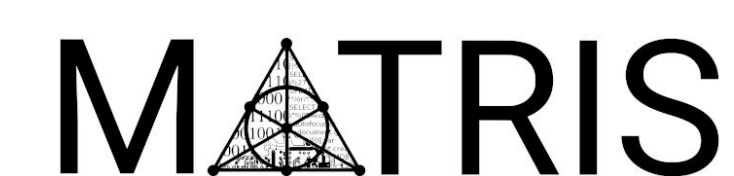


# Using Combinatorial Scenarios to Advance Disaster Preparedness for Natural and Technological Hazards

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## A Combinatorial Approach to Disaster Scenario Generation

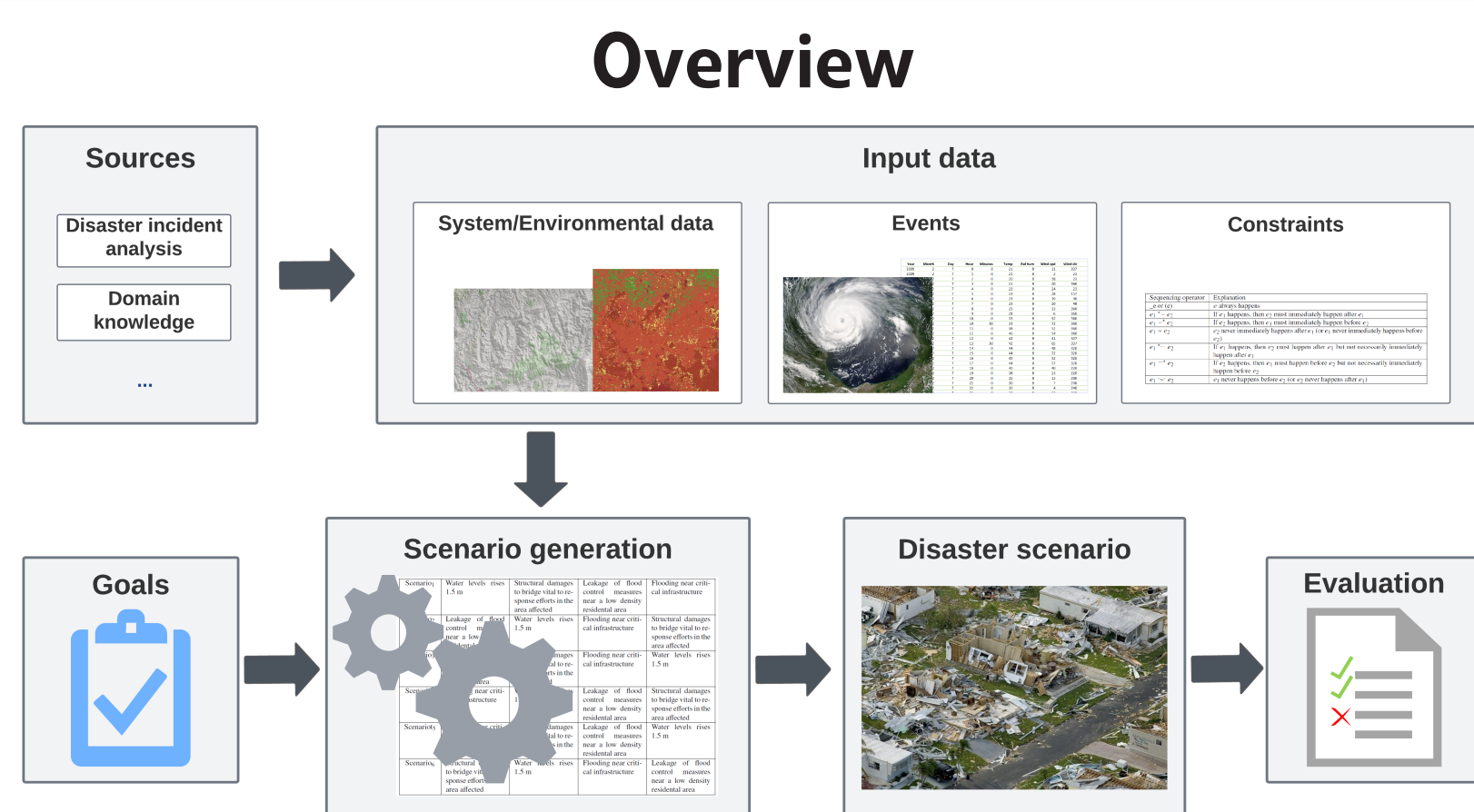


Figure 1: A combinatorial disaster management framework.

- ▶ Considering all possible disaster scenarios is impossible.
- ▶ Scenarios that cover as many event interactions as possible can be effective.
- ▶ For the modelling and analysis of disasters and disaster response plans.

### Combinatorial Scenarios in Disaster Research

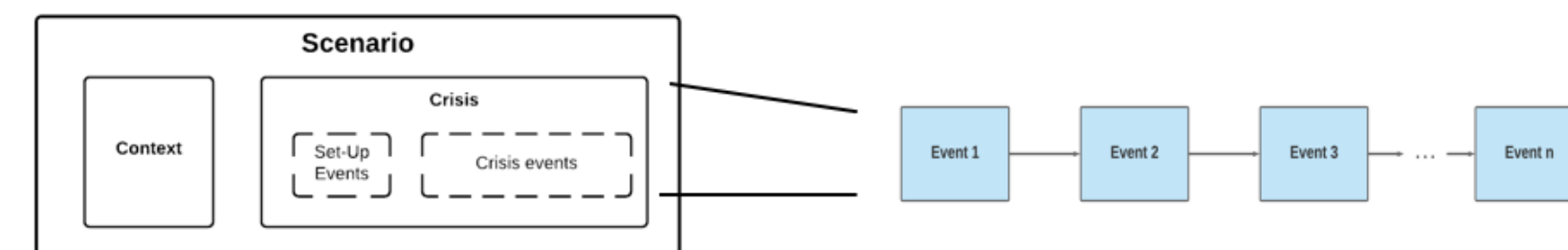


Figure 2: Modelling disaster scenarios as sequence of events.

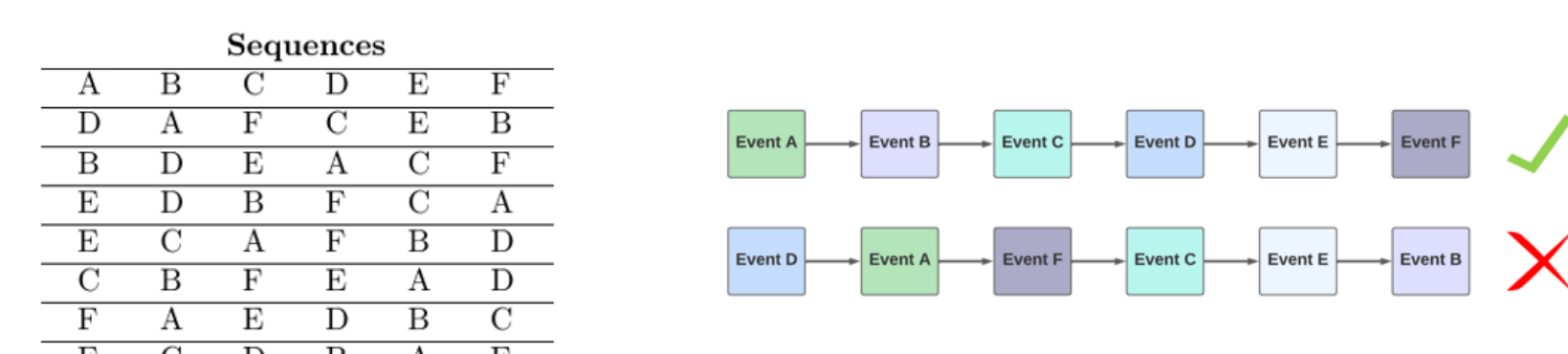


Figure 3: Combinatorially generated sequences of disaster events.

- ▶ For safely testing and validating response plans and measures in times of no disasters.

### Utilizing Scenarios in Simulations and Exercises



Figure 4: Hurricane simulation & disaster training exercise.

- ▶ For training crisis management personnel in a controlled and safe environment.

## Combinatorial Fire Scenarios for Simulations

### Fire Scenario Generation by Permutation of Weather States

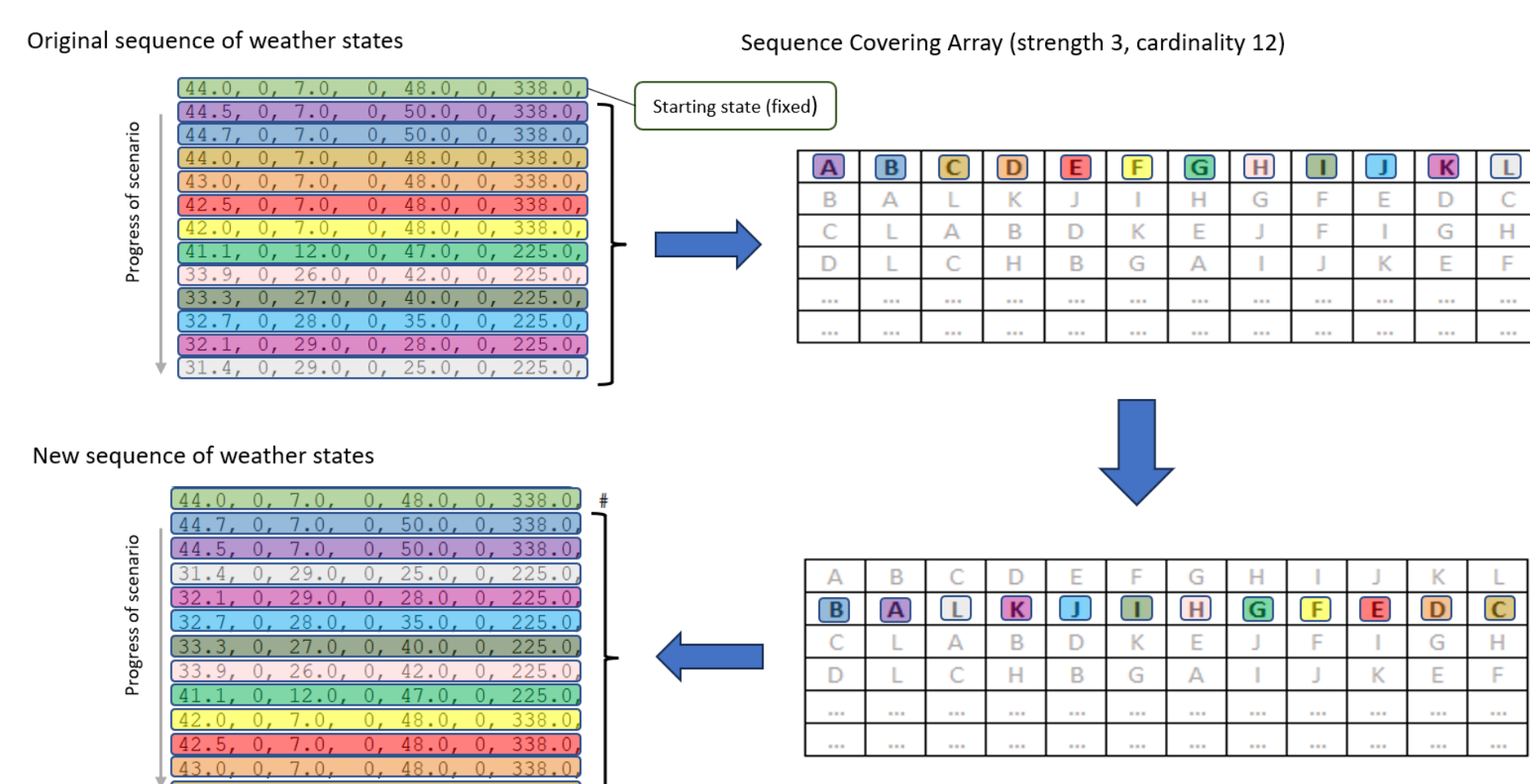


Figure 5: Mapping between time series of weather data and combinatorial structures.

### Comparing Simulated Scenarios

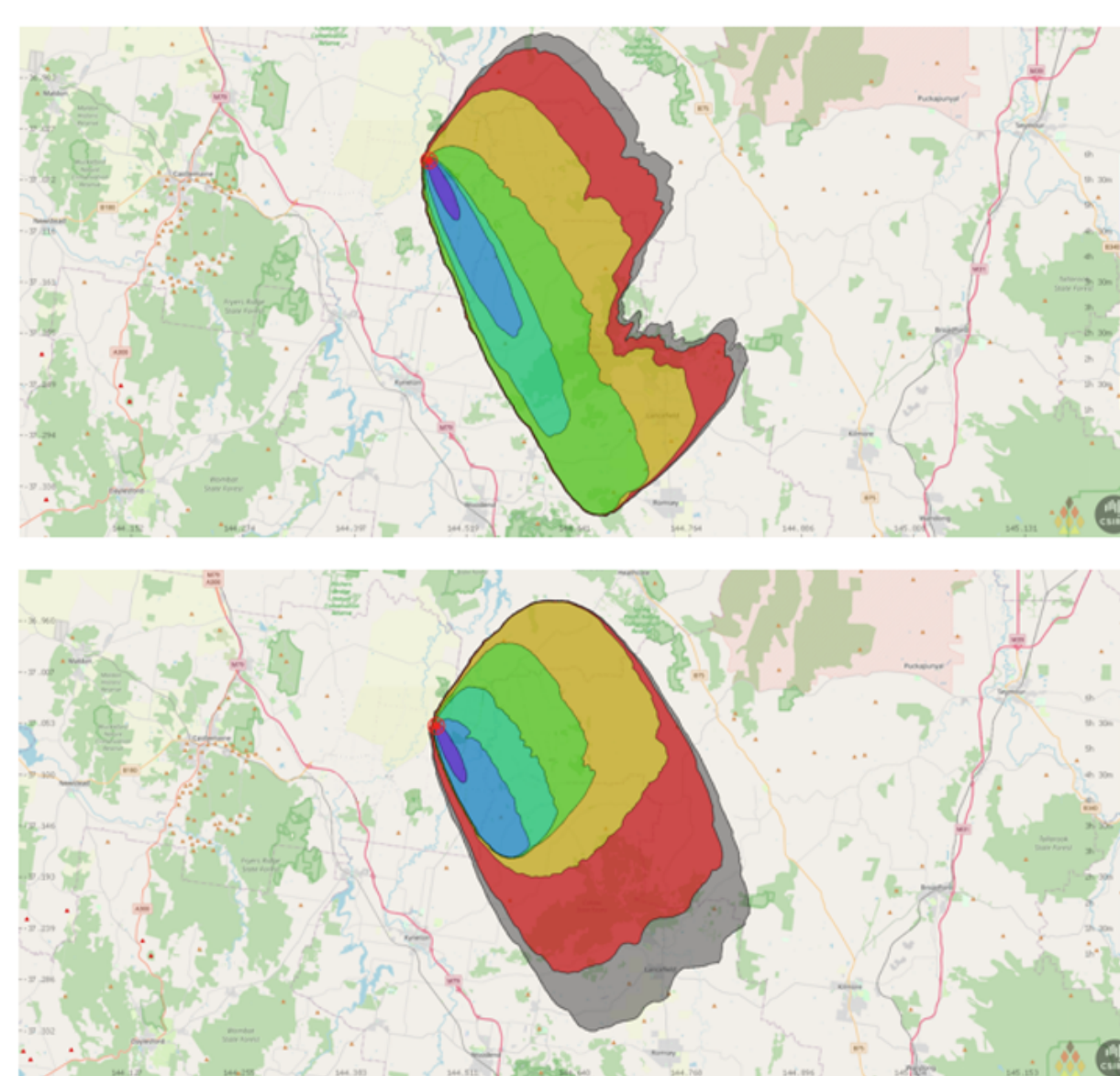


Figure 6: Exemplary comparison between *base* (top) and *new* (bottom) fire scenario.

### Evaluation

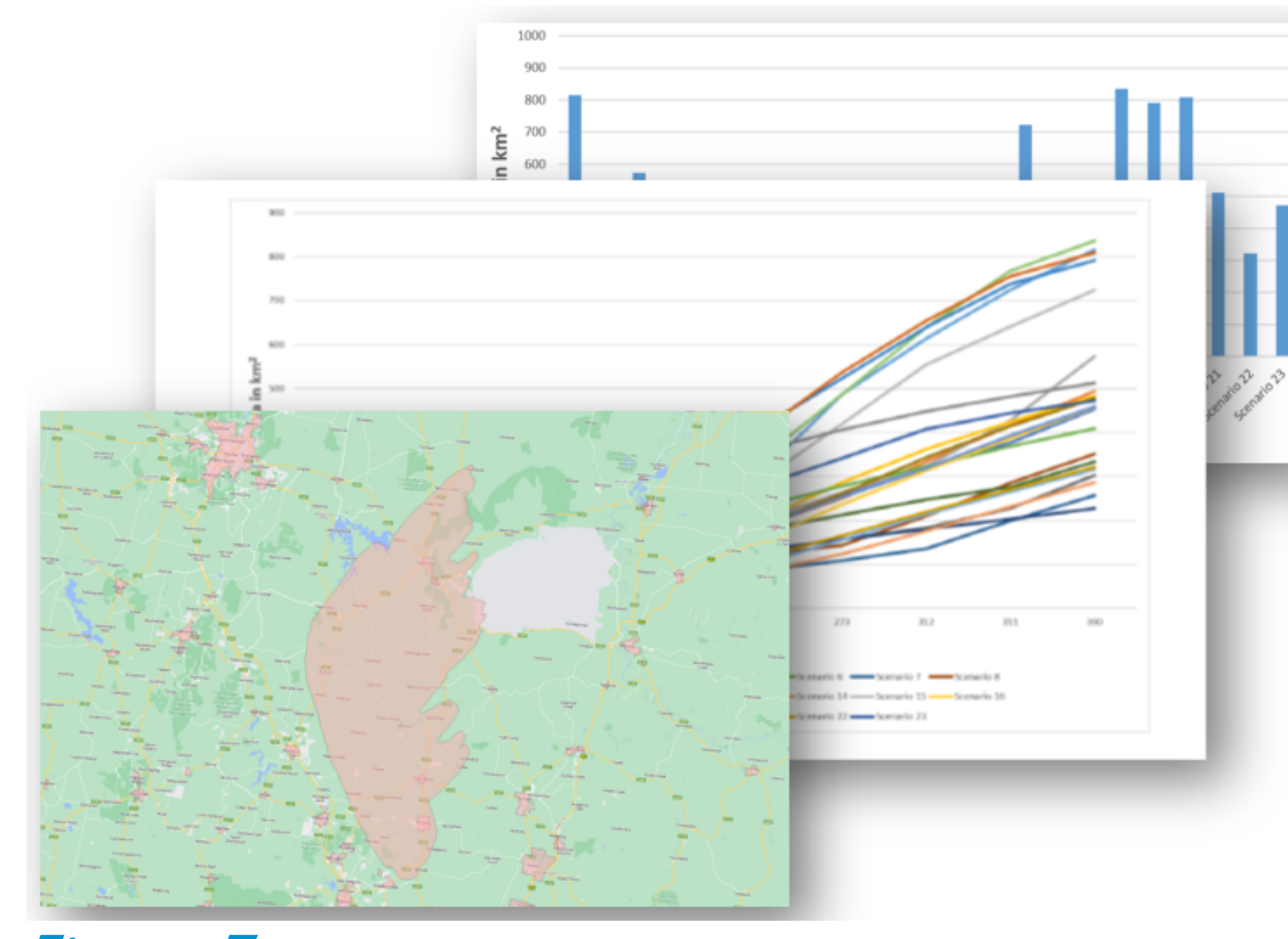


Figure 7: Metrics used for evaluation include speed of spread, total area affected or towns/infrastructure threatened.

## Combinatorial Flood Scenarios for Training Exercises

### Floods Cause Severe Damages



Figure 8: Flood in Germany in July 2021.

### Flooding Disaster Exercise

<b>Purpose</b>	Analyze impact in order to find weaknesses in current response strategies
<b>Type of exercise</b>	Tabletop exercise
<b>Participants</b>	Regional government officials and emergency services
<b>Exercise complexity</b>	3
<b>Duration of exercise</b>	Over 4 weeks on separate days
<b>Visibility</b>	All events visible

### Combinatorial Exercise Plan

Scenario <sub>1</sub>	Water levels rises 1.5 m	Structural damages to bridge vital to response efforts in the area affected	Leakage of flood control measures near a low density residential area	Flooding near critical infrastructure	✗
Scenario <sub>2</sub>	Leakage of flood control measures near a low density residential area	Water levels rises 1.5 m	Flooding near critical infrastructure	Structural damages to bridge vital to response efforts in the area affected	✓
Scenario <sub>3</sub>	Leakage of flood control measures near a low density residential area	Structural damages to bridge vital to response efforts in the area affected	Flooding near critical infrastructure	Water levels rises 1.5 m	✓
Scenario <sub>4</sub>	Flooding near critical infrastructure	Water levels rises 1.5 m	Leakage of flood control measures near a low density residential area	Structural damages to bridge vital to response efforts in the area affected	✓
Scenario <sub>5</sub>	Flooding near critical infrastructure	Structural damages to bridge vital to response efforts in the area affected	Leakage of flood control measures near a low density residential area	Water levels rises 1.5 m	✗
Scenario <sub>6</sub>	Structural damages to bridge vital to response efforts in the area affected	Water levels rises 1.5 m	Flooding near critical infrastructure	Leakage of flood control measures near a low density residential area	✓

Figure 9: Combinatorial sequence structure with 6 flooding scenarios for 4 events.

## Natural Hazards Triggering Technological Disasters (Natech)

### Natech Issues



Figure 10: JRC database tracking Natech.

### Natech Challenges

- ▶ High frequency of extreme weather events (simulation based on combinatorial modelling).
- ▶ Impact on electric power grid resulting in blackouts: resilience of energy systems & effects on critical infrastructure.
- ▶ Coordinated response plans, combinatorial coverage of corner cases.

### Disaster Preparedness

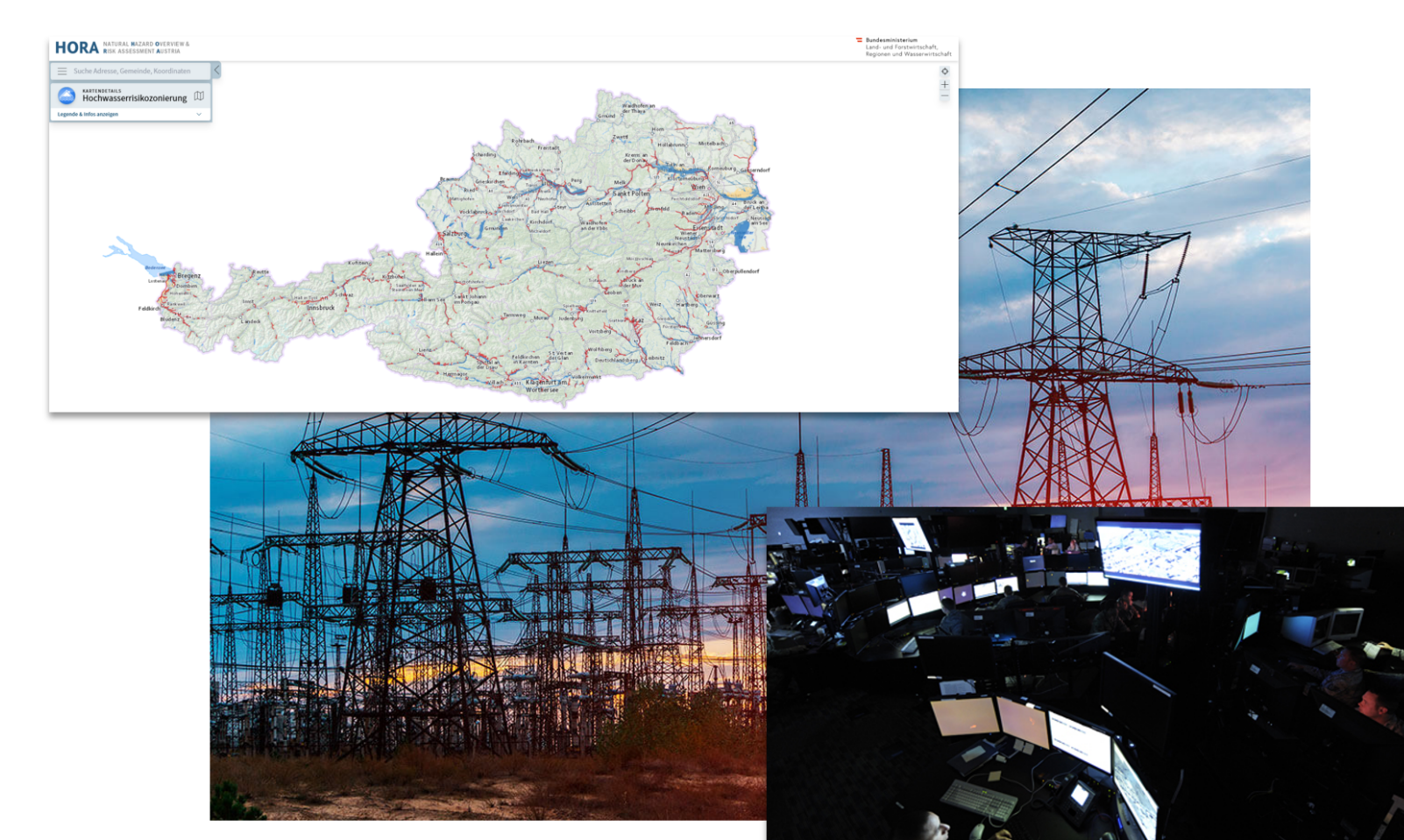


Figure 11: Multi-hazard aspects of Natech.

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