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Modeling of connectivity: What for? How do we do it? Where to go?

Frédéric Darboux

► **To cite this version:**

Frédéric Darboux. Modeling of connectivity: What for? How do we do it? Where to go?. Laboratory seminar, Université Catholique de Louvain (UCLouvain). Louvain, BEL., Sep 2015, Louvain-La-Neuve, Belgium. hal-01292348

HAL Id: hal-01292348

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Submitted on 5 Jun 2020

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Modeling of connectivity: What for?

How do we do it? Where to go?





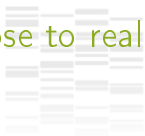
Foreword

- Surface hydrology and sediment transport
- Not a review
- A few insights about how numerical models are used for connectivity

Questions addressed using models

- Where are the links/connections in the watershed?
- How do they vary in space and time?
- How do they vary with climate?

How close to reality?



Hydraulic models vs. Phenomenologic models

- Distance to reality
- Input parameters
- Computation time
- Result interpretation
- Skills

Which one is better?

Hydraulic models are used for water flow simulation, while phenomenologic models are used for water quality simulation.

How close to reality?

Hydraulic models vs. Phenomenologic models

- Distance to reality
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Which one is better?

According to Antoine *et al.* (2009, Adv. Water Res.):

Simple can be good enough.

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Spatial distribution



Some kind of spatial distribution must be included

⇒ spatially-distributed models (1D, 2D, 3D)

2 (related) challenges

Algorithms make a difference

Details are critical

Spatial distribution



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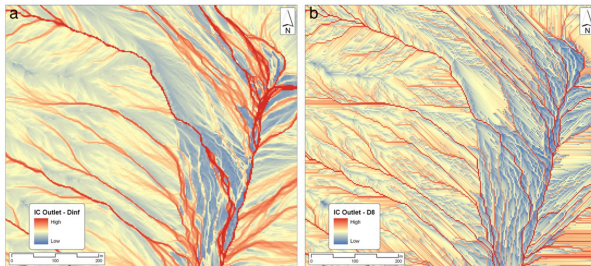
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Algorithms make a difference

Examples on flow accumulation algorithms



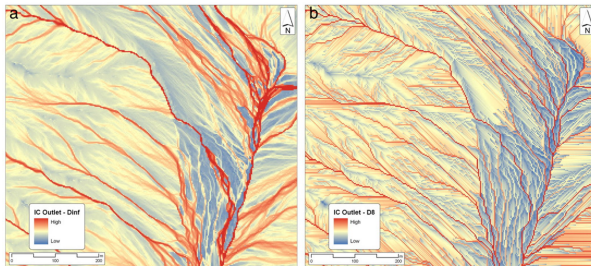
[Cavalli *et al.*, 2013, *Geomorphology*]

How sensitive to data resolution?

2 (related) challenges

Algorithms make a difference

Examples on flow accumulation algorithms

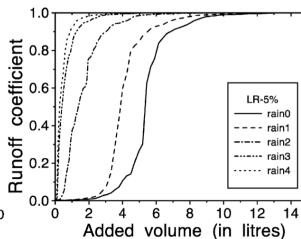
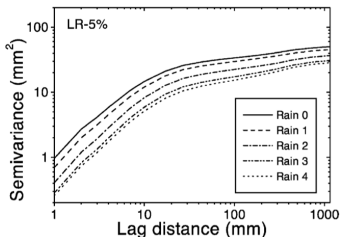


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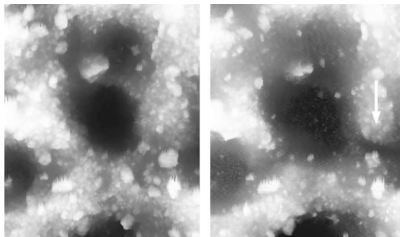


[Darboux et al., 2001, Catena]

⇒ Can we account for details
without representing them explicitly?

2 (related) challenges

Details are critical

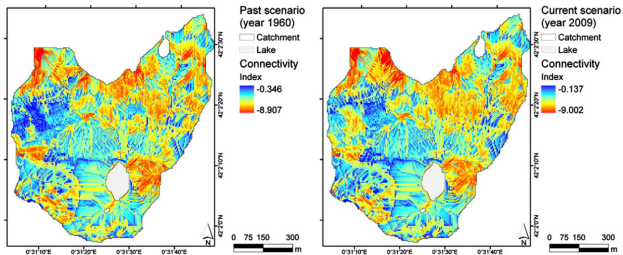


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From pattern to connectivity

Spatial data + spatial model \implies spatial pattern

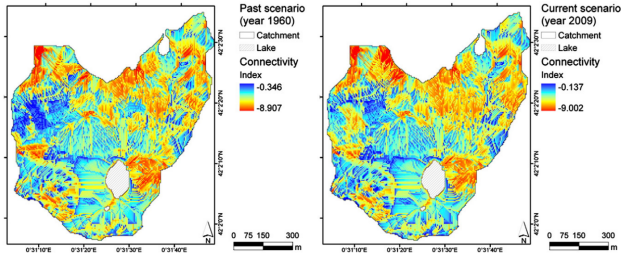


[López-Vicente *et al.*, 2013, Catena]

How to go from a (detailed) connection map to
an (overall) connectivity value?

From pattern to connectivity

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[López-Vicente *et al.*, 2013, *Catena*]

How to go from a (detailed) connection map to
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Indices!



Distributed models: tools to find overall connectivity indices

An overall connectivity index = a lumped parameter!

⇒ From spatially distributed models to non-spatially distributed models.

Indices!



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...but which one?

RSC: The connectivity indicator for overland flow?

Indices!



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Connectivity indicator	Connectivity type	Information requirement	discriminant?
(1) Semivariogram	Structural	Sampling points	No
(2) Relative bivariate entropy	Structural	Sampling points	No
(3) <i>n</i> -Point rectilinear connectivity	Structural	Transect information	No
(4) Connectivity function integral scale	Structural	Full knowledge	Yes
(5) Euler number	Structural	Full knowledge	Yes
(6) Percolation thresholds	Structural	Full knowledge	Yes
(7) Relative surface connection function	Functional	Full knowledge	Yes

[Antoine *et al.*, 2009, *Adv. Water Res.*]

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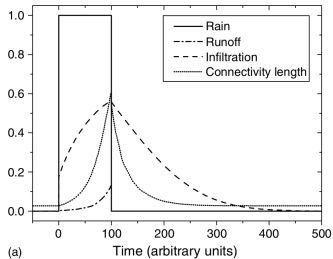
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RSC: The connectivity indicator for overland flow?

+1D: time!



Connectivity changes with time



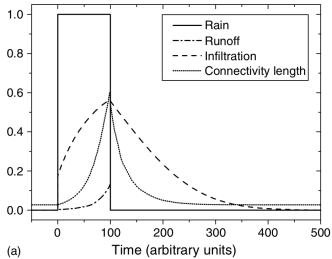
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Connectivity to the outlet \neq Connectivity inside the system

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Connectivity changes with time

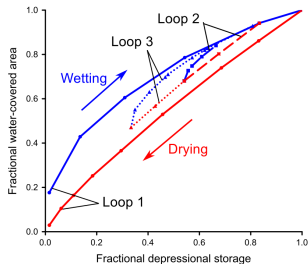


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How to deal with the temporal pattern?



[Shook *et al.*, 2011, *Hydro. Proc.*]

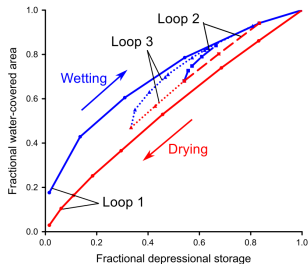
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\implies A very rich dynamics, *but under-studied.*

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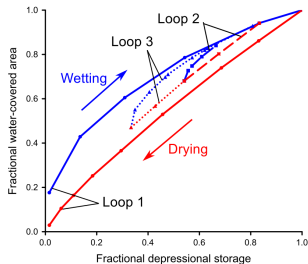
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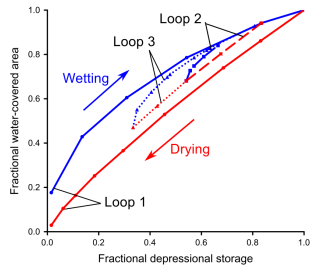
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Poor sediments...

Few works on modelling sediment connectivity

- López-Vicente *et al.*, 2013, Catena
- Cavalli *et al.*, 2013, Geomorphology

Water connectivity vs Sediment connectivity

In hydrology, you need water to carry the sediments

- Sediment connection \Rightarrow Water connection
- Water connection \nRightarrow Sediment connection

More work on sediment connectivity needed,
and models can help on this.

Connectivity-related theories: Inputs & Outputs

Theoretical inputs

Percolation theory



- [Darboux *et al.*, 2002, *Earth Surf. Proc. Landf.*]
- [Lehmann *et al.*, 2007, *Hydrol. Earth Syst. Sci.*]
- [Harel *et al.*, 2013, *Water Res. Research*]

Graph theory



- [Heckmann *et al.*, 2013, *Geomorphology*]

Queuing theory



- [Harel *et al.*, 2013, *Water Res. Research*]

Theory: Inputs & Outputs



Theoretical outputs

- Simplification in modeling
- Understanding
- Scale change

Questions that could be addressed

- Do connection directions matter? How much?
- How to account for connection intensity?

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Do we need data?



Measured data

Study of one watershed:

- What are the important features?
- How to make things more general?
- How to go farther than case studies?

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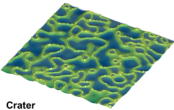
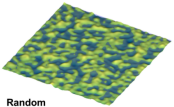
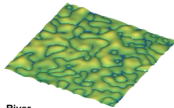
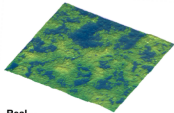
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Computer-generated data



[Peñuela *et al.*, 2013, *Hydrol. Earth Syst. Sci.*]

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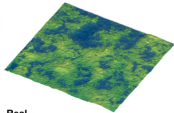
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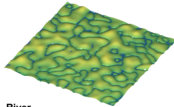
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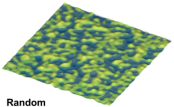
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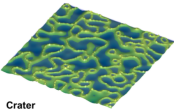
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Crater

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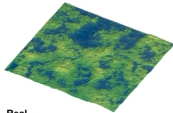
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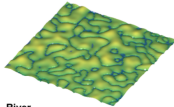
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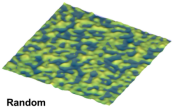
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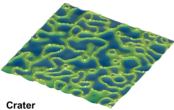
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