A probabilistic model to explain drainage network evolution and emerging scaling laws of river networks

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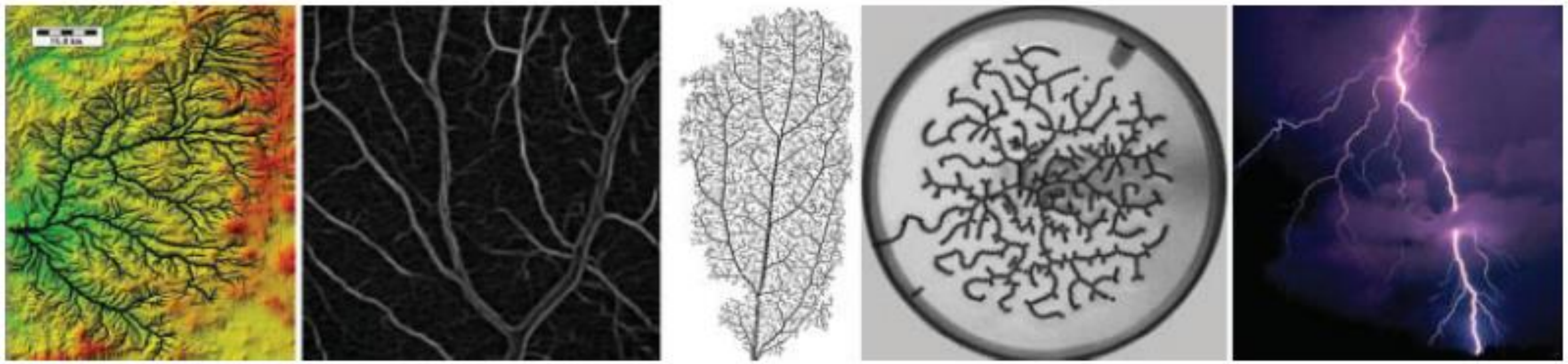
Self-Organization and tree-like Patterns

- Open dissipative systems often organize into tree-like self-similar patterns

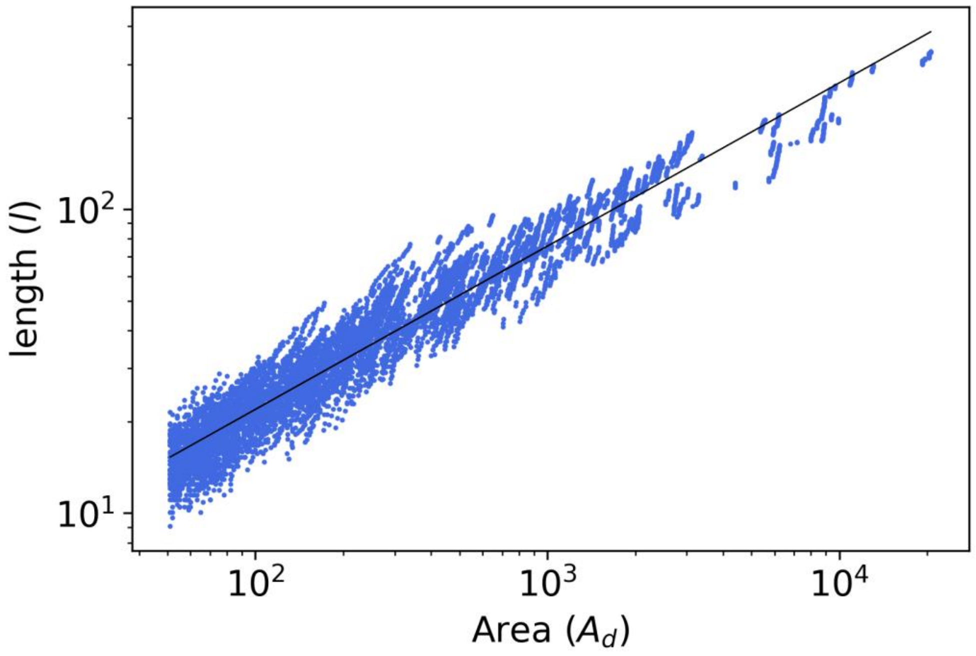


- Why river networks self organize themselves into tree-like self-similar patterns?
- Quantitative Understanding of Geomorphology crucial for landscape behaviour and hydrological response

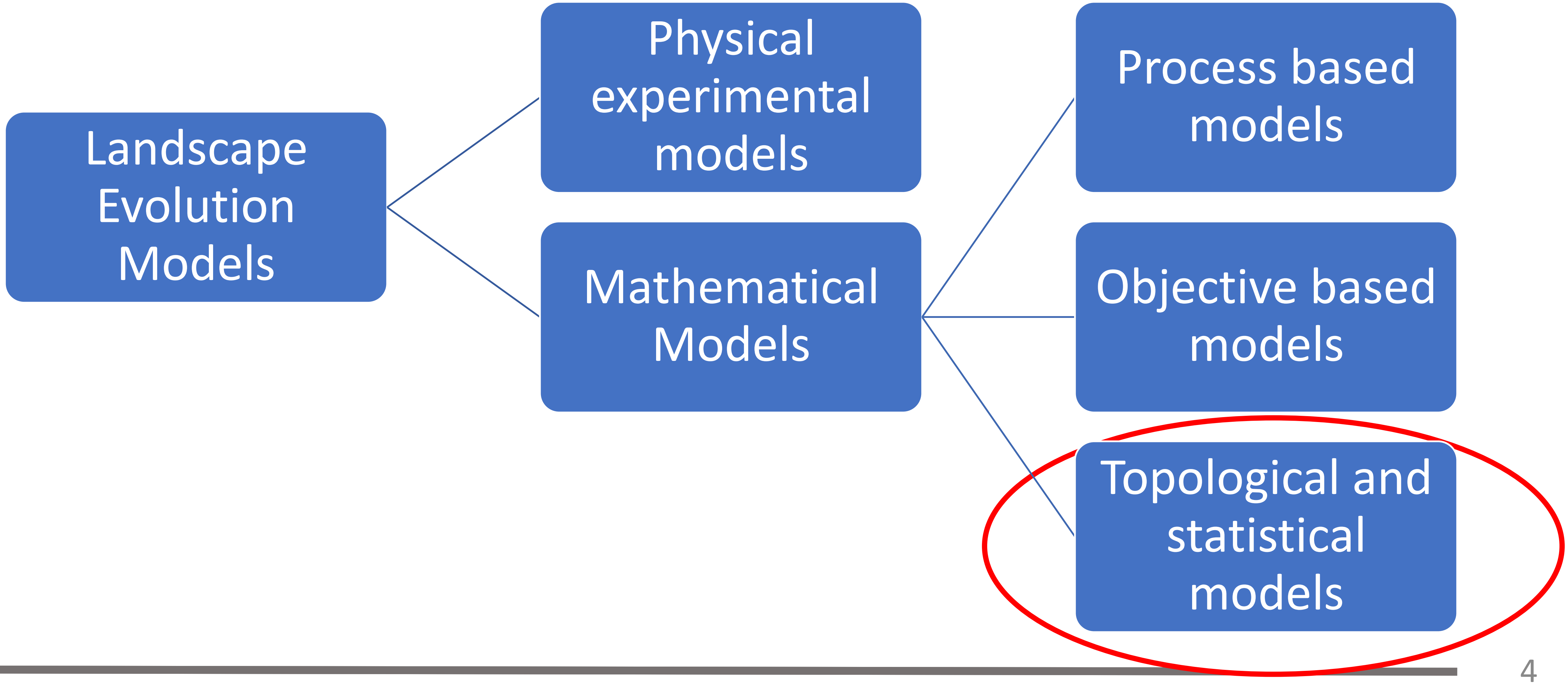
Scaling laws in River networks

- Organization out of complex landscape evolution Process
- Common statistical laws despite underlined differences

1. Hack's law
2. Distribution of Contributing Area
3. Distribution of Upstream Lengths



Landscape Evolution Approaches



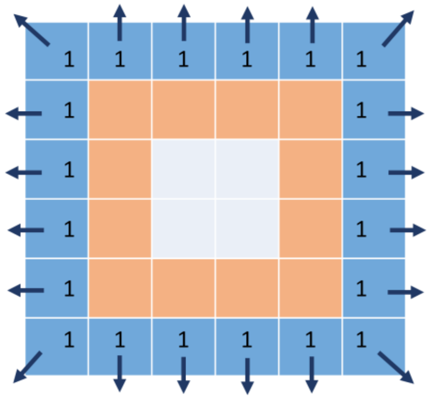
Proposed Model

Model Assumptions

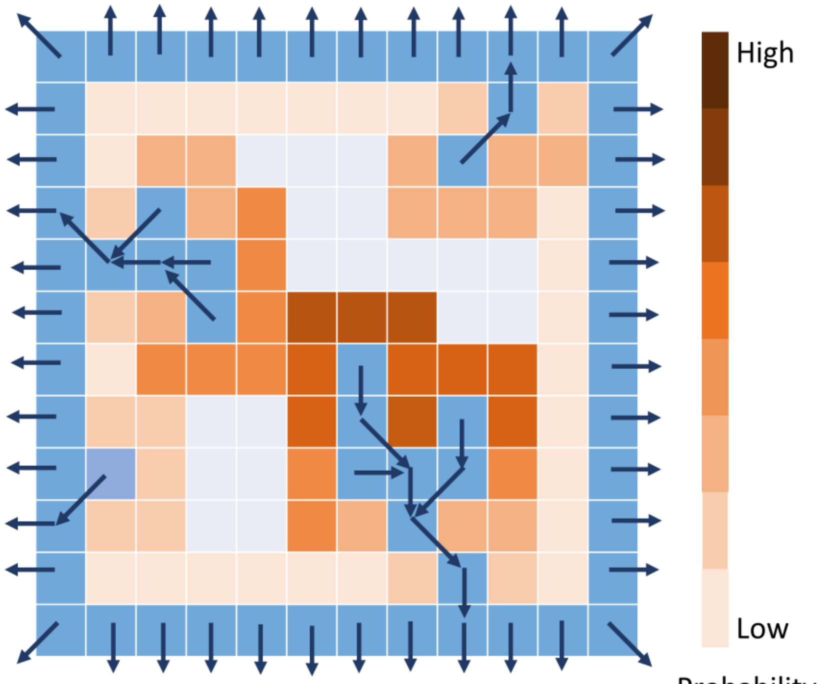
- Growth from outlets
- Headword growth

Algorithm

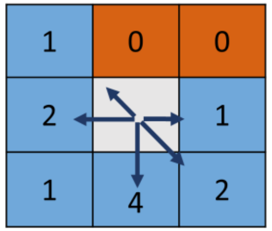
- Demonstrated with a planar matrix
- At every step, choose a pixel among potential pixels and assign a flow direction to it
- Goal is to assign Flow Directions to all the pixels



(a)



(b)

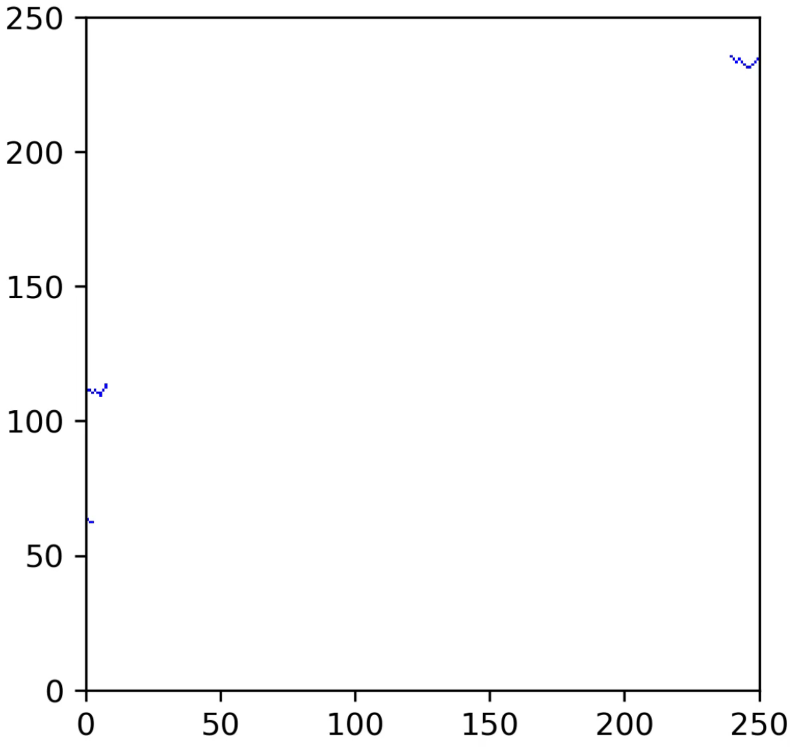


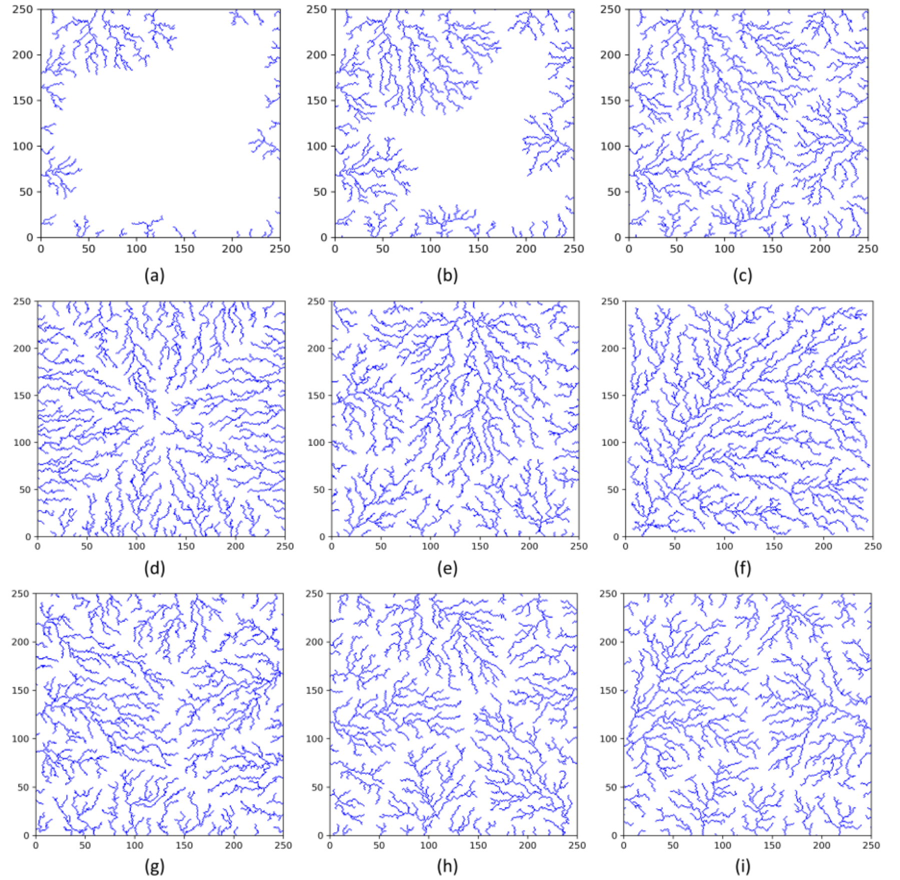
(c)

Choosing Potential Pixel $P(pixel) \propto l^{\alpha}$

Assigning Flow direction $P(FD) \propto A_d^{\beta}$

Resulting Drainage network patterns

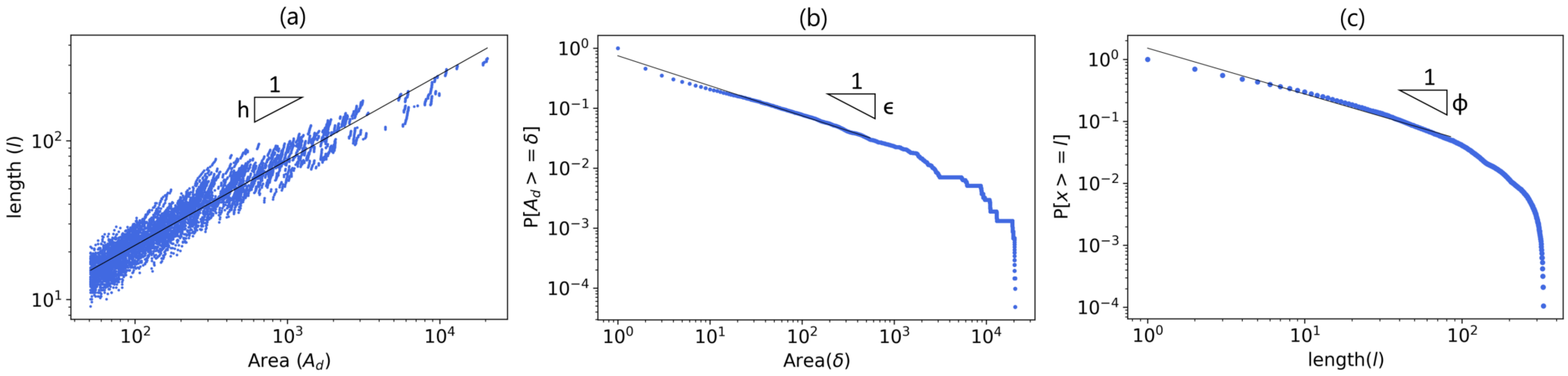




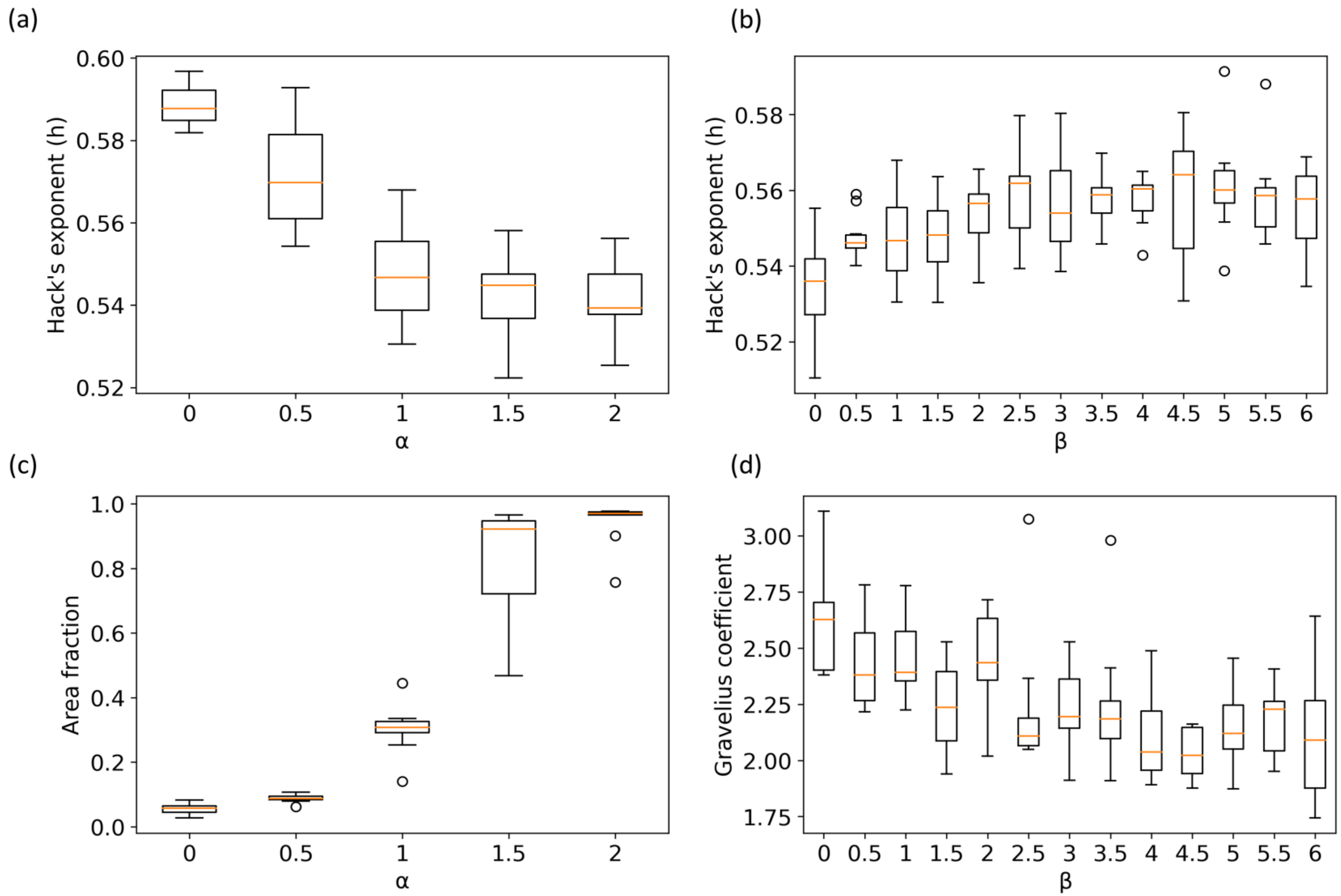
(a), (b)&(c) : Drainage network Evolution for $\alpha = 1$ & $\beta = 1$
(d), (e)&(f) : Networks for α = 0,1 and 2 for constant β=0
(g), (h)&(i) : Networks for β = 0, 2 and 4 for constant α=1

Scaling Laws followed by these Networks

- Hack's law ($L \propto A^h$) , Exceeding probability distribution of contributing area and upstream lengths $P(A_d \geq \delta) \propto \delta^{-\epsilon}$ and $P(x \geq l) \propto l^{-\phi}$
- The modelled *h*, *ε* and *ϕ* values are 0.57±0.04, 0.45±0.03 and 0.72±0.05 whereas observed values are 0.5-0.6, 0.41-0.43, and 0.7-0.8, respectively

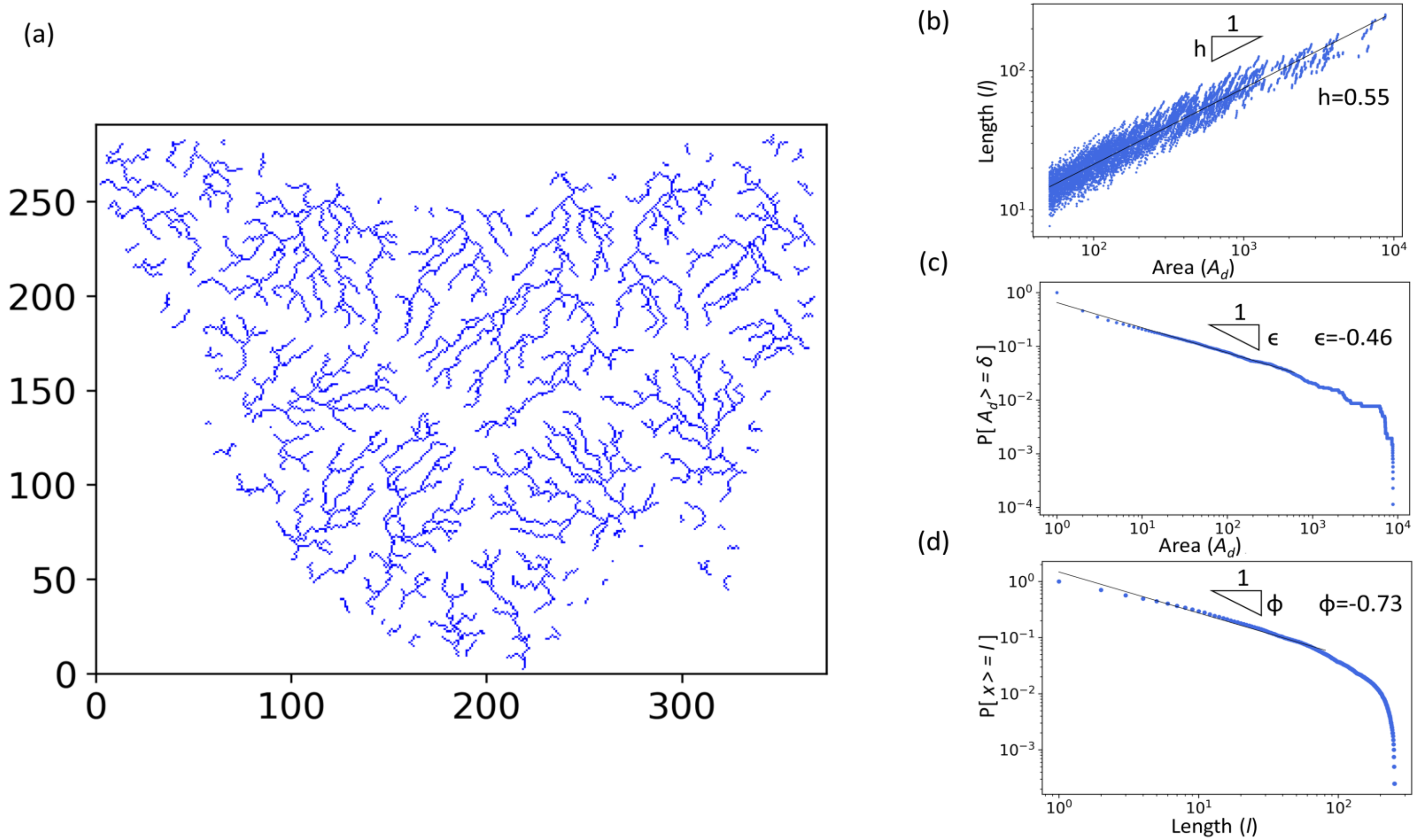


Networks with varying shapes and sizes



Modelled network within real boundary conditions

- With Tasmania Island Model Captures Statistical Properties



Limitations and Future Scope

- Improvements to capture the dynamic nature of networks
- Ability to construct a full fledged artificial landscape topography
- Applications of networks in some ecological modelling studies
- Proposed approach can be extended to other complex phenomenon which shows scaling behaviour

Link to Abstract

Important References

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Thank You

Link to Abstract