RIVER FLOW 2026 · IAHR INTERNATIONAL CONFERENCE ON FLUVIAL HYDRAULICS

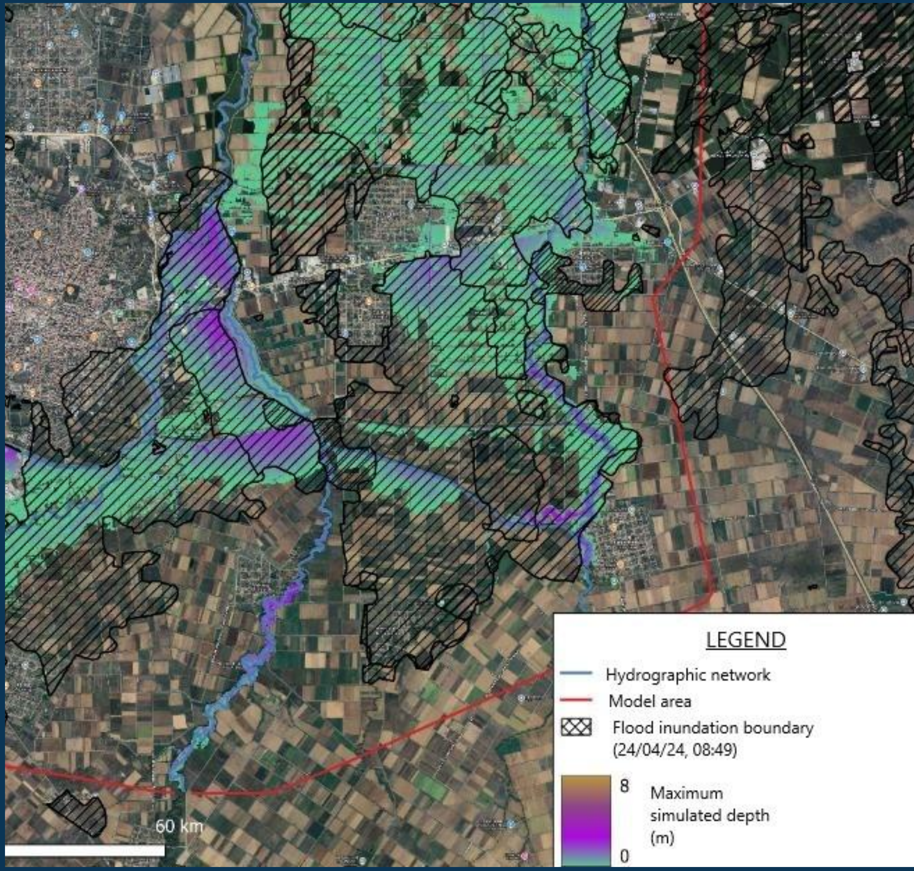
Combined Hydrologic & Hydrodynamic Simulation of Extreme Floods

Ianos & Daniel

Kalentzis River Basin, Western Thessaly (Greece)

National Technical University of Athens

URBAN WATER MANAGEMENT AND HYDROINFORMATICS GROUP



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Why lowland agri-urban floodplains are hard

- Flooding here is not driven by rainfall magnitude alone.
- Natural runoff interacts with dense man-made drainage: levees, diversions, artificial collectors, interconnected channels.
- Response is governed by thresholds, system memory and flow redistribution — not captured by simple design-storm methods.
- Two recent extreme events offer a natural experiment in the same basin:
    - Ianos (Sep 2020) — dry antecedent conditions
    - Daniel (Sep 2023) — wet antecedent conditions

The paradox

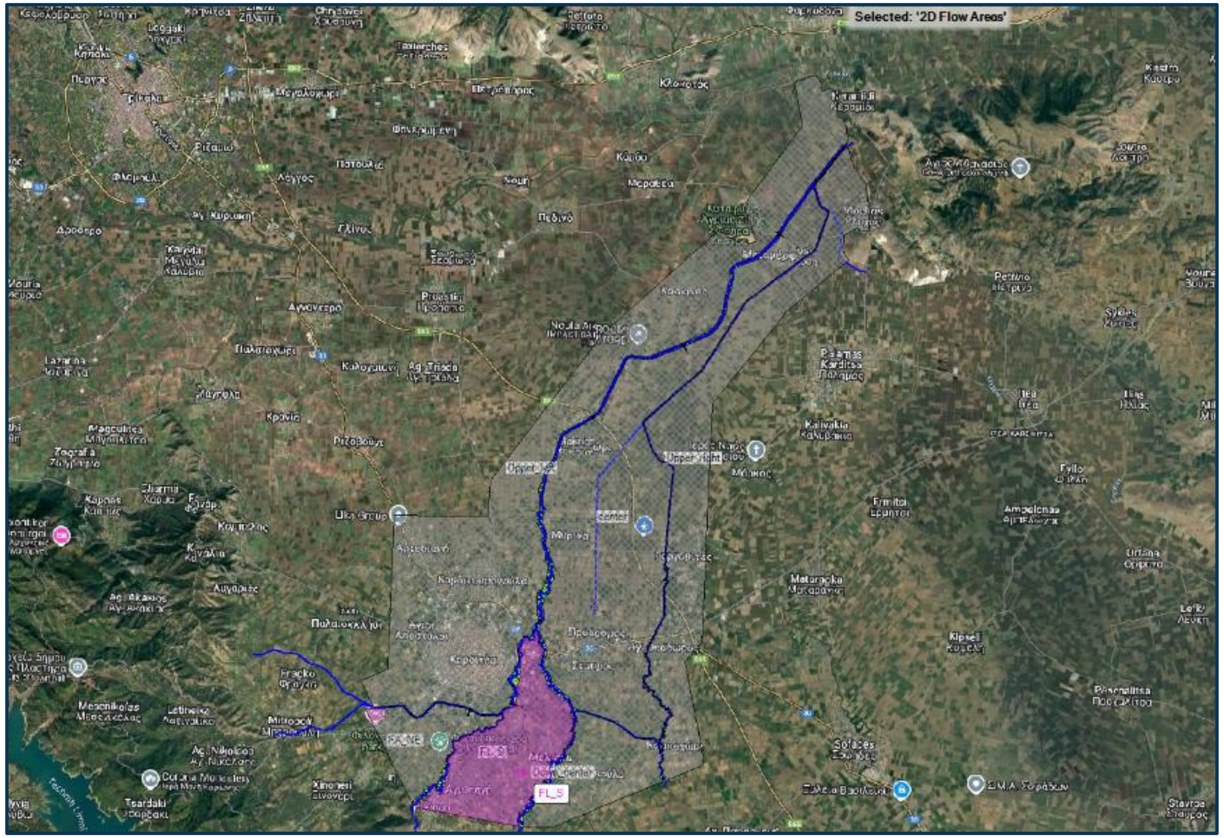
Daniel produced far more widespread and persistent flooding than Ianos —

despite comparable, or even lower, short-term rainfall intensities in parts of the basin.

So what made the difference?

Kalentzis River basin & the Karditsa plain

- 528.8 km² tributary of the Pinios River, draining the western Thessalian plain.
- Lower half ≈ a highly modified agri-urban floodplain.
- Heavily engineered: artificial channels, embankments, diversions, controlled collectors.
- These connect rural floodplains to the urban area of Karditsa.
- Flow paths are shaped as much by infrastructure as by natural topography.



1D–2D model domain over the Kalentzis network (satellite base)

OBJECTIVES

What we set out to do

01

Antecedent wetness

Assess how pre-event soil moisture modulates runoff generation under extreme rainfall.

02

Infrastructure control

Analyse how levees, diversions and collectors control flood routing and inundation patterns.

03

Added value of coupling

Demonstrate the value of coupled hydrologic–hydraulic modelling for post-event reconstruction.

Ianos vs. Daniel — a natural experiment

	IANOS · Sep 2020	DANIEL · Sep 2023
Driver	Medicane (Mediterranean hurricane)	Storm Daniel (slow, persistent)
Antecedent soil moisture	Very dry	Wet / pre-saturated
Runoff efficiency	Limited — short-lived peaks	High — sustained inflows
Inundation extent	Localized, discontinuous	Widespread, persistent
Dominant mechanism	Channel overtopping, levee failures	Floodplain storage & connectivity
Karditsa city	Flooded (levee failures N of Gavrias)	Not directly flooded

Same basin.

Same infrastructure.

Very different floods.

An integrated, event-based framework

Rainfall–Runoff

HEC-HMS

- 15-min basin hyetographs (rain gauges)
- NRCS Curve Number method
- CN conditioned on antecedent wetness

Hydrodynamics

HEC-RAS 6.6

- Coupled 1D–2D framework
- 2D diffusive wave + LiDAR subgrid
- Levees as explicit lateral structures

Validation

Multi-source

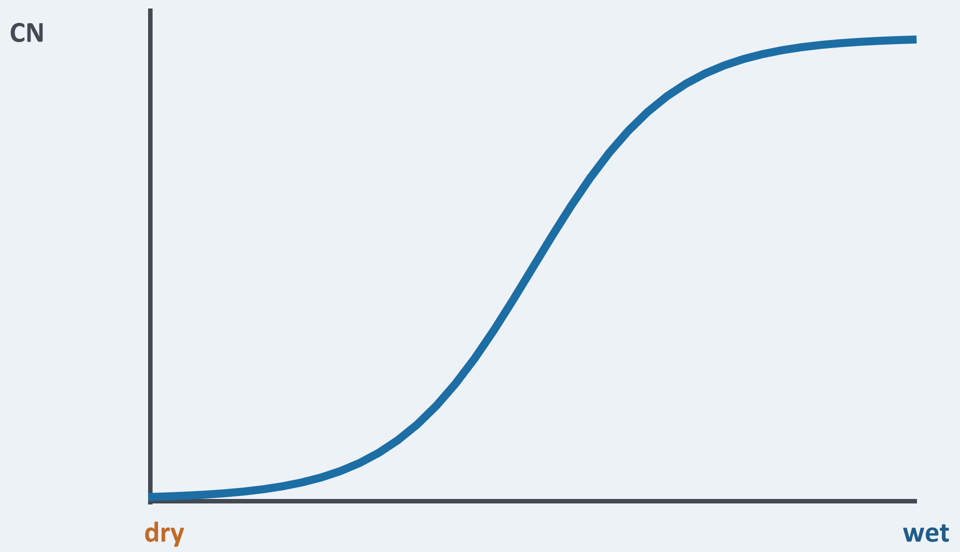
- Copernicus EMS flood extents
- Field marks, drone & news footage
- Forensic report (Ianos levee breaks)

Hydrographs from HEC-HMS drive HEC-RAS as boundary conditions — one consistent chain from rainfall to inundation.

Curve Number conditioned on antecedent wetness

- Event-based rainfall–runoff, explicitly conditioned on pre-event wetness.
- Curve Number treated as a variable, linked to cumulative rainfall over the preceding 15 days (P_{15}).
- Smooth non-linear transition between a dry-limit and a wet-limit CN.
- Same storm → very different runoff depending on P_{15}.

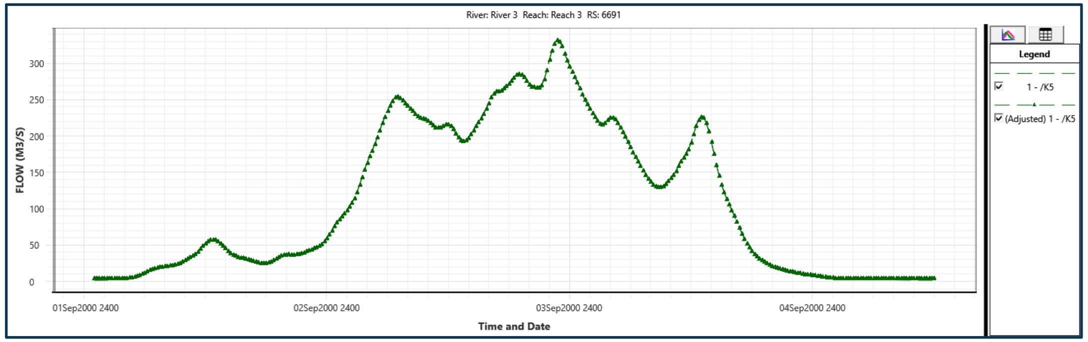
CN as a function of antecedent rainfall P_{15}



Schematic — low runoff when dry (Ianos), high when wet (Daniel)

Infrastructure-explicit 1D–2D routing

- Channels & collectors as 1D; floodplains as 2D diffusive wave.
- Sub-grid terrain from high-resolution LiDAR.
- Levees, diversions & breaches as explicit lateral structures.
- Dynamic exchange: overtopping, flow redistribution, drainage activation.



HEC-HMS inflow hydrograph applied as boundary condition (Ianos, main reach)

Numerical setup

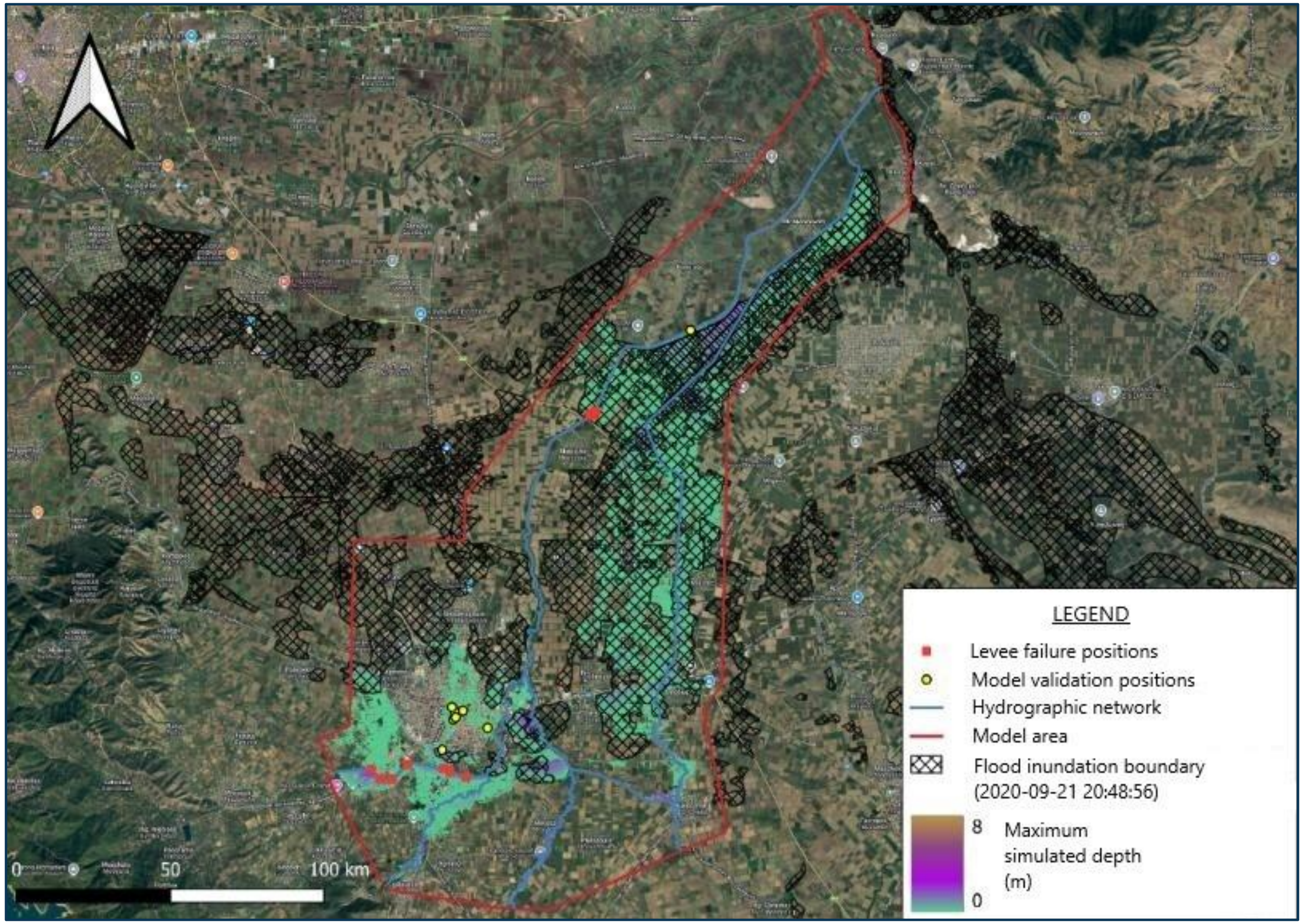
Δt = 0.5 s · 1D spacing ≈ 200 m · 2D grid = 50 m

Mixed-flow regime (exp. 128) · implicit scheme (Courant > 1 admissible)

Why 2D matters:

levee overtopping, flow reversals and floodplain storage cannot be captured by 1D channel routing alone.

Localized flooding, driven by discrete controls

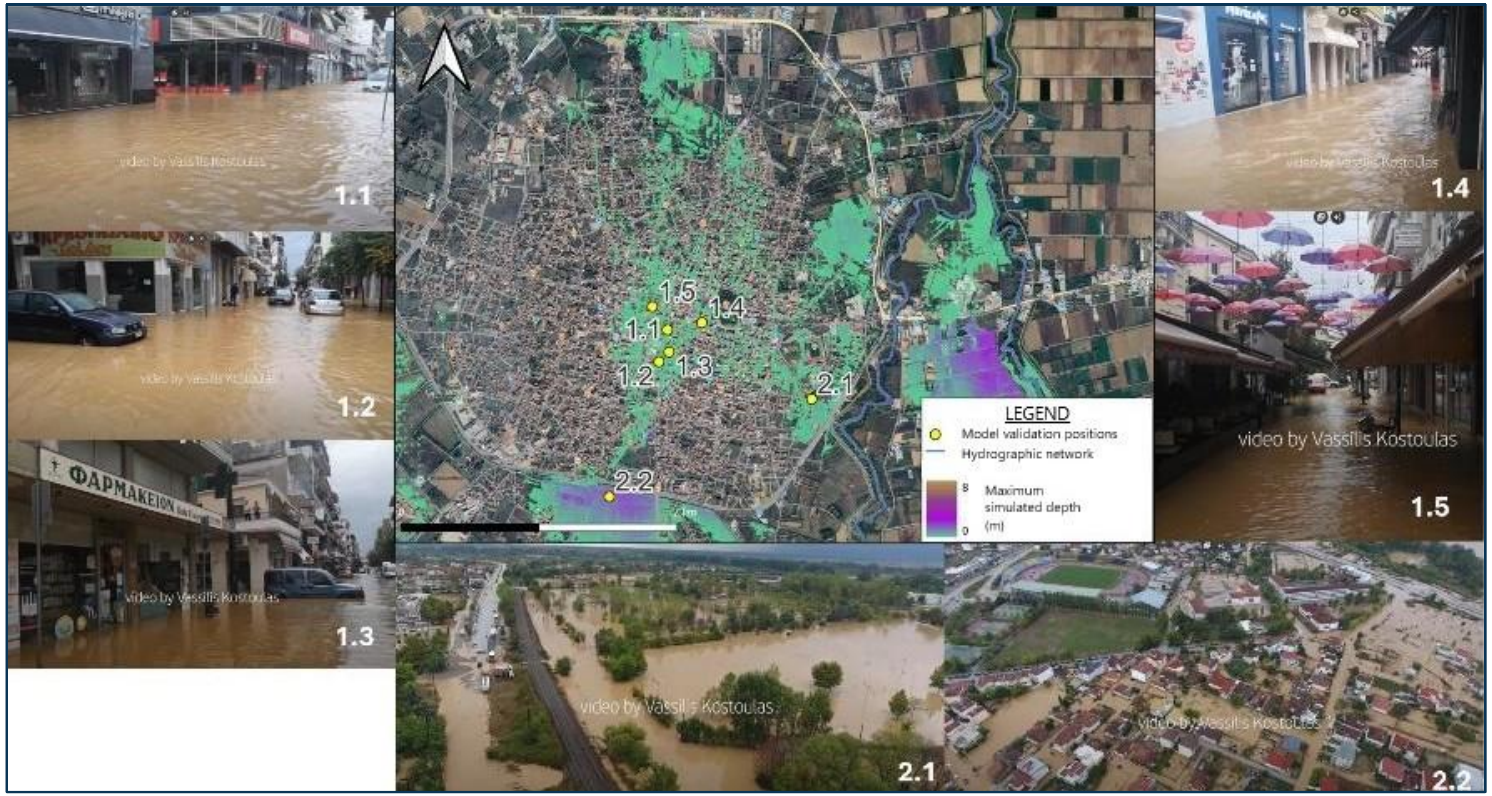


Simulated max depth vs. Copernicus EMS delineation — Ianos

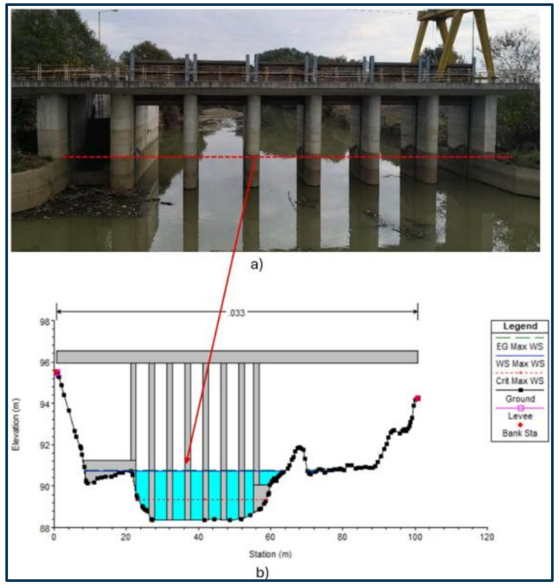
DRY ANTECEDENT

- Dry soils → limited runoff, short-lived peaks.
- Flooding confined to channels and collectors.
- Driven by local conveyance exceedance and embankment overtopping.
- 12 levee failures (forensic report) reproduced as lateral openings.
- Floodplain storage plays a secondary role.

Validated against independent evidence



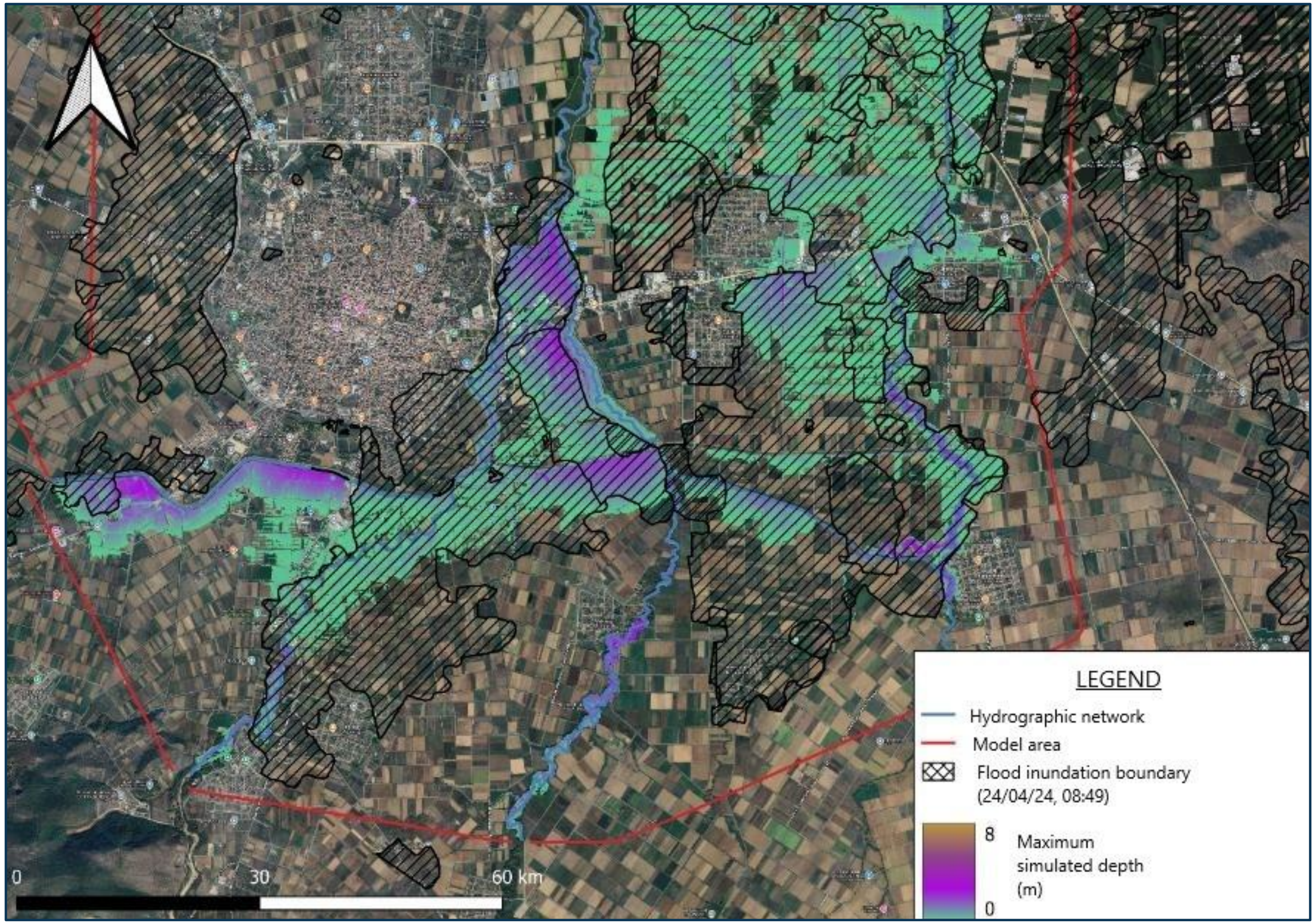
Urban flood records (drone & street footage) vs. simulated depths — Karditsa



Flood marks at the Palamas–Koskinas barrage

- Copernicus extent — good basin-scale match.
- Urban records align with levee-failure flooding.
- Barrage flood marks ≈ simulated water levels.

Widespread flooding & floodplain storage



Simulated max depth vs. merged Copernicus extent — south of Karditsomagoula

WET ANTECEDENT

– Wet soils → efficient, sustained runoff.

– Surcharge of channels → widespread overtopping.

– Floodplain storage becomes the dominant response.

– Delayed recession; connectivity governs spread.

– Karditsa city NOT directly flooded — reproduced.

Two mechanisms explain the contrast

1 · Event memory

- Antecedent wetness (P_{15}) is a first-order control on runoff.
- Dry → extreme rain ≠ extreme runoff (Ianos).
- Wet → moderate rain → disproportionate, persistent floods (Daniel).
- Threshold-driven: small change in initial state → different outcome.

2 · Infrastructure is active

- Embankments & collectors reshape storage–conveyance, add thresholds.
- Daniel: shift from channel routing to floodplain storage.
- Intact local defences can raise hazard elsewhere via redistribution.
- Requires explicit, spatially-distributed representation.

Flood response emerges from rainfall × antecedent state × infrastructure — not rainfall magnitude alone.

What the reconstruction tells us

– A coupled 1D–2D, event-based framework reconstructed both Ianos and Daniel in a heavily modified agri-urban basin.

– Flood response is controlled by antecedent wetness + rainfall structure + infrastructure-induced redistribution.

– Explicit levees and floodplain processes were essential — including the contrasting urban impact (Ianos flooded Karditsa; Daniel did not).

– Coupled hydrologic–hydraulic modelling is a prerequisite for credible event reconstruction and flood-risk planning here.

– Limitations: inter-basin contributions, undocumented diversion operation, post-event terrain changes, approximate Daniel inflows.

Take-home

In engineered lowland plains, **how wet** and **where the water is steered** matter as much as **how much it rained.**

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Thank you

Questions & discussion welcome

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