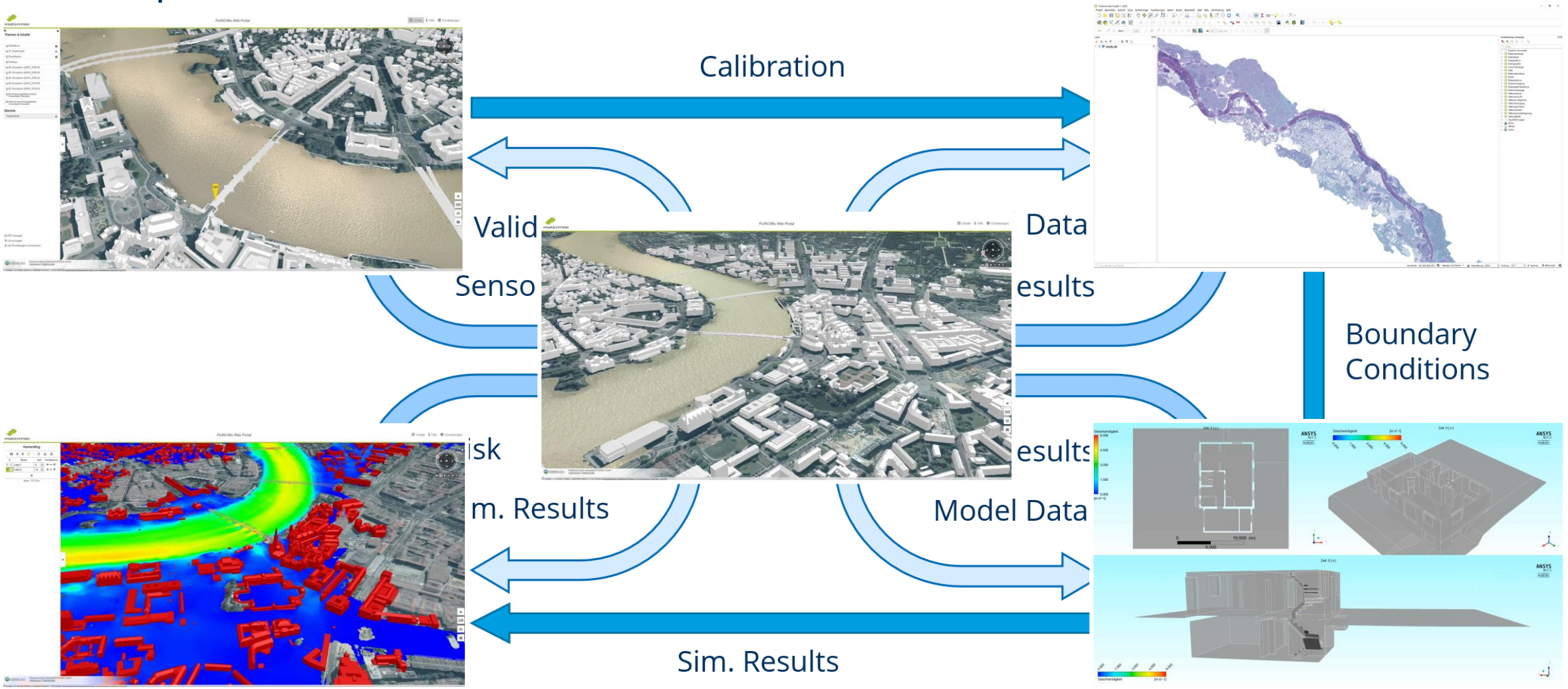
Based on previous projects

→ „**FloRiCiMo**“ (DBU): https://youtu.be/DJgqTUDpUpc
→ „**Urban Catchments**“ (BMBF): https://youtu.be/kjVold9M6yM

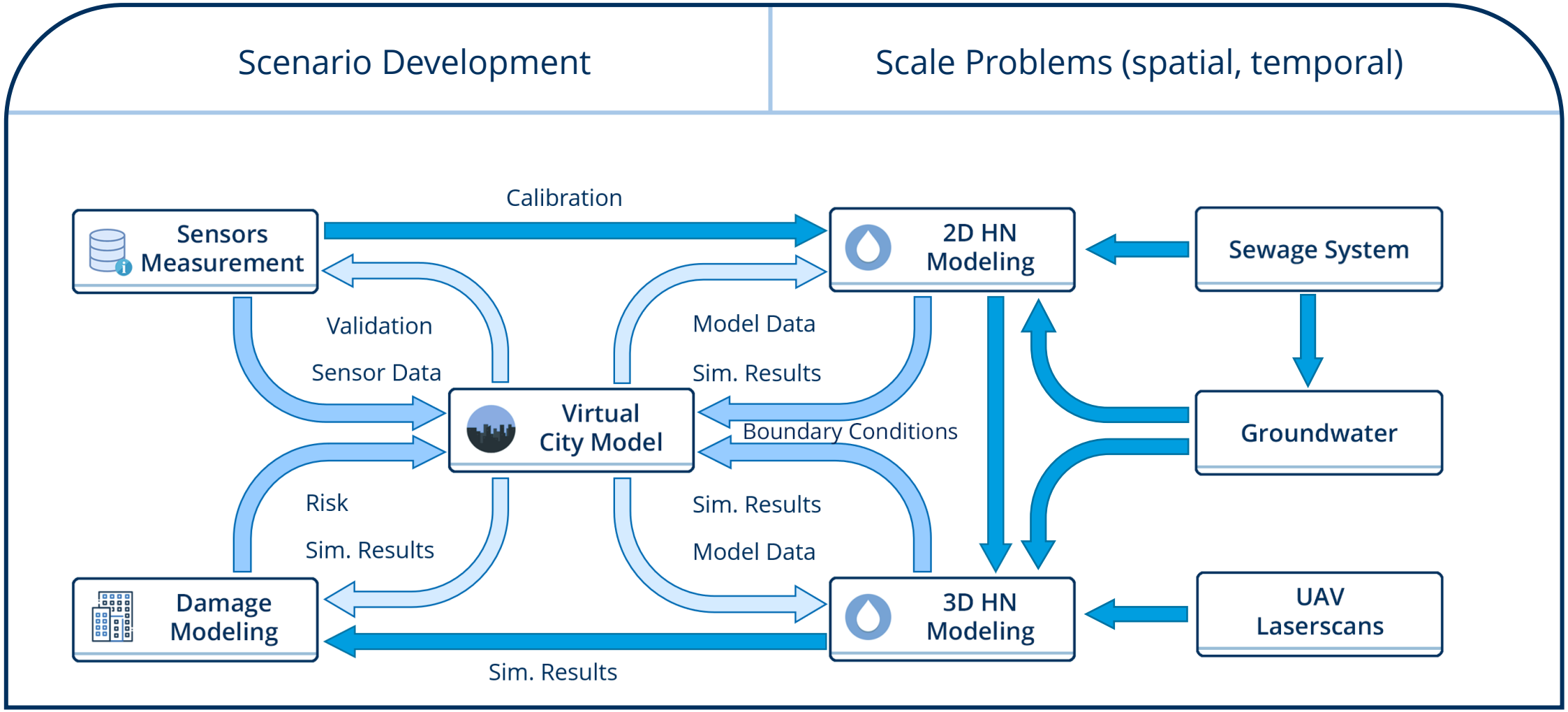
Methodology „FloRiCiMo“
Components



Methodology „FloRiCiMo“
Examples

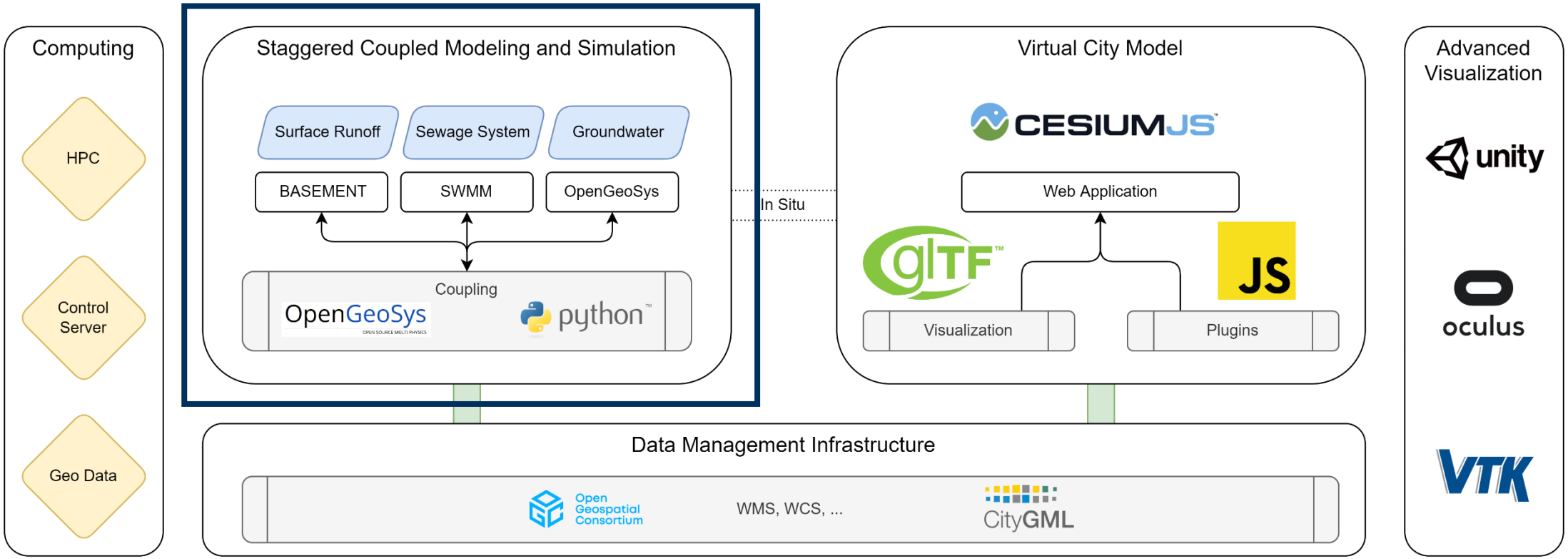


WetUrban – Extending the Methodology

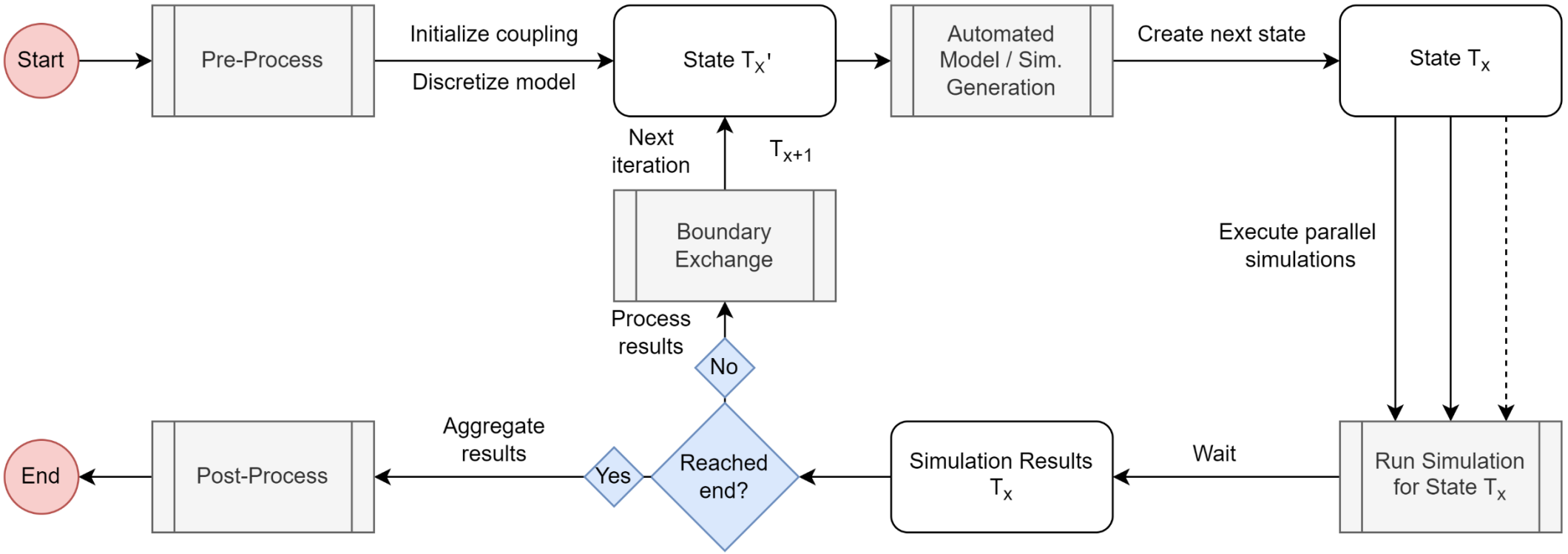


WetUrban - IT System Architecture

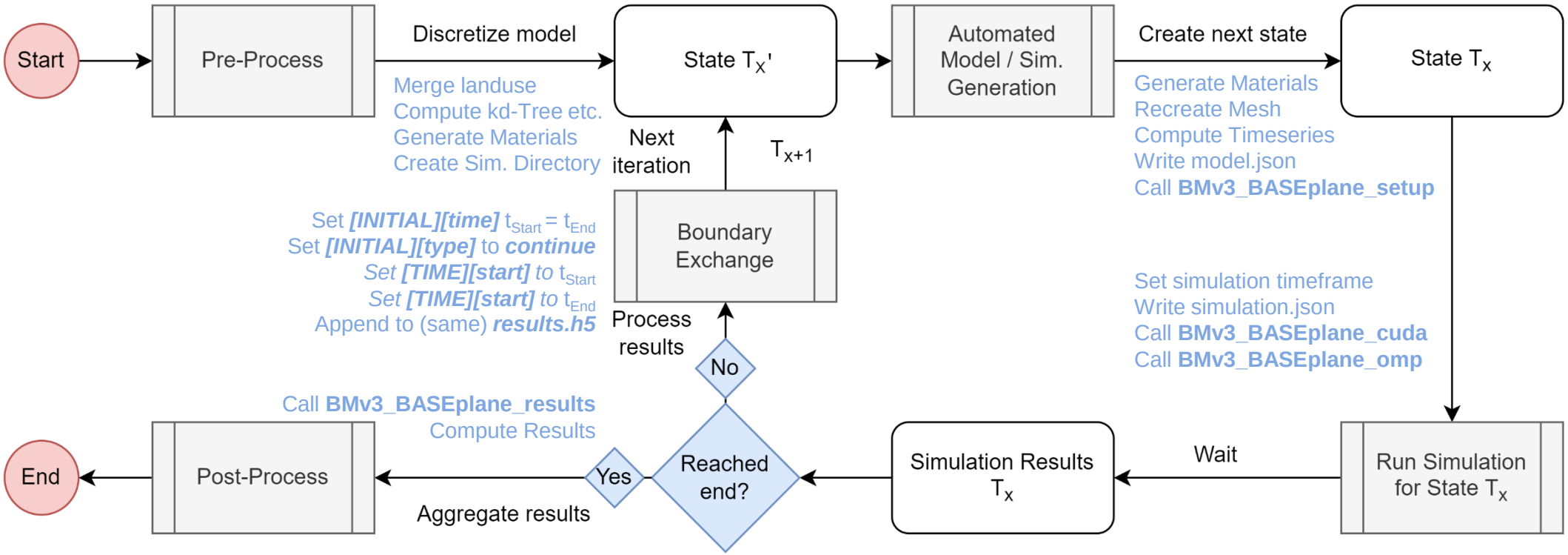
Whenever possible: Free Open Source Software (FOSS) and Open Data!



Staggered, Coupled Modelling and Simulation



BASEMENT Model & Simulation Loop



BASEMENT Features

— **Python interface** for creating and manipulating model and simulation configurations

- Covers basic needs with focus on precipitation modeling
- Create new model from scratch or edit existing one
- Run BASEMENT executables from script
- **Work in progress, missing documentation / user guide**

```python
def add_constant_source(self, name: str, region_name: str, data: float,
                        sink: str = "exact", _type: str = "distributed") -> None:
    self.__add__source(name, region_name, data, None, sink, _type)

def add_rain_region(self):
        # if "rain" source, set all materials
    rain_source = self.get_source("rain_event")
    if rain_source:
        rain_materials = []
        for r in self.get_regions():
            rain_materials.extend(r["index"])
            rain_materials = sorted(list(set(rain_materials)))

        rain_region = self.get_region("rain")
        if rain_region:
            rain_region["index"] = rain_materials
        else:
            self.add_region("rain", rain_materials)
```

Python framework code excerpt

— Automatic generation of dynamic material IDs

- Based on a set of attributes,
- Mapping similar to a hash function
- May change every loop iteration
- Requires rewriting of the .2dm mesh

Material ID (initial)	Landuse Class	Dynamic Sink / Source	Friction
1	5	-1	25

Example element attribute set for dynamic materials

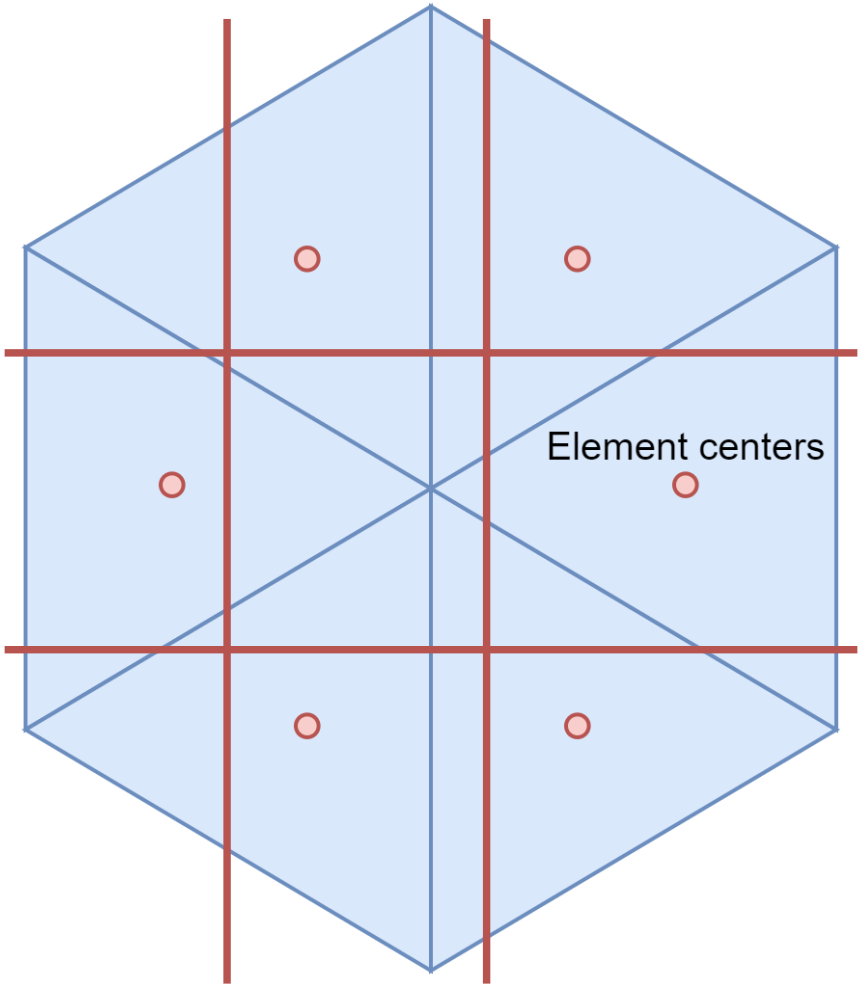
Coupling – kd-Tree

— Goal: **Quick spatial lookup** of elements

- Similar to BASEmeshs „Get mesh element by location“
- Using *scipy.spatial.KDTree*
- Main objective: **XY-position test**

  → Point XY in mesh or not? If so, which element?
- Used for overlapping element / point and element / element

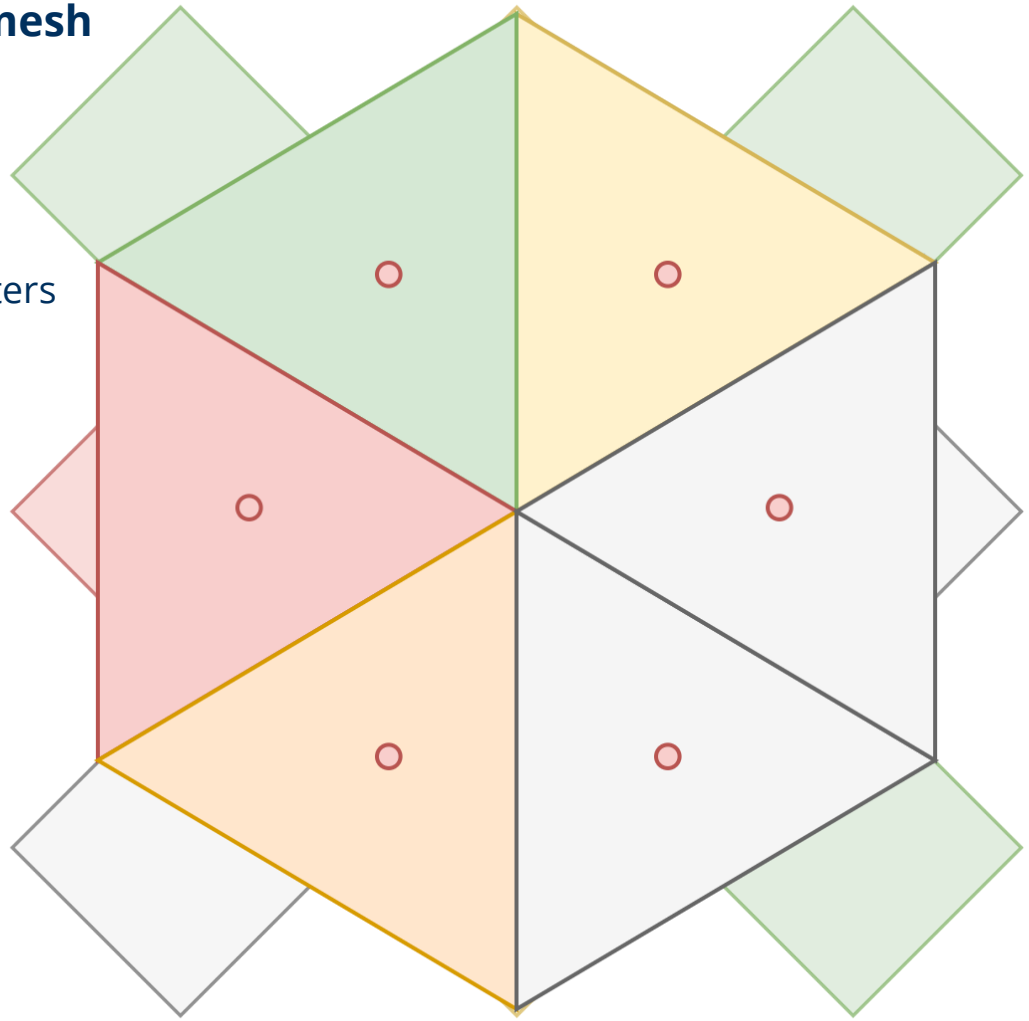
  → e.g. in coupling: Which element contains which manhole?



Coupling – Landuse

— Goal: Map highly detailed **landuse shape data to 2dm mesh**

- Similar to BASEmeshs „Assign material ID“
- Load exisiting 2dm mesh and compute element centers
- Load landuse shape
- Using *GeoPandas spatial join* (*sjoin; “intersects”*) on element centers
- Receive pair <element ID – landuse ID> mapping
- Set **landuse ID as new material for every element**
- Write mesh



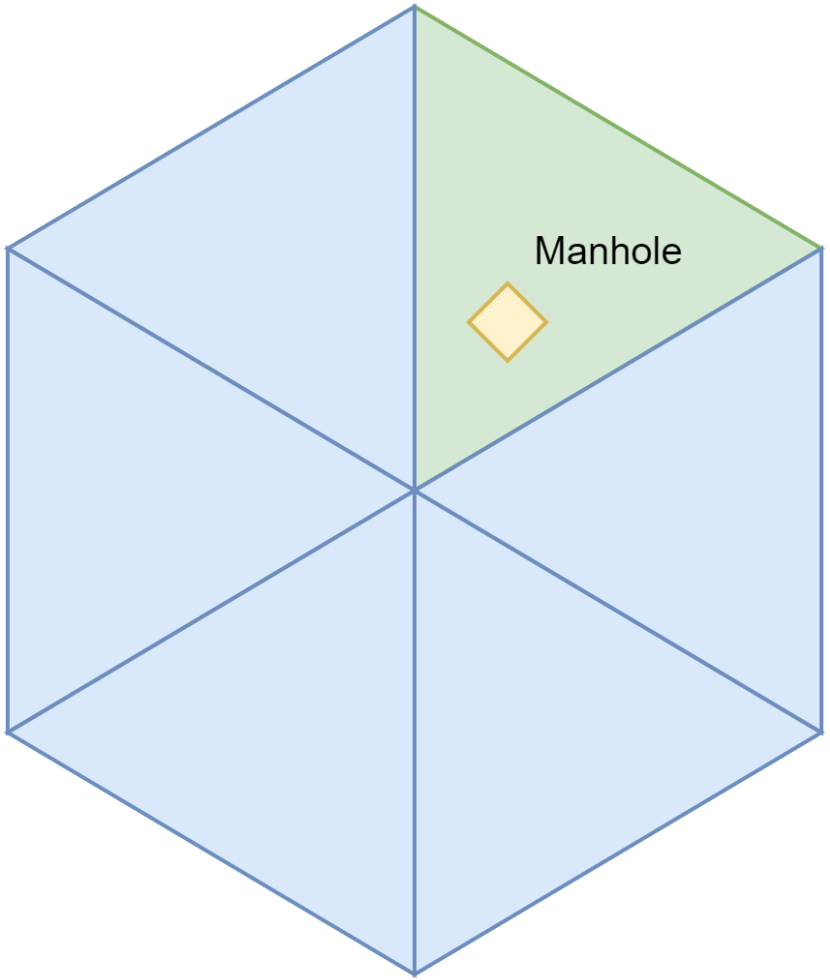
Coupling – Manhole and Subcatchments

— Goal: **Couple SWMM manholes to BASEMENT elements**

- Use kd-Tree for quick lookup for mapping
- Store mapping for later usage
- Special material ID elements act as **dynamic sink / source**
- Caveat: region cannot be source and sink at the same time

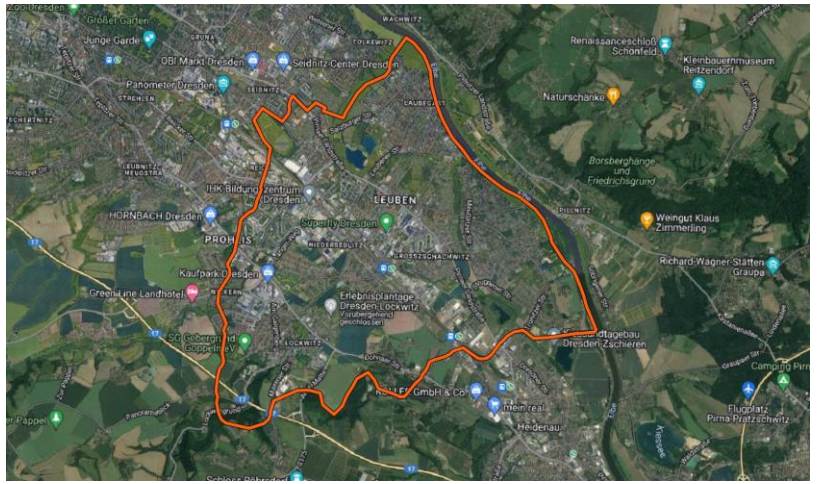
  → No precipitation on manhole elements

- Use subcatchment aggregation for manhole inflow from BASEMENT
- **Total inflow** = connected **element areas * element water depth**



Model Overview

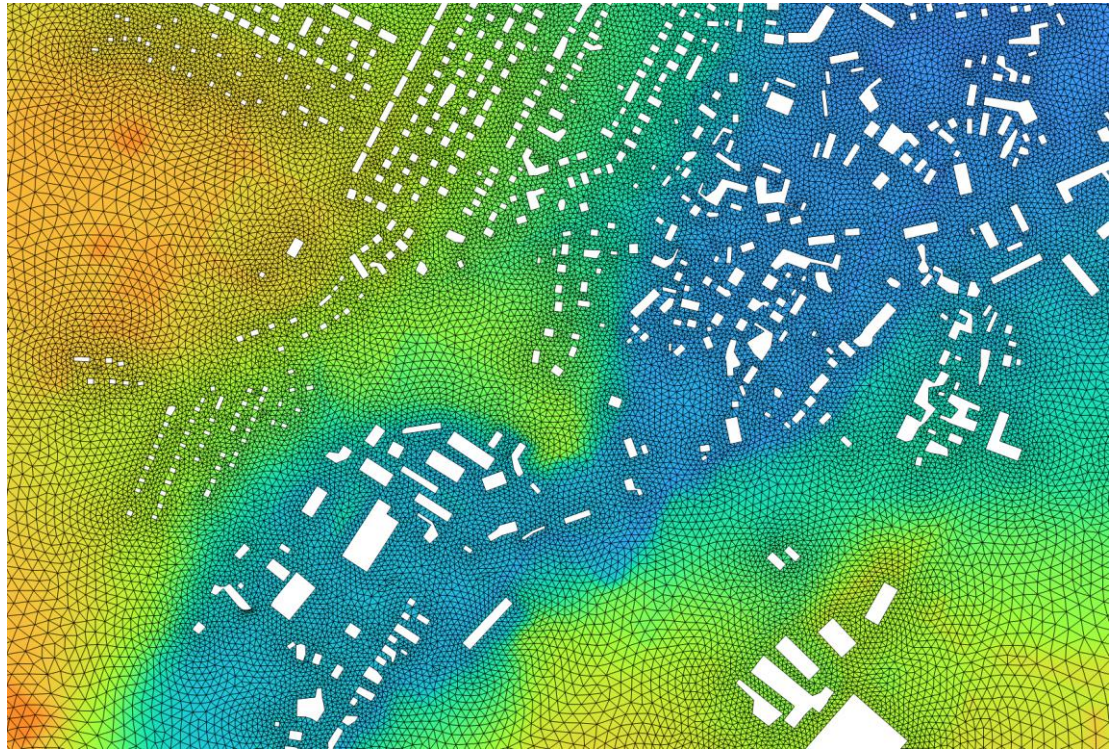
- Study areas spans over multiple city districts of Dresden
  - Focus on the hydrological / sewage catchment of the Lockwitzbach creek
- Combined urban investigation area of ca. **35 km²**
  - Surface Model: ca. **3M** cells, area 3m² to 25m²
  - Sewage Model: **5616** conduits, ca. **130k** subcatchments
  - Groundwater Model: **328 km²** area
- Using mostly (processed) open data
  - DEM, bathymetry, landuse, buildings, vegetation, surface roughness, permeability, infiltration, groundwater heads and many more
  - Historical climate and groundwater data
  - Scenario based generation of weather data (LARS-WG)



Model Area, Lockwitzbach catchment

Landuse map (detail zoom)

Surface- and Groundwater model



Computational mesh including DEM and building holes

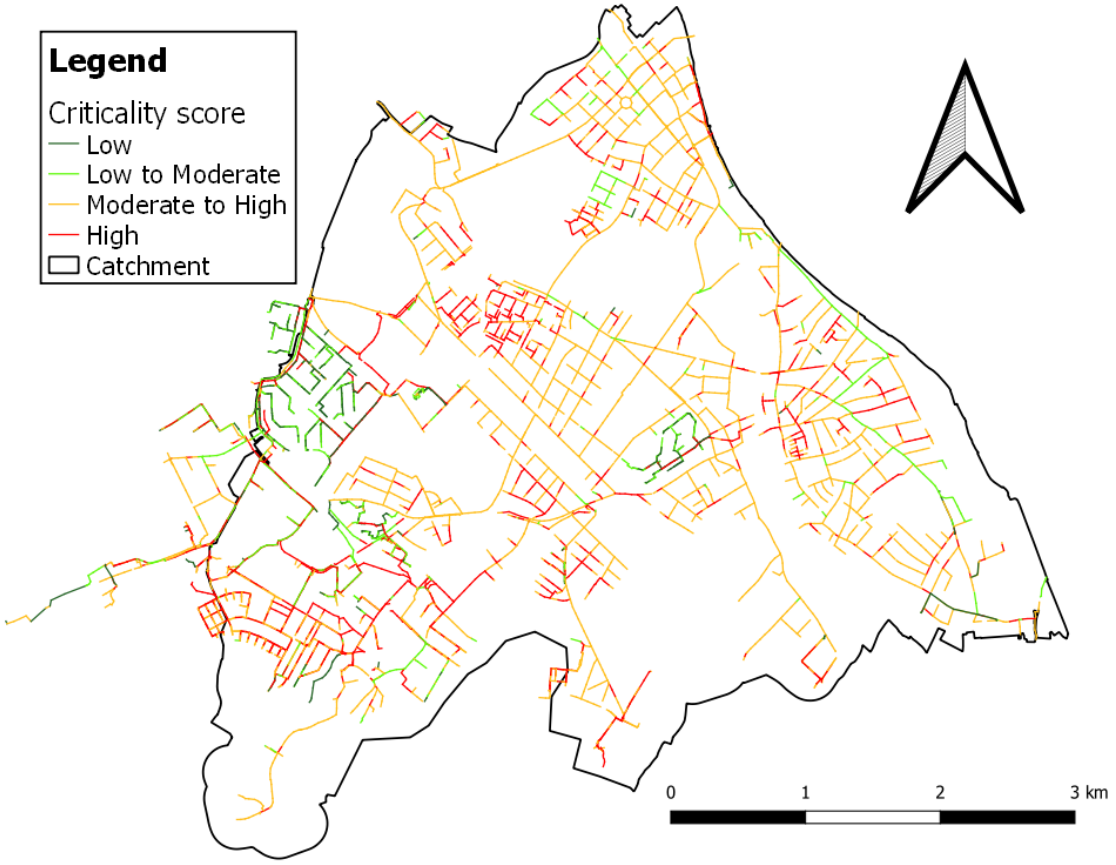
Joint landuse data with 2dm mesh

Sewage System Model

SWMM INP file

Junctions:	5567
Conduits:	5616
Storages:	11
Weirs:	23
Outfalls:	49
Subcatchments:	131744
Subcatchment areas:	1m² - 36808m²

— Conduits of critical rating of special interest for coupled modeling (in- / exfiltration, seepage, ...)

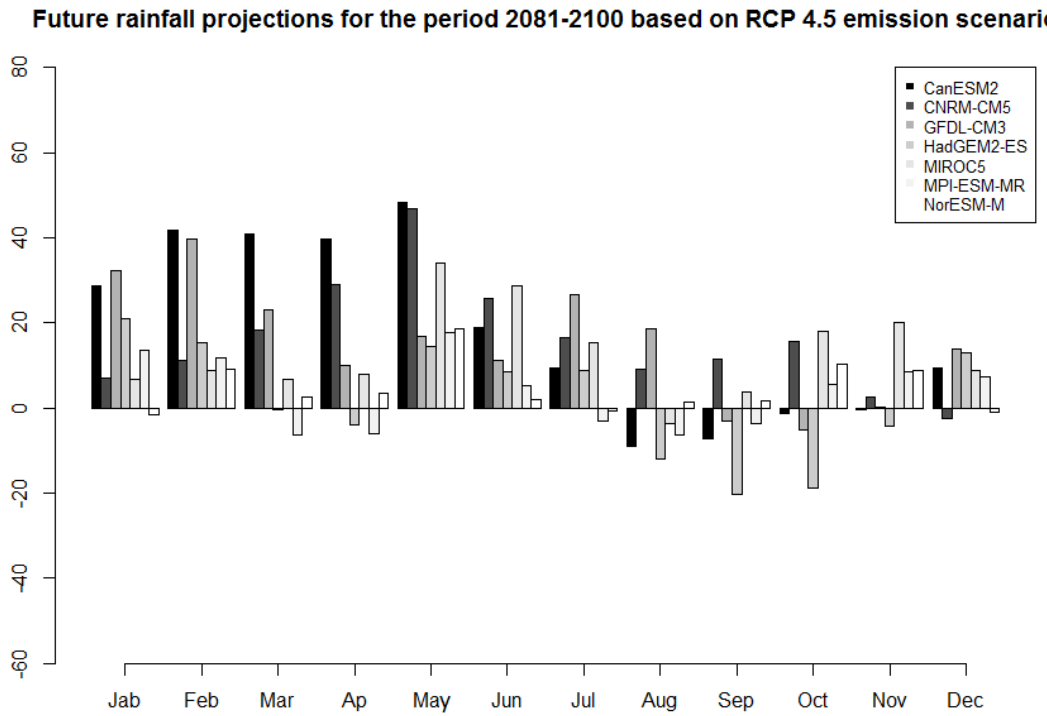


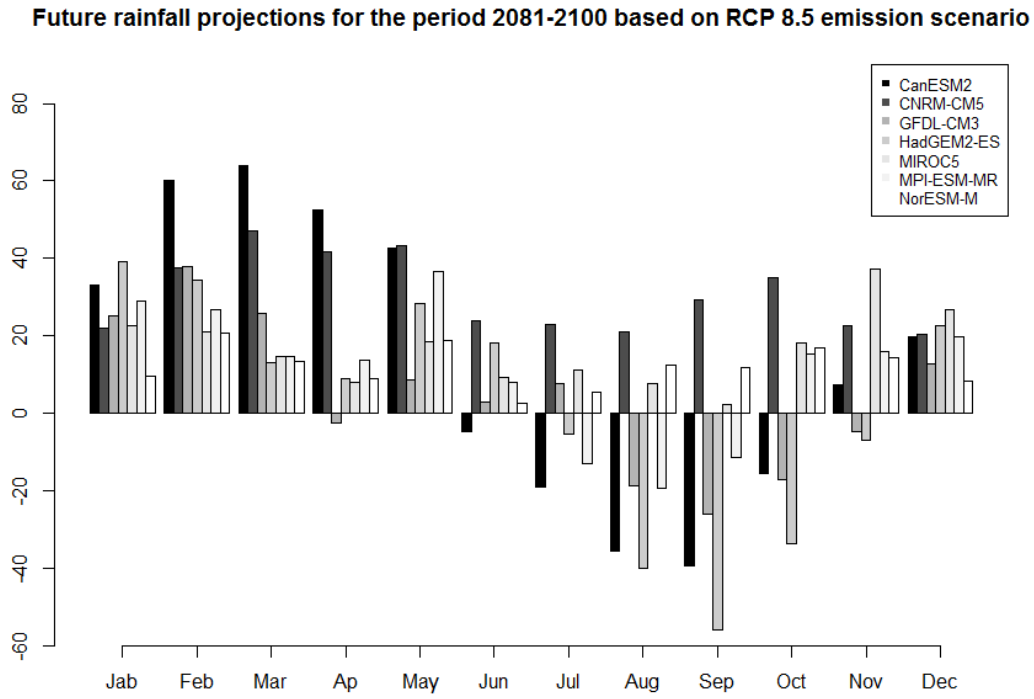
Final Sewage system model, incl. landuse, critical conduits

Development / Generation of Weather Scenarios

— **Objective:** To predict possible impacts of climate change on stormwater systems in Dresden in the future periods: 2041-2060 and 2081-2100

— Scenarios considered: - **RCP 4.5:** Medium-low emission scenario - **RCP 8.5:** High emission scenario

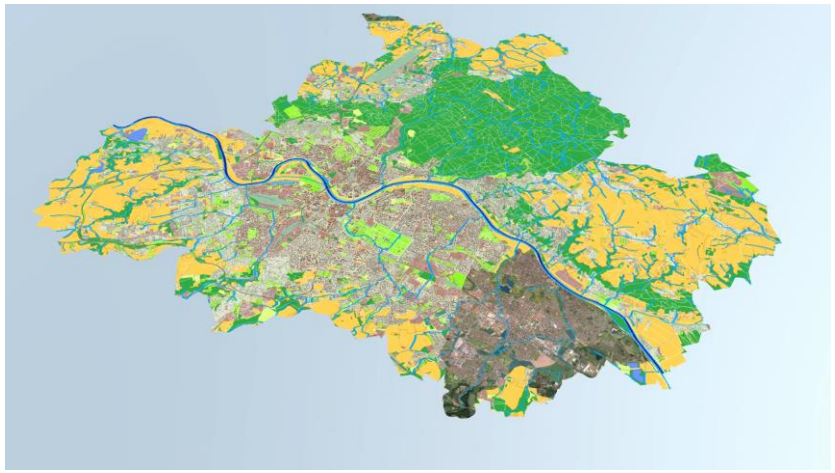




Figures: Relative difference of monthly rainfall in percentage (%) based on (a) RCP 4.5, (b) RCP 8.5 emission scenarios

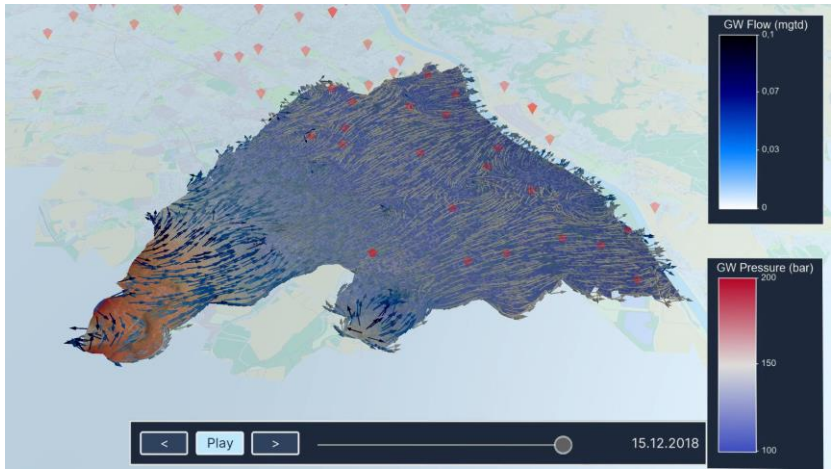
Results Overview

Overview over entire digital city model



Combined view of landuse and study area (bottom right)

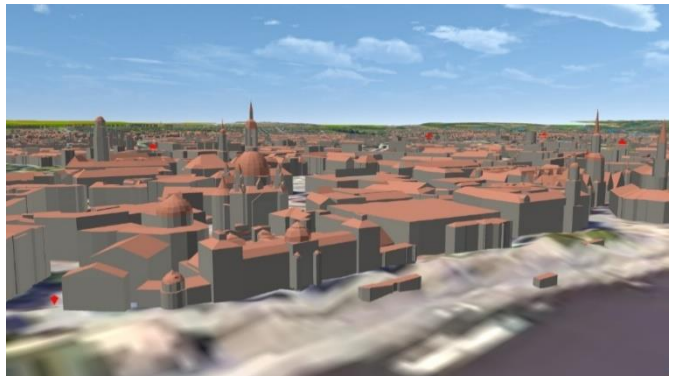
Surface flow (test case)



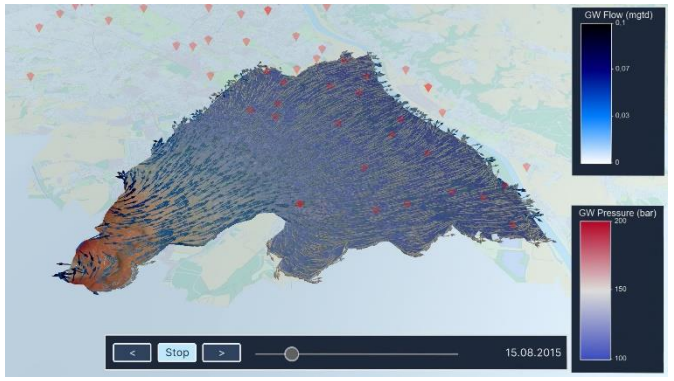
Groundwater flow and display of local streams

Results Overview II

Birds eye view of the study area, stream overlay



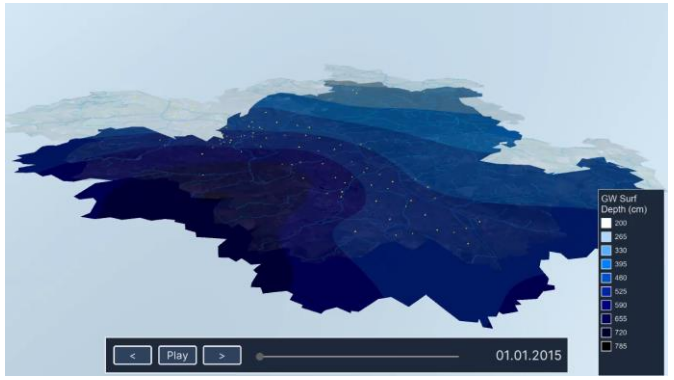
3D digital city model



Visualization of groundwater flow

Coupled surface flow (test case)

Coupled sewage system flow (test case)



Visualization of historic groundwater levels

Summary

- Project **FloRiCiMo → working system** for flood risk management (**surface flow**)
- Project **WetUrban** → Extension of the FloRiCiMo system with components and processes related to underground water (**coupled surface/sewage/groundwater flow**) for risk management of urban water extremes
- **Adaptive** and **extensible system** for urban water management → **Open for cooperation**!
- https://bitbucket.org/IWD-Dev/weturban/src/master/

FloRiCiMo: https://youtu.be/DJgqTUDpUpc

Urban Catchments: https://youtu.be/kjVold9M6yM

WetUrban: https://youtu.be/vM4M4ExrdMo

Lars Backhaus M.Sc.
Technische Universität Dresden
Institute of Hydraulic Engineering and Technical Hydromechanics (IWD)
August-Bebel-Straße 30
01062 Dresden

☎ +49-(0)351-463 32262
+49-(0)351-463 37120
iwd.tu-dresden.de
wasserbau@tu-dresden.de

SACHSEN

Diese Maßnahme wird mitfinanziert mit den Steuermitteln auf Grundlage des vom Sächsischen Landtag beschlossenen Haushaltes.