EGU General Assembly 2021

Surface runoff connectivity across scales: revisiting three simulation studies

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Introduction

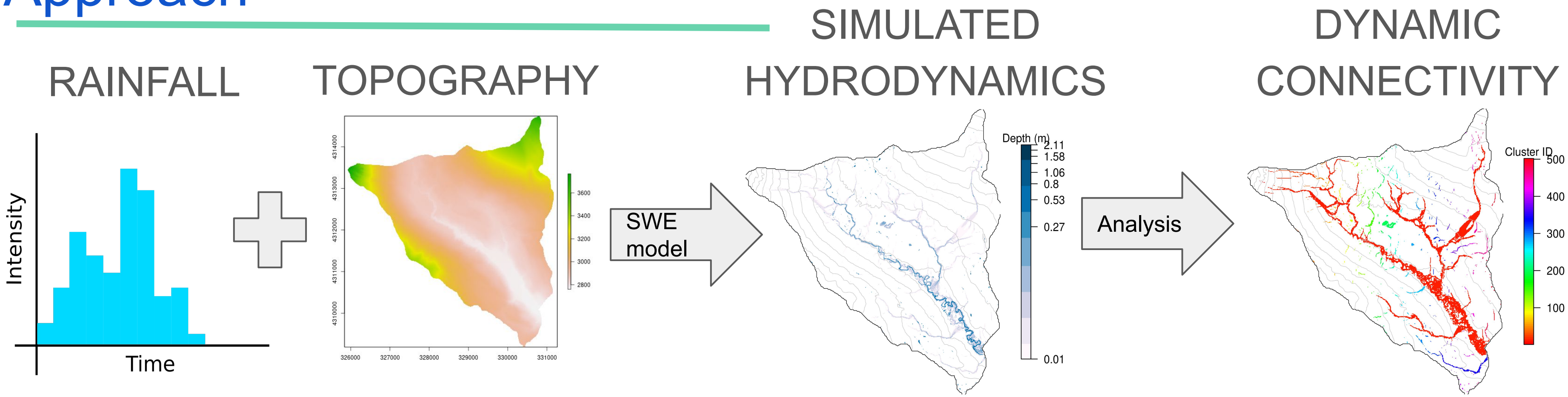
- Surface runoff connectivity as a multiscale feature, which manifests in hydrological signatures
- Flux re-scaling: how do small(er) fluxes and connectivity manifest at large(r) scales?
- Topography determines the structural connectivity
- Hydrodynamics determine the dynamic connectivity
- Three rainfall-runoff studies:

1- **Patch scale** (< 1 ha), 24m^2 local decimeter horizontal and vertical heterogeneity, idealized periodic microtopography.

2- **Hillslope scale** (1 ha < area <1 km^2), 6ha, local heterogeneity, rill networks caused by erosion - decimeter depths, length scales around 100 m.

3- **Catchment scale** (> 10 km2), 15km^2, local heterogeneity, mountain catchment and stream network in km scale)

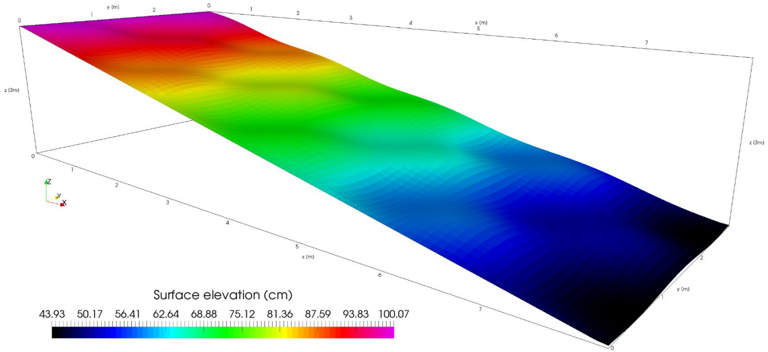
Approach

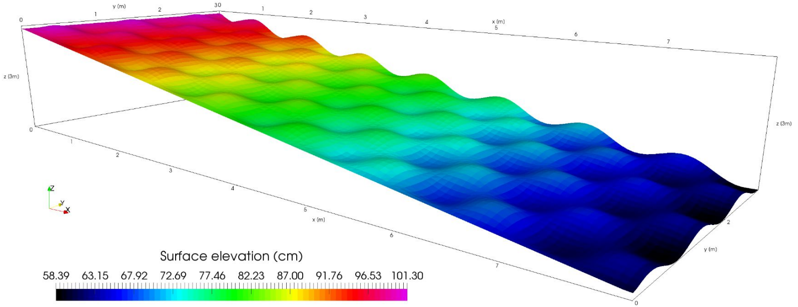


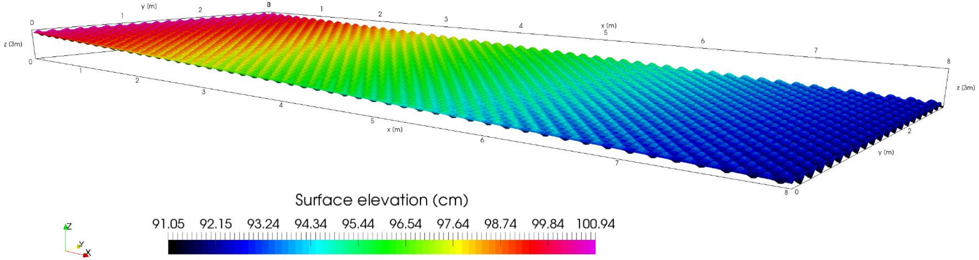
- Topography determines the structural connectivity
- Interaction of spatial heterogeneity and rainfall temporal variability determines dynamic connectivity… but how?
- Hydrodynamics integrate heterogeneity and variability, and thus determine dynamic connectivity
- Use physically-based simulations to generate transient hydrodynamic fields and hydrological signatures (e.g., water balance, hydrographs)
- Characterise dynamic connectivity (somehow)

Plot scale & microtopography

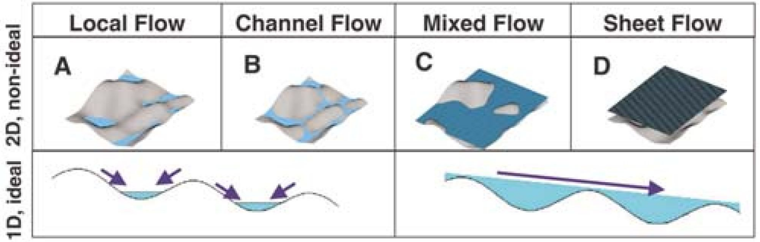
- Patch of 24 m^2, at cm resolution
- Fill-and-spill + puddle-to-puddle processes
- Large set of sinusoidal microtopograhies







Thompson, et al. Microtopography and rainfall-runoff partitioning. WRR. 2010

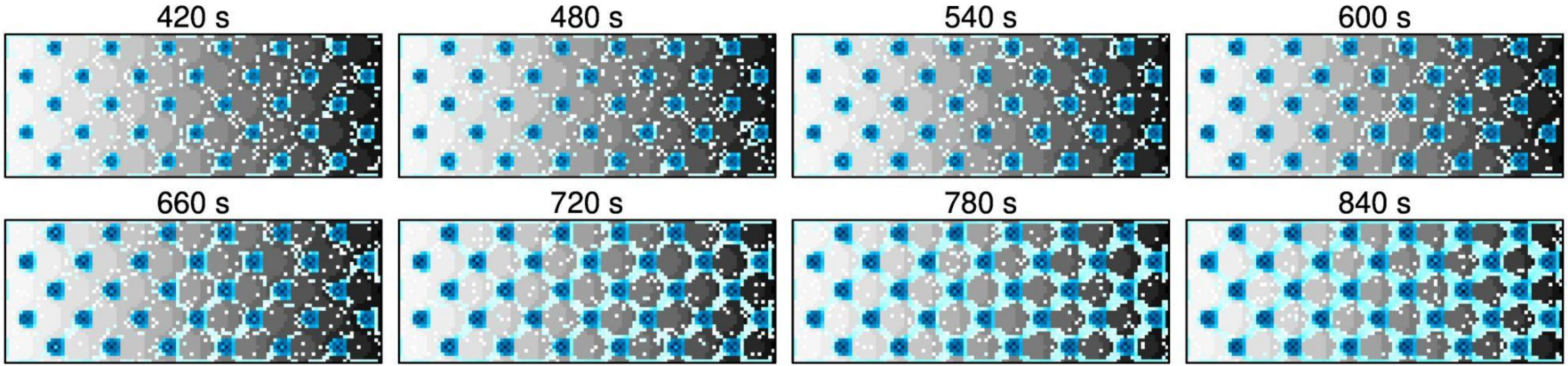


Caviedes-Voullième et al. Interactions of microtopography, slope and infiltration cause complex rainfall-runoff behaviour at the hillslope scale for single rainfall events. Water Resources Research. Under Review.

Plot scale & microtopography

Development of connectivity leading to the onset of runoff and steady flow

Local flow into puddles



Onset of channel connectivity

Connected channels

Developed connectivity

Onset of runoff

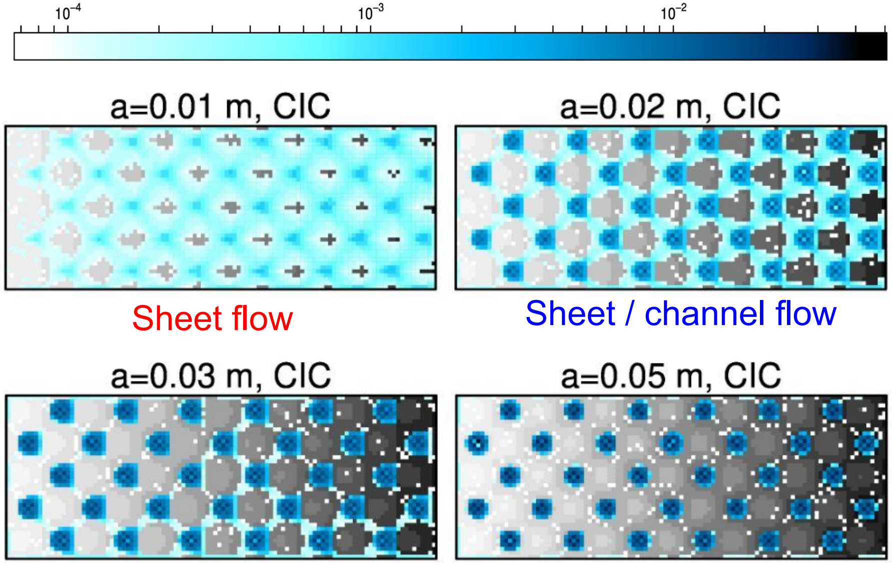
Steady runoff

Caviedes-Voullième et al. Interactions of microtopography, slope and infiltration cause complex rainfall-runoff behaviour at the hillslope scale for single rainfall events. Water Resources Research. Under Review.

Plot scale & microtopography

Amplitude (at constant wavelength) can strongly affect (developed) connectivity

Water depth, at the end of pulse of rain

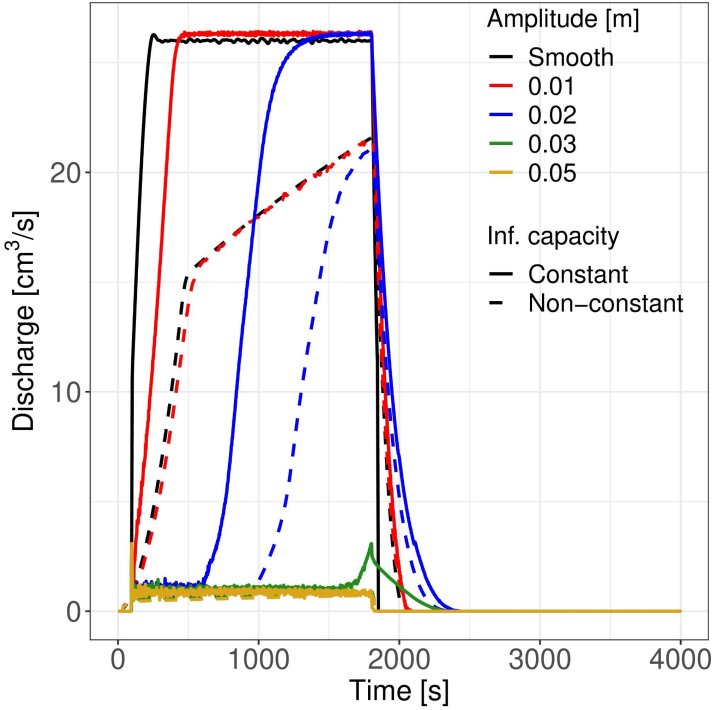


Sheet flow

Sheet / channel flow

Channel / local flow

Local flow, zero discharge



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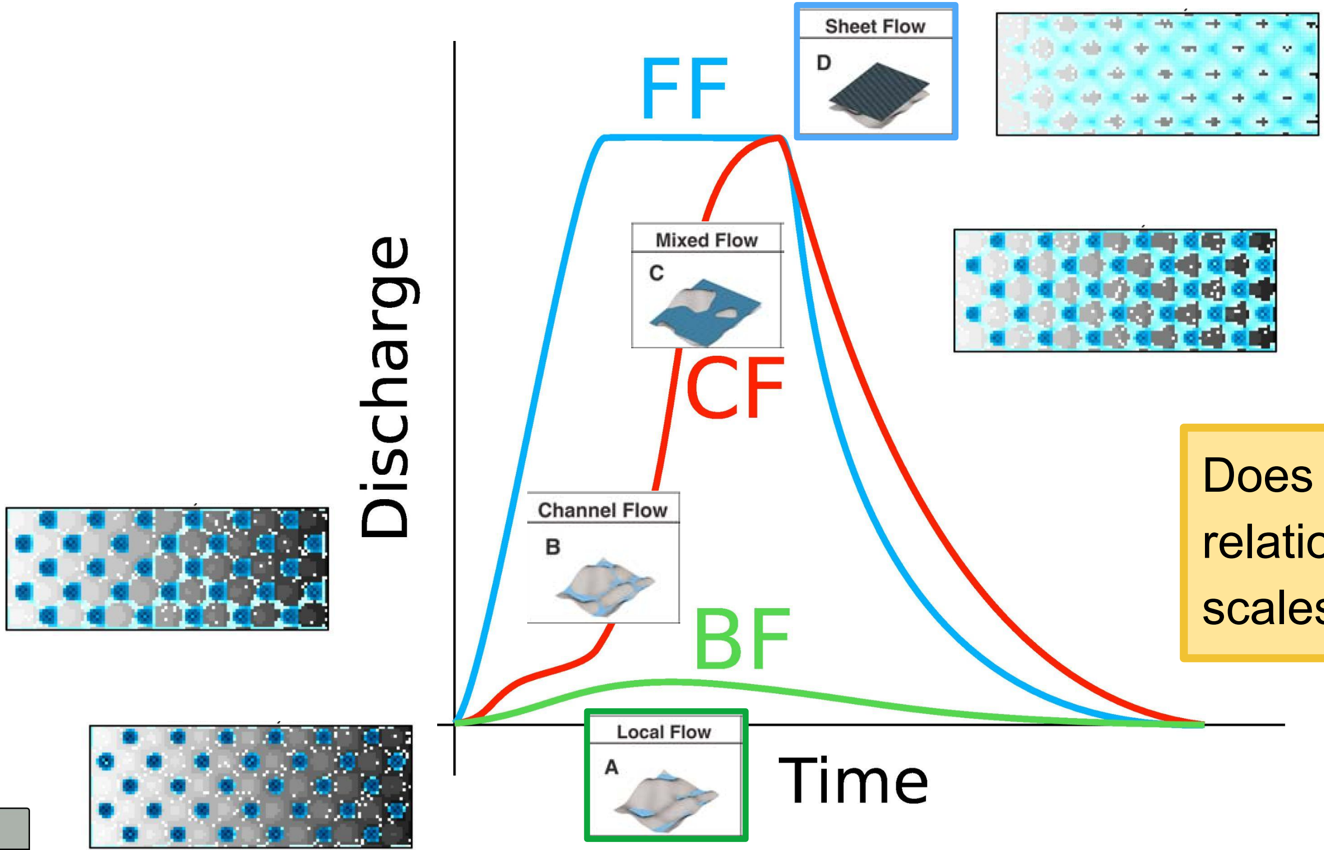
Plot scale & microtopography

Hydrographs are related to the dynamic connectivity

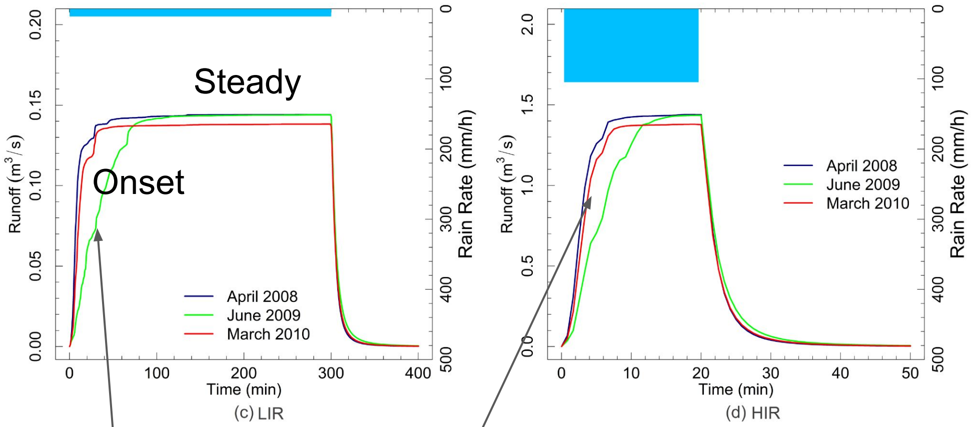


Does these types of relationship hold across scales?

Hillslope scale and rills

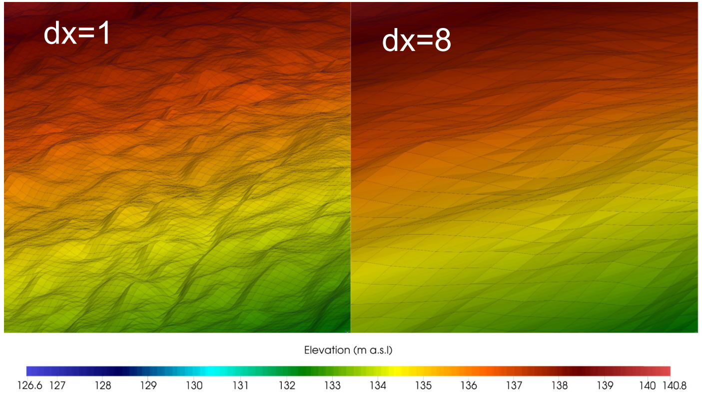
Hühnerwasser catchment

- Experimental catchment, area 60000 m^2, 1m^2 resolution
- Observed terrain evolution, 9 DEMs measured throughout 5 years
- Explored effects of DEM evolution and coarsening up to 8m^2 resolution
- Runoff generation from patch-scale to hillslope, single pulse of rain
- Rill flow concentration and active rill connectivity



DEM differences affect discharge mostly at the onset of runoff, not at steady state

Manifestation of microtopography flow connectivity



DEM coarsening mimics natural erosion smoothing, but misrepresents rill/channel geometry

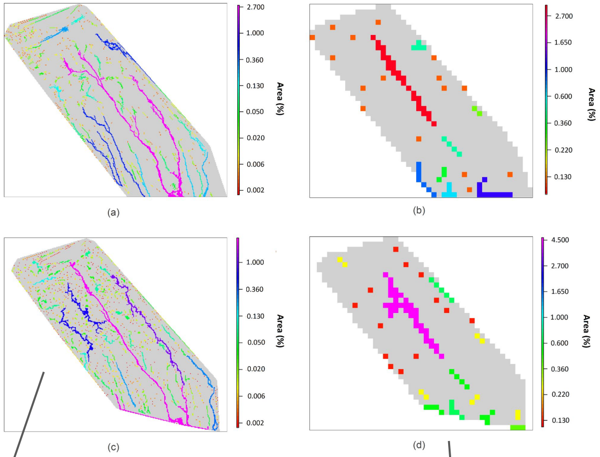
Khosh Bin Ghomash et al. *Effects of erosion-induced changes to topography on runoff dynamics*. Journal of Hydrology. 2019

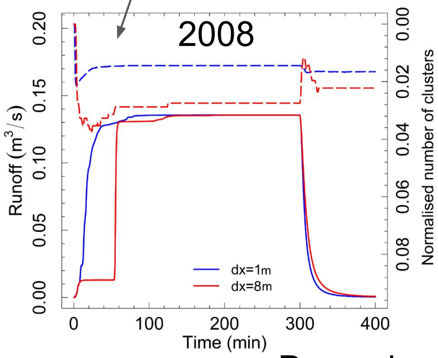
Hillslope scale and rills: *steady flow*

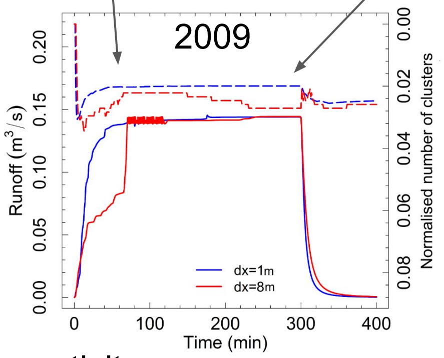
Hühnerwasser catchment

2009

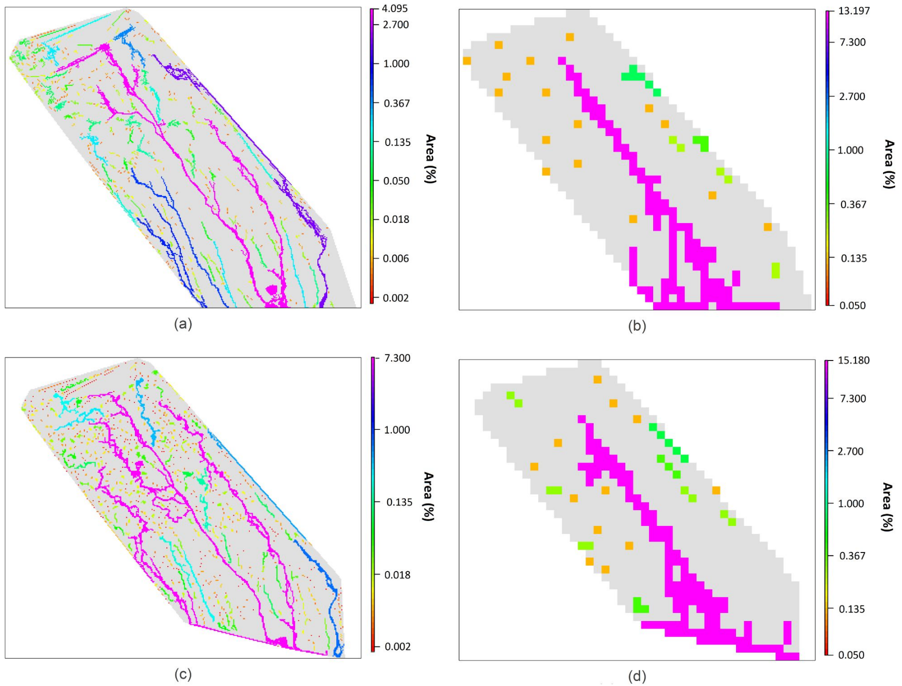
2008







Dynamic connectivity

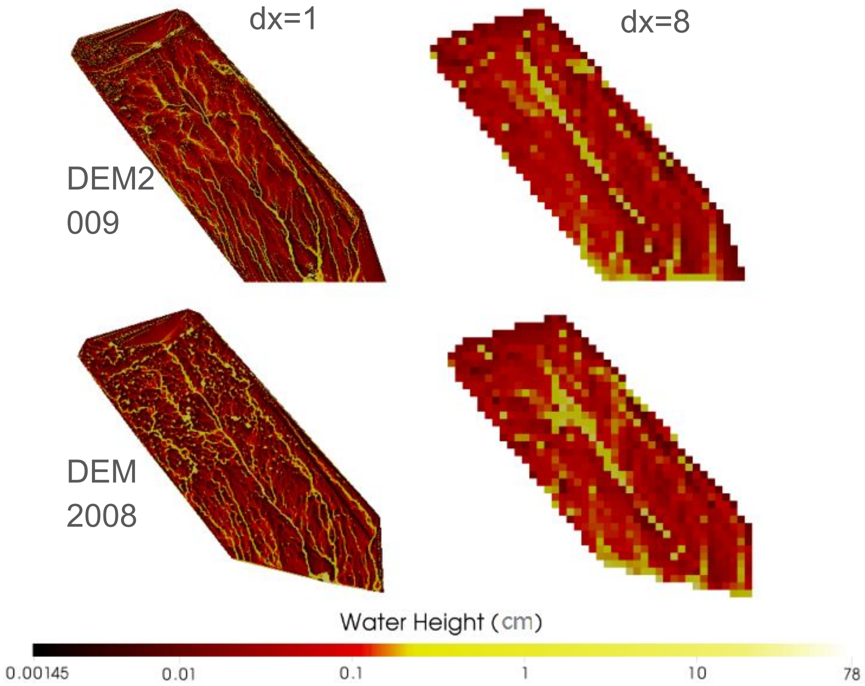


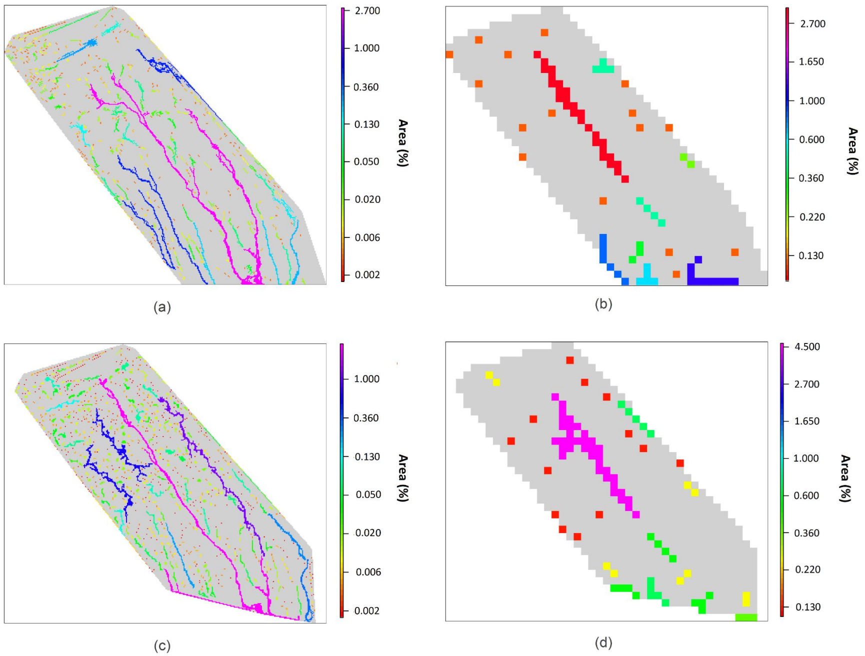
Main surface runoff connectivity is established at steady flow, regardless of DEM coarsening, but local connectivity is different

Khosh Bin Ghomash et al. *Effects of erosion-induced changes to topography on runoff dynamics*. Journal of Hydrology. 2019

Hillslope scale and rills: *onset of runoff*

Hühnerwasser catchment





Flooded clusters, colored by area

DEM Coarsening increases flooding of main rills, but loss of overall runoff connectivity.

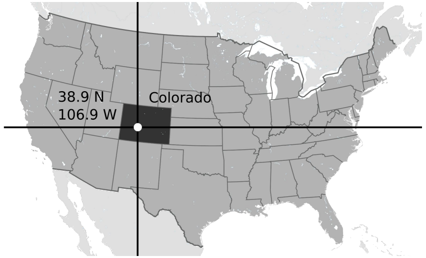
DEM evolution affects how rills connect during the onset of runoff

Khosh Bin Ghomash et al. *Effects of erosion-induced changes to topography on runoff dynamics*. Journal of Hydrology. 2019

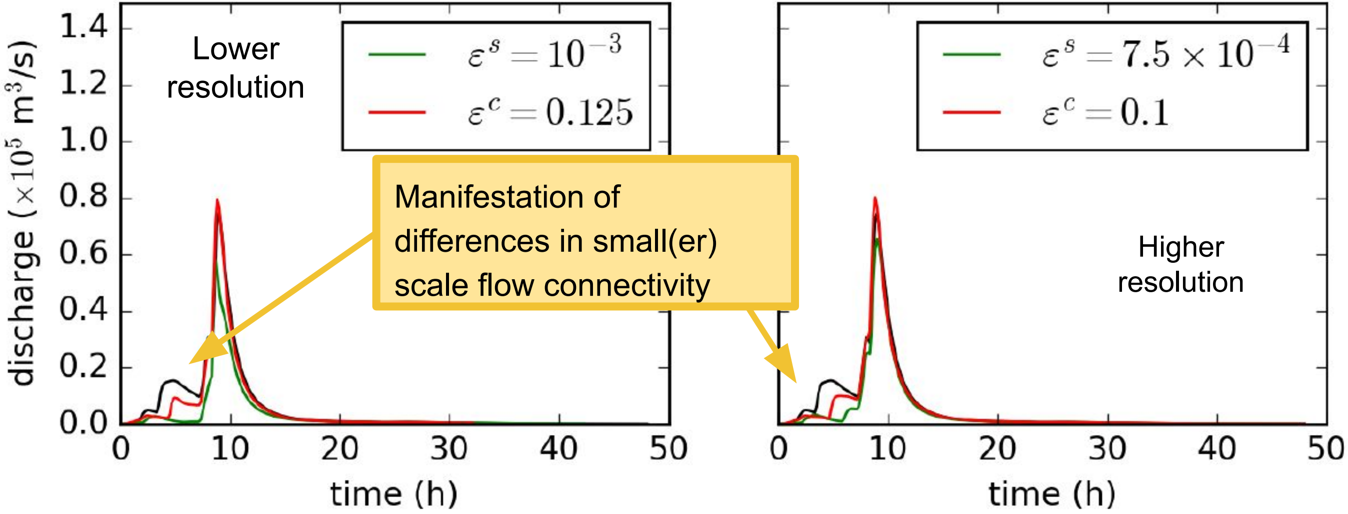
Catchment scale

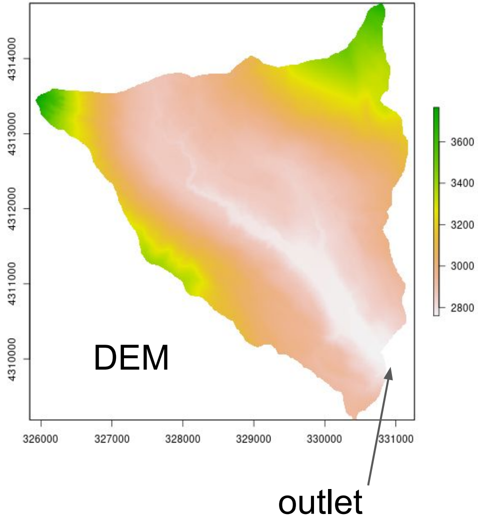
Lower Triangle, East River

- 14.82 km^2 basin area, at 1 m^2 resolution.
- Runoff generation from hillslope to stream
- Studies with different meshes and rainfall



Different computational meshes created with different criteria generate similar artifacts on the **onset of runoff** to the effects seen in smaller systems



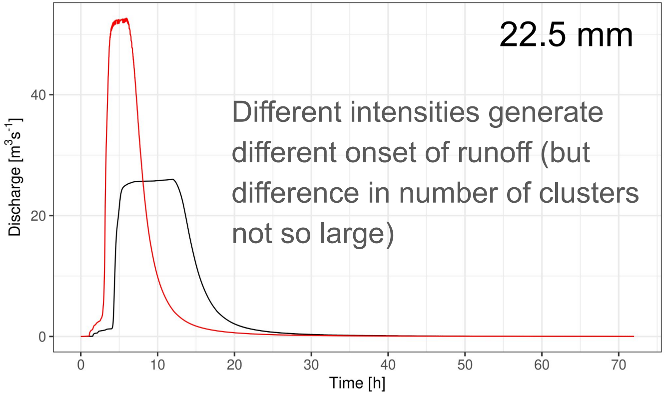


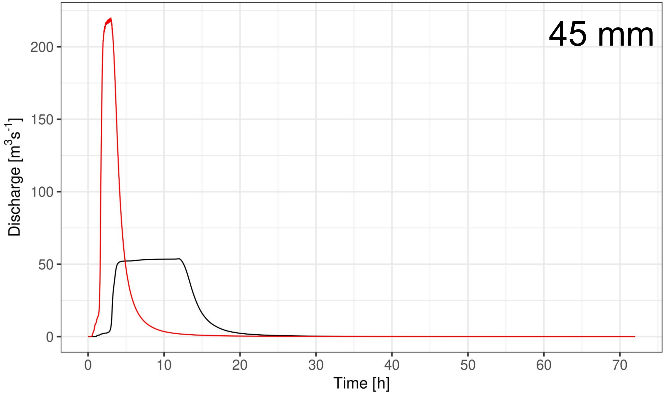
Özgen-Xian et al. Wavelet-based local mesh refinement for rainfall-runoff simulations. Journal of Hydroinformatics. 2020.

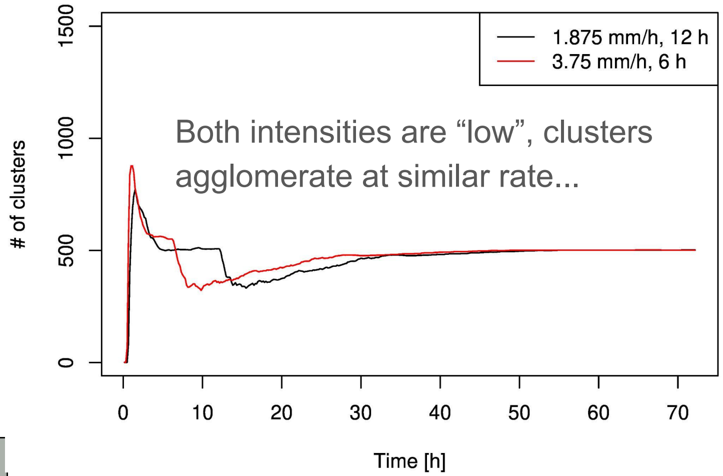
Catchment scale

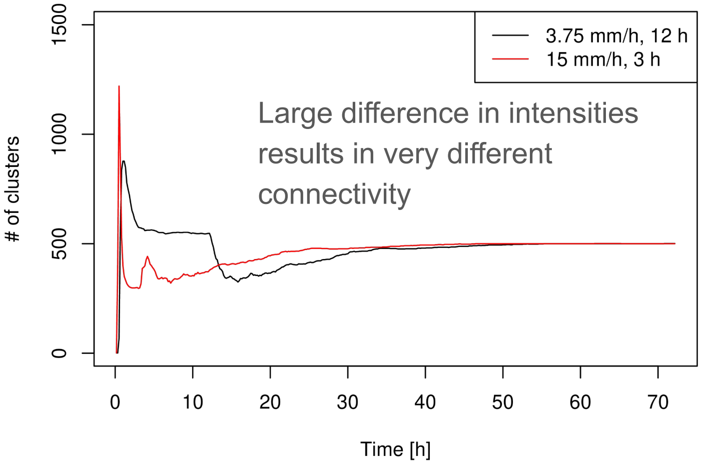
Lower Triangle, East River

Single pulse rainfall, no infiltration





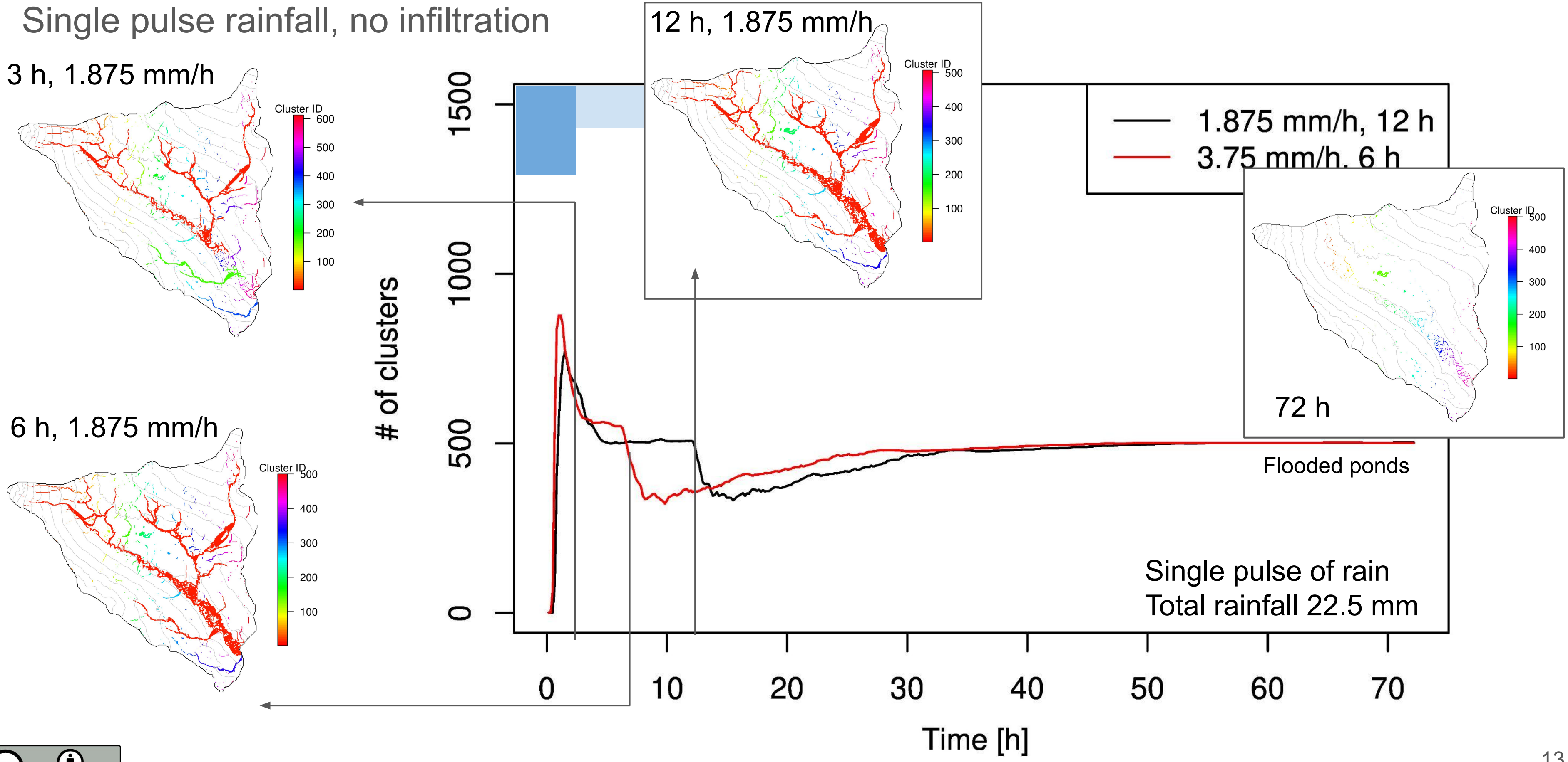




Catchment scale

Lower Triangle, East River

Single pulse rainfall, no infiltration

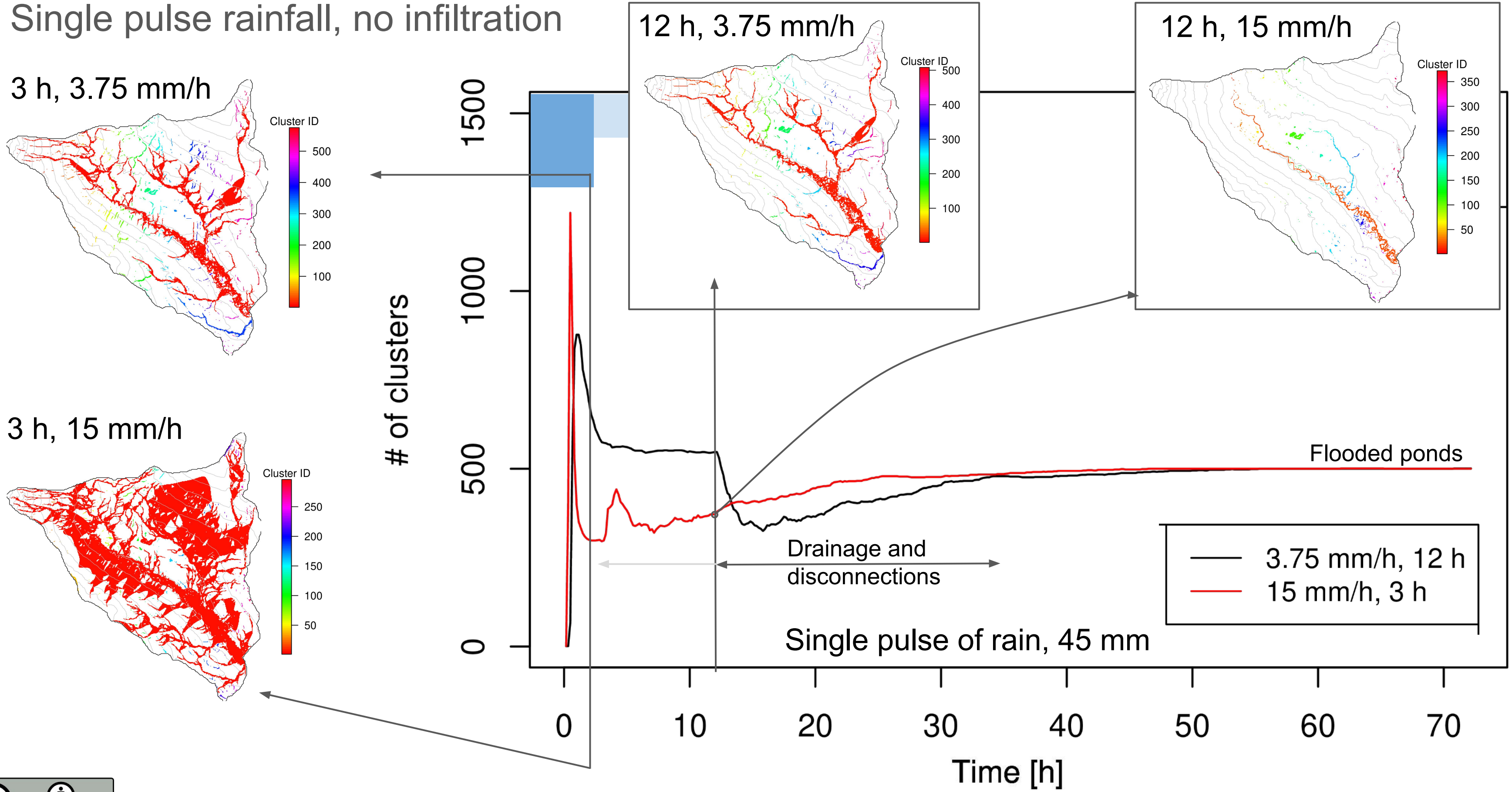


Özgen-Xian et al., Overland flow connectivity states in Lower Triangle Region, East River, Colorado. AGU Fall Meeting 2020.

Catchment scale

Lower Triangle, East River

Single pulse rainfall, no infiltration



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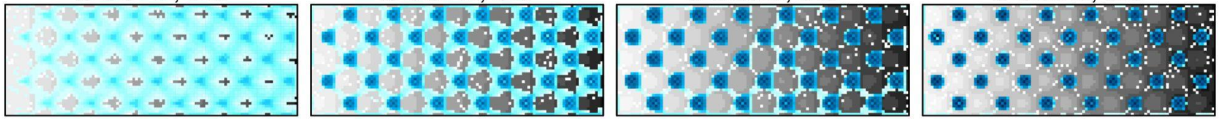
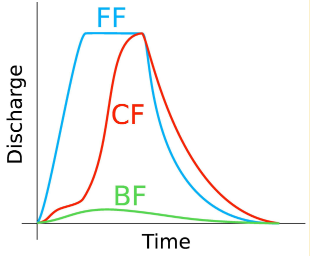
Plot scale (dis)connectivity build up over microtopography (scales cm^2 to m^2)

a=0.01 m, CIC | a=0.02 m, CIC | a=0.03 m, CIC | a=0.05 m, CIC

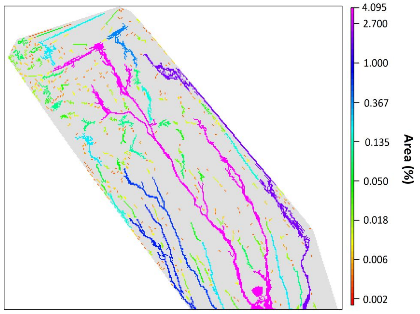


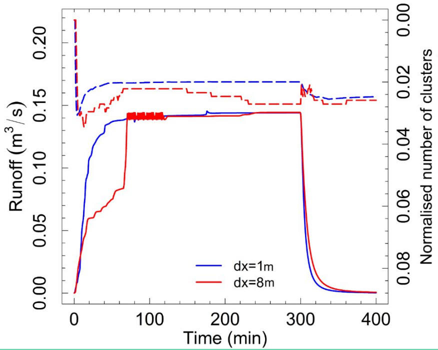
Sheet flow | Sheet / channel flow | Channel / local flow | Local flow

Dynamic (connectivity shows up in hydrographs



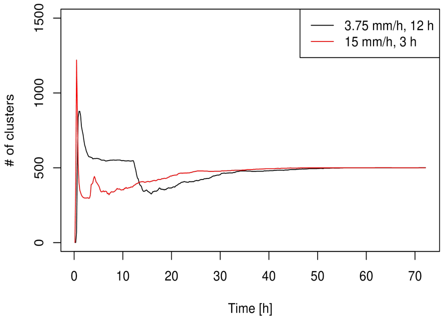
Hillslope scale connectivity build up in rill network (scales m^2 to ha). Patch scale (dis)connectivity appears as nonlinearities in the hydrograph.

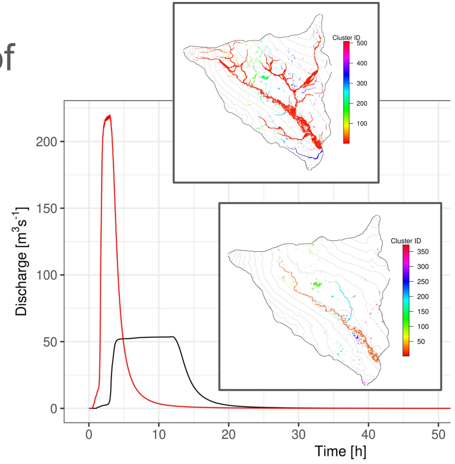




Catchment scale

connectivity (km2). Onset of runoff remains affected.





Discussion teaser: dynamic connectivity behaviours can be perceived across scales and related to hydrographs

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