Does catchment nestedness enhance hydrological similarity?

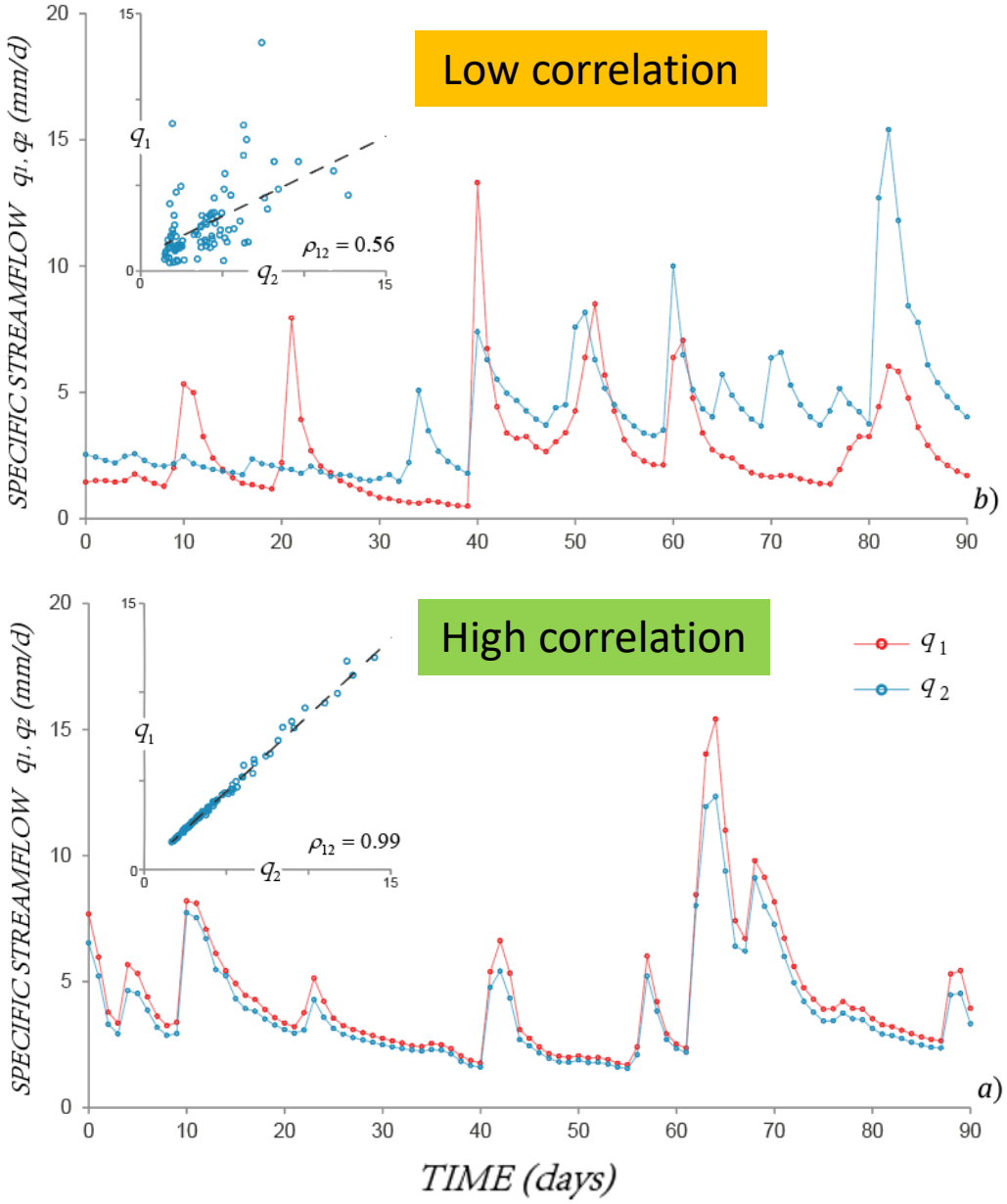
A. Betterle[1,3], G. Botter[2]

1 UNIVERSITÀ DI TRENTO

2 UNIVERSITÀ DEGLI STUDI DI PADOVA

3 European Commission Joint Research Centre

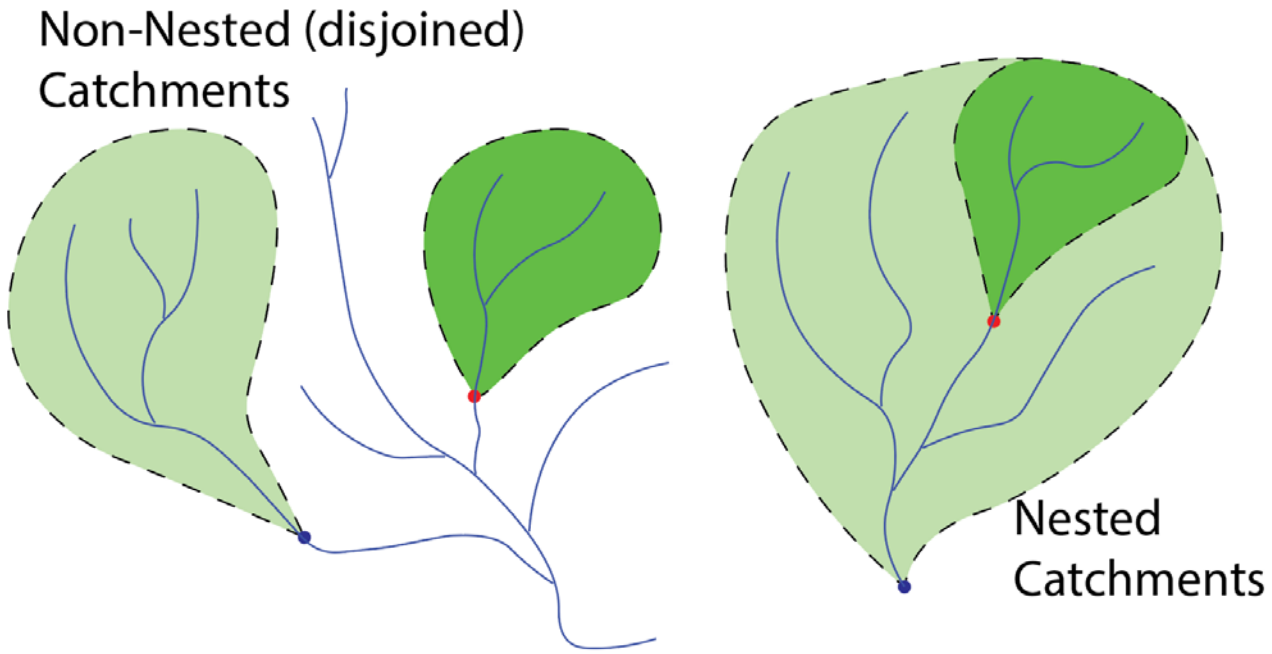
Streamflow correlation & catchment topology



Streamflow correlation:

A simple and effective metric that quantifies how similar are the hydrological responses of two catchments

$$\rho(q_1, q_2) = \frac{cov(q_1,q_2)}{\sqrt{var(q_1)var(q_2)}}$$

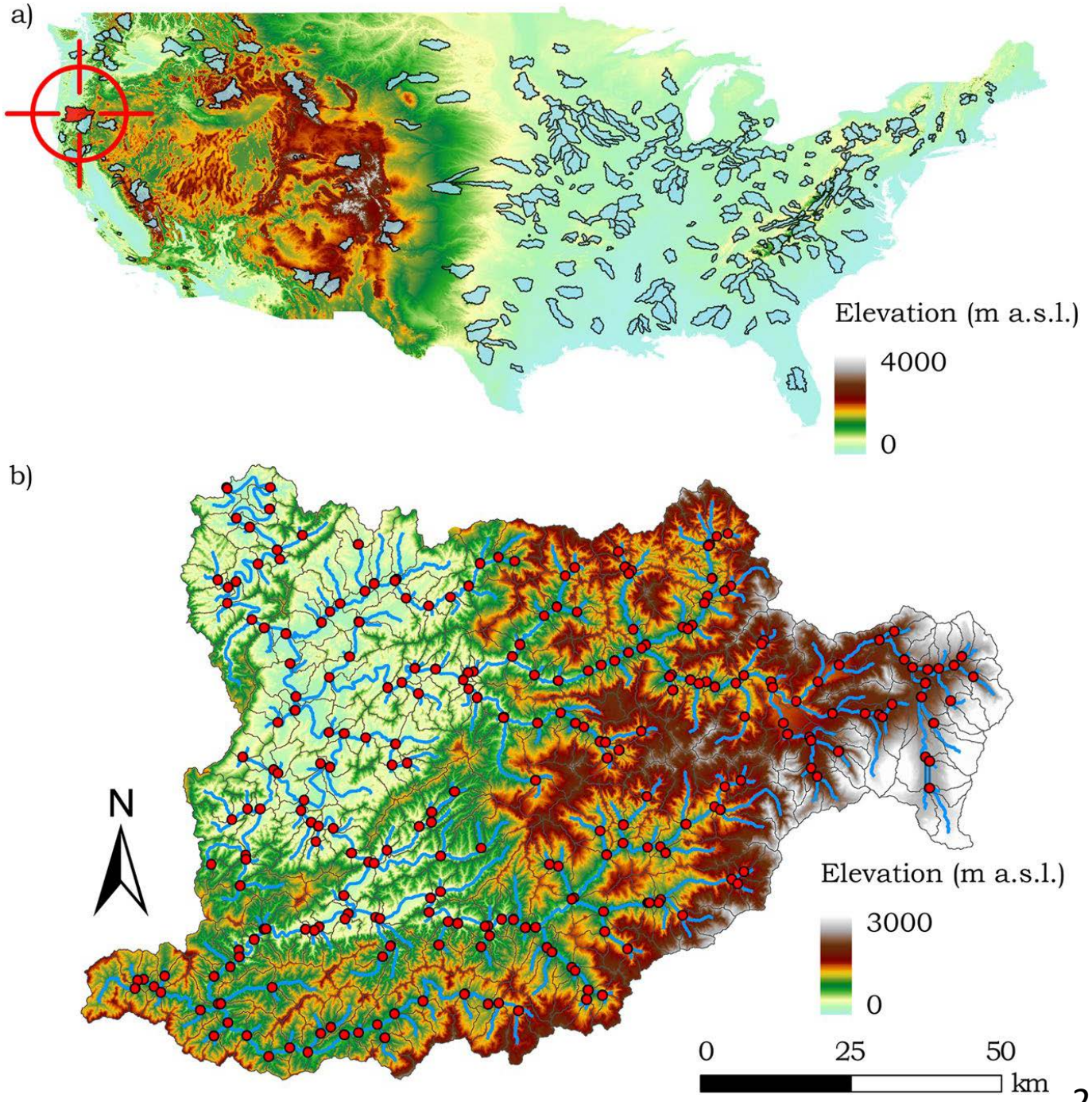


Data

- Large dataset
- Catchment characterized by different geomorphoclimatic conditions

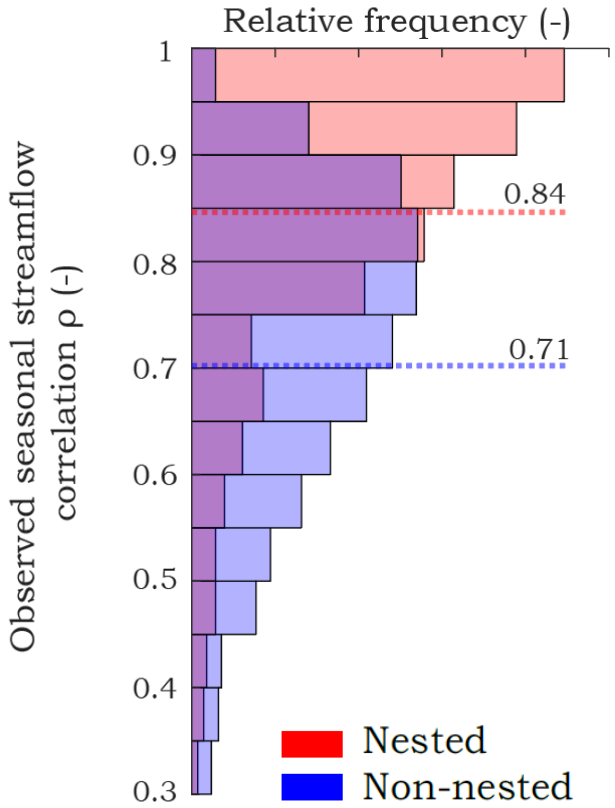
Number of possible combinations of pairs of catchments (many!):

	MOPEX	Umpqua
Nested	140	85000
Non-nested	18000	124000



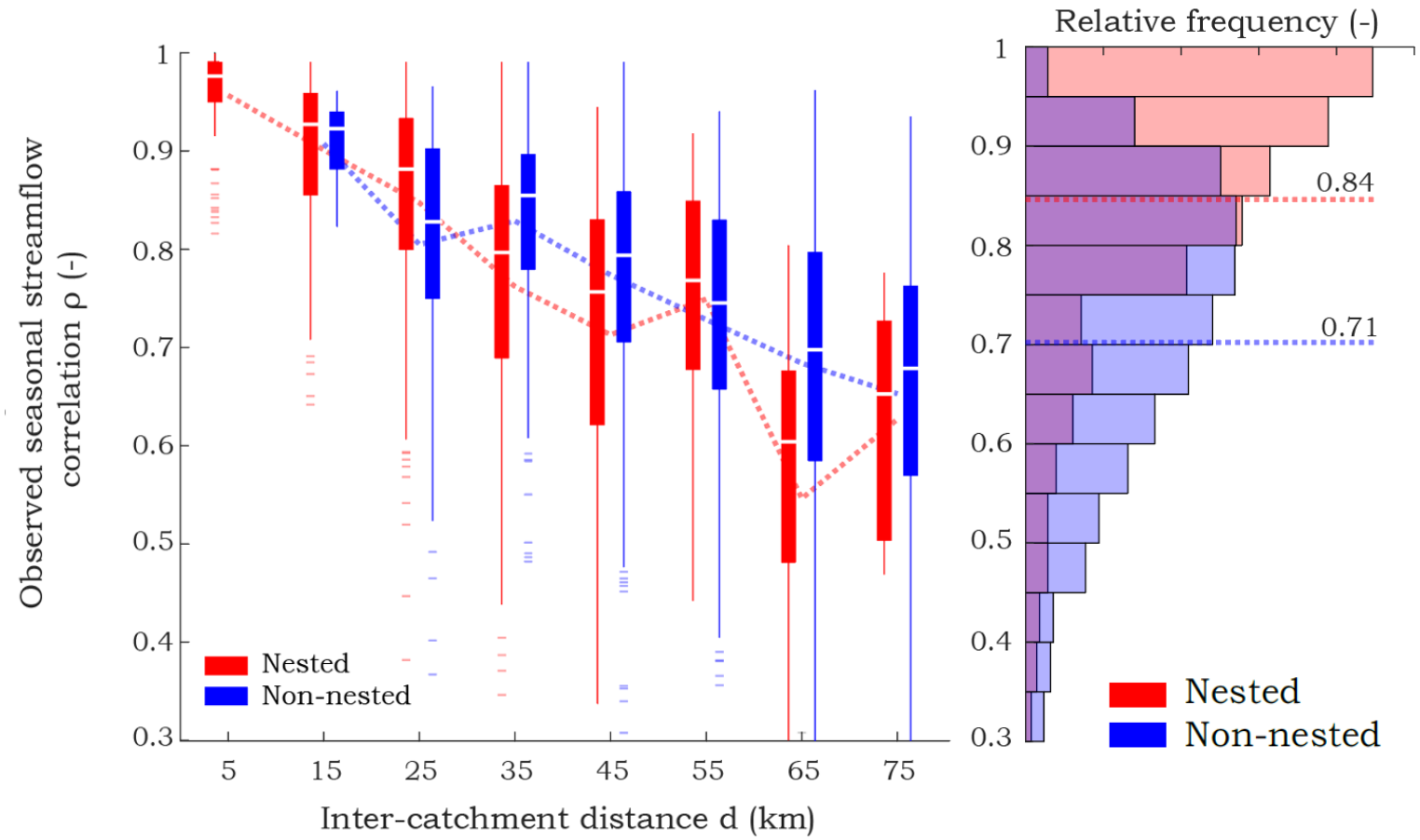
Are nested catchments hydrologically more similar?

- Nested catchments seem to behave more similarly (their streamflows are more correlated)



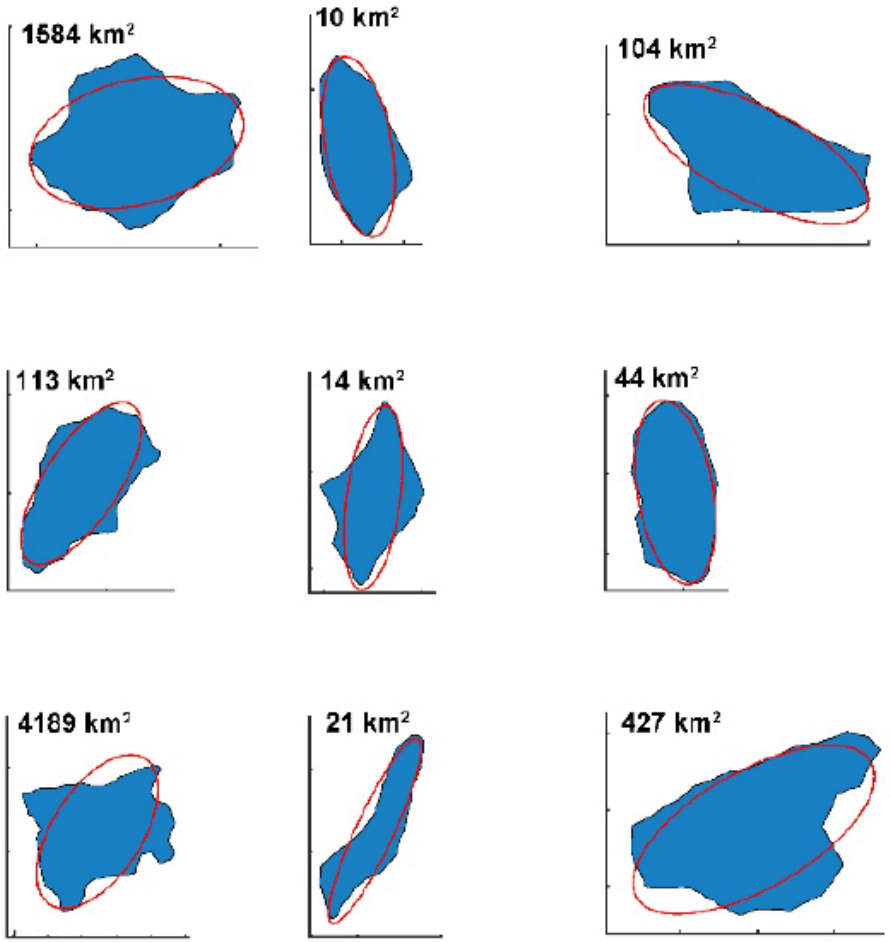
Are nested catchments hydrologically more similar?

- Nested catchments seem to behave more similarly (their streamflows are more correlated)
- However nested catchments are more frequent at smaller scales
- As distance increases nested catchment seem to lose correlation faster!
- At larger distances nested catchment have less correlated flows!



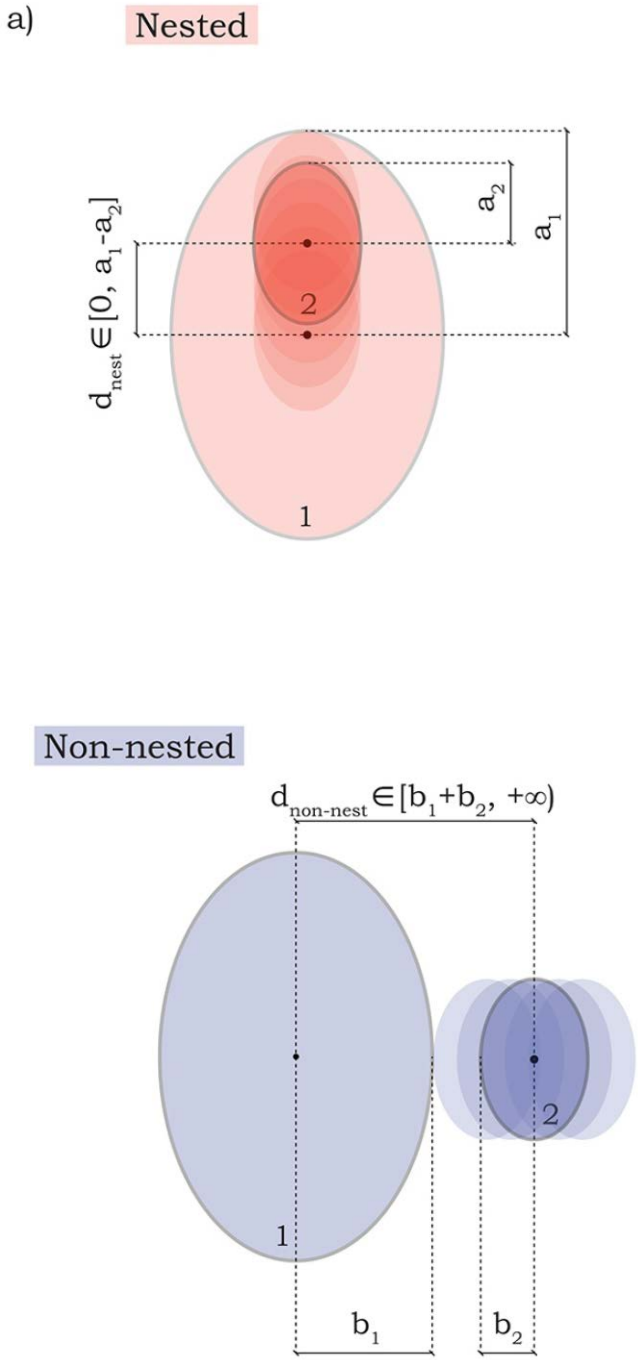
??? WHY ???

Geometrical model

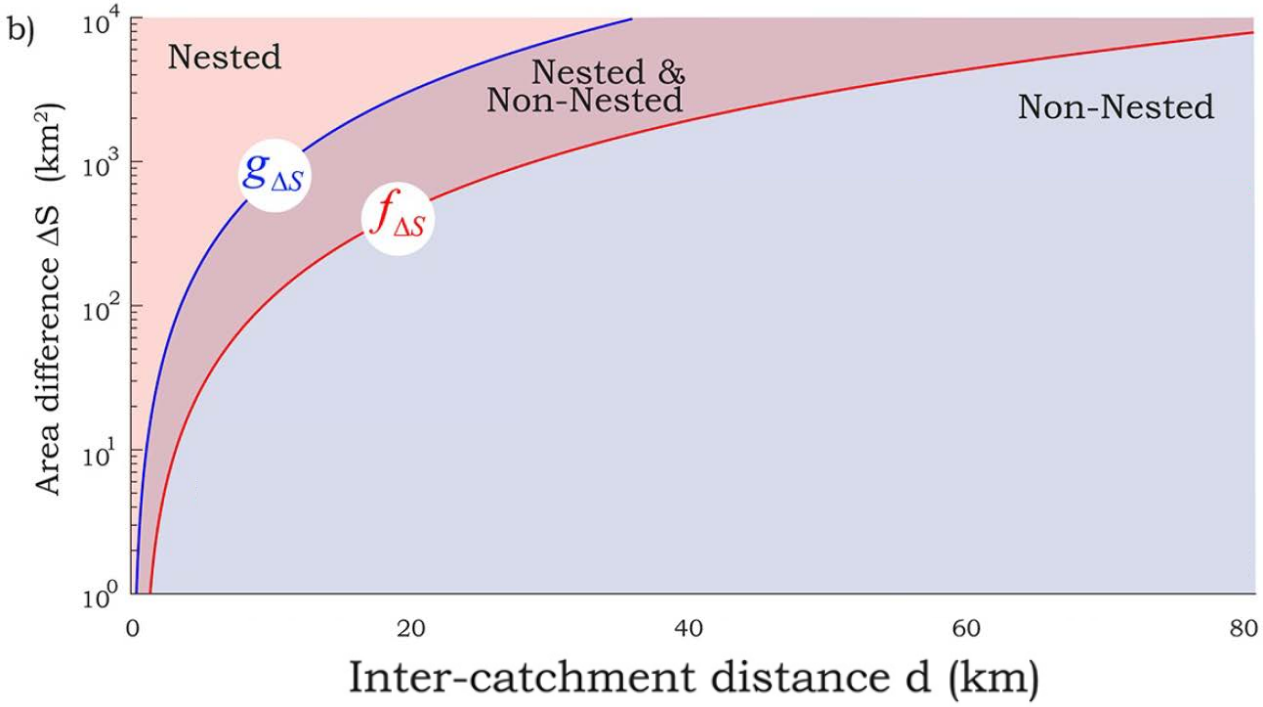


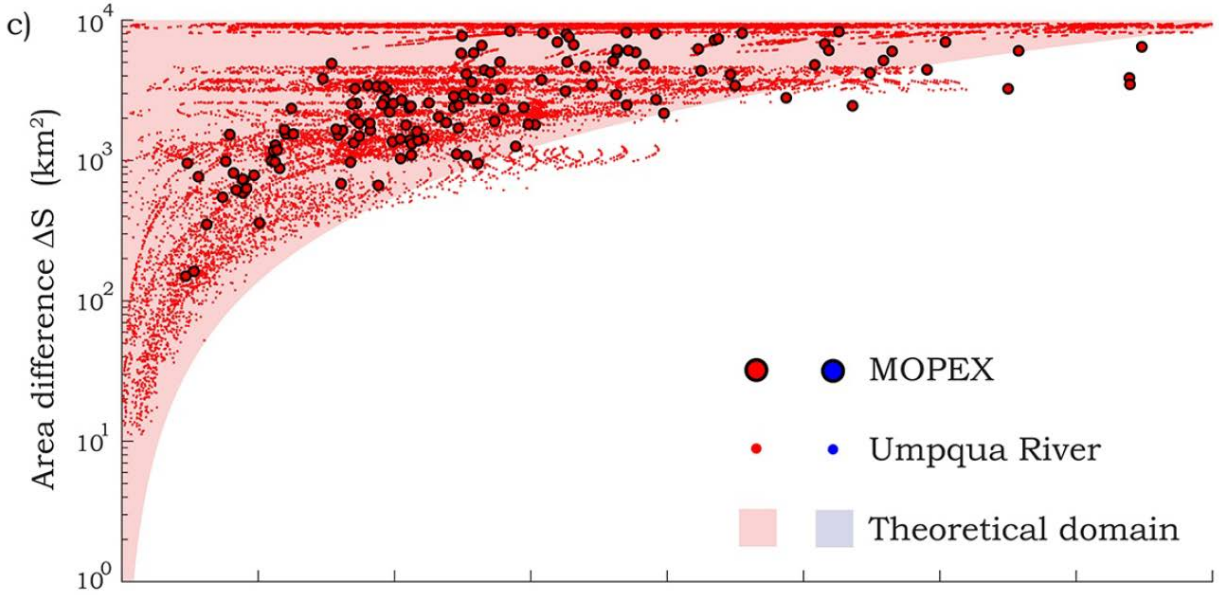
- **Elliptical approximation** of the shape of catchments

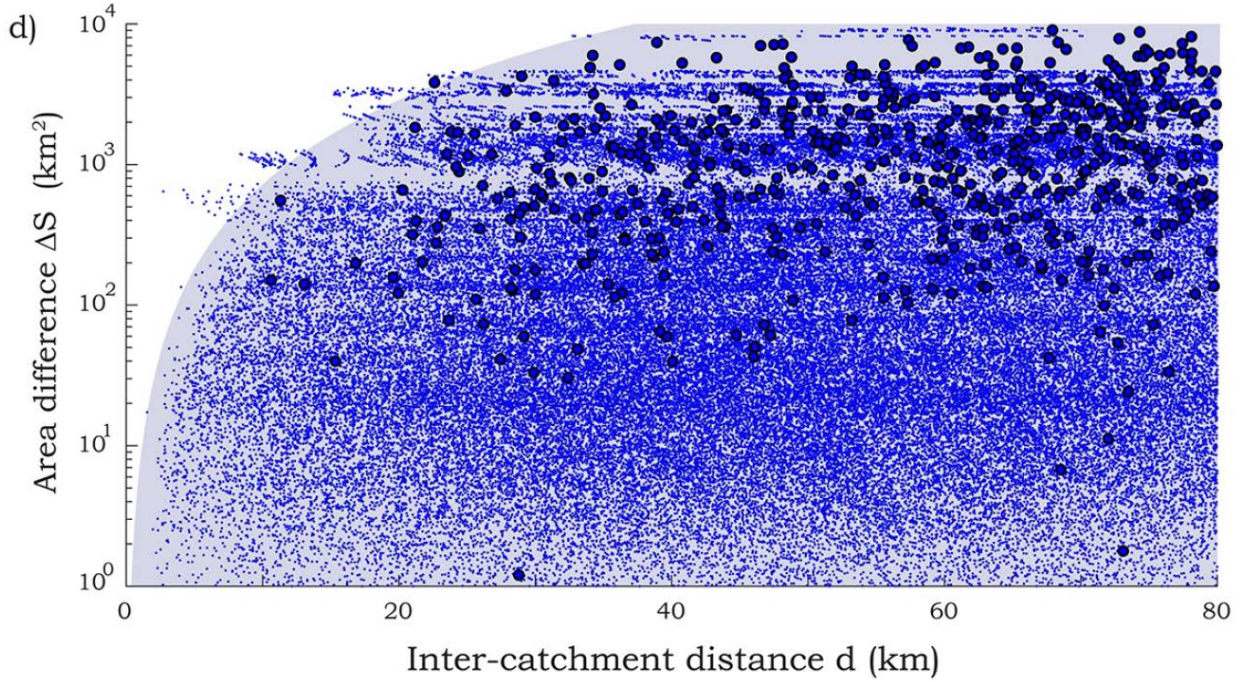
Geometrical model: how inter-catchment distance is related to catchment sizes



Result 1







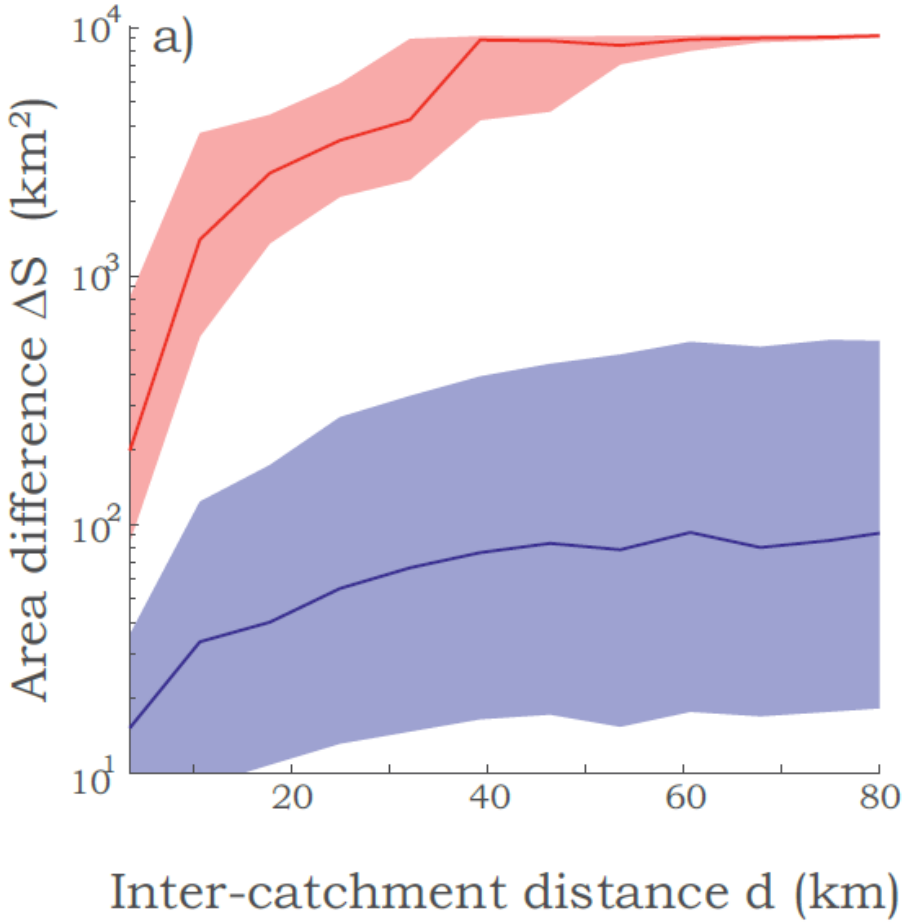
For a given distance, nested catchments are more heterogeneous in terms of size

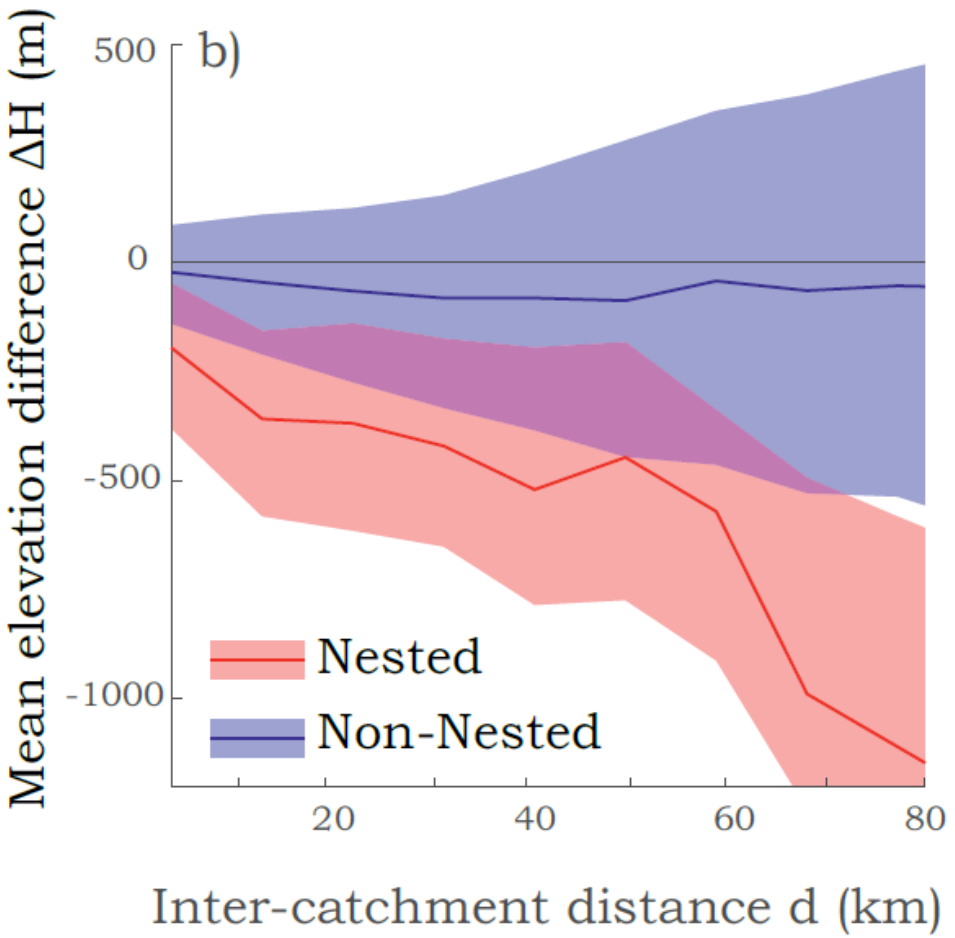
Result 2

$\Delta S = S_1 - S_2$

$\Delta H = H_1 - H_2$

Subscript
1: larger catchemnt
2: smaller catchment





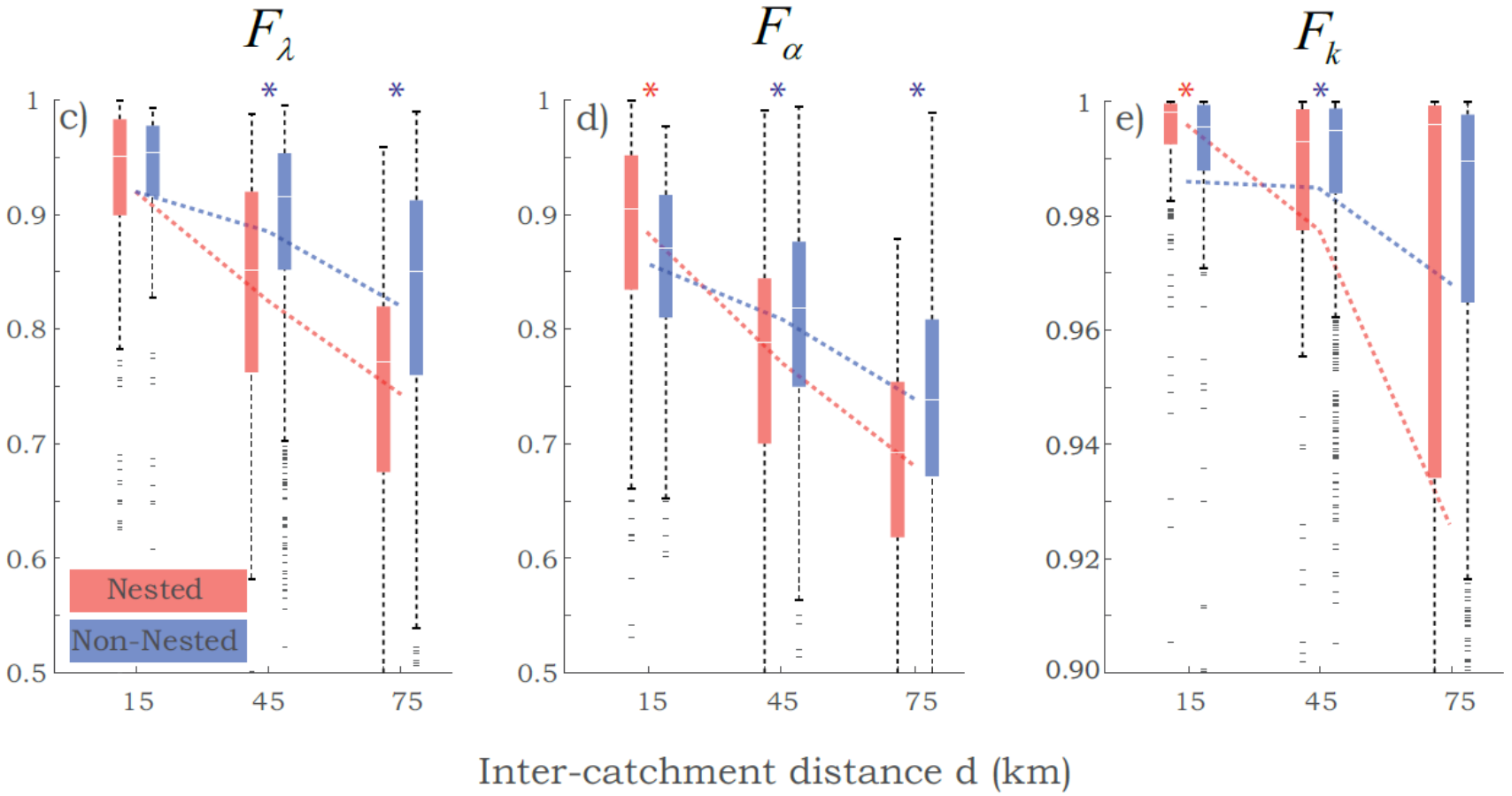
Couples of nested sites are systematically more different both in size and elevation as their distance increase

Can this explain the enhanced loss of correlation observed in nested conditions?

Result 3

$$\rho = F_\lambda F_\alpha F_k = \cdots$$

Betterle et al. (2017a, 2017b)
Betterle et al. (2019)



As distance increases, nested catchments experience:

- Faster loss of synchronicity of runoff events ($F_\lambda \downarrow \downarrow$)
- Larger differences in the intensities of runoff events ($F_\alpha \downarrow \downarrow$)
- Larger differences in catchment response rates ($F_k \downarrow$)

$\rho \downarrow \downarrow$

Conclusions

- Nested catchments are «by definition» close to each other. When **distance** is explicitly considered they turn **NOT to be more hydrologically similar**
- As catchment **distance increases**, the **correlation** between daily flows tend to **decrease faster** in **nested** as compared to non nested sites
- Critical **morphological traits** and **hydrological processes** display **larger differences** among nested catchments for increasing scales

- As the scale increases, heterogeneities in hydrologic signatures can increase fast along river networks → important to densely **monitor** nested catchments (e.g. for water management or ecological purposes)
- **Ecohydrological barriers** along river networks can be more critical that expected (e.g. minimum flows for fish mobility)
- Important to **test** hydrological models within large nested catchments

References

- Does catchment nestedness enhance hydrological similarity? (2021) Betterle, Botter, *Geophysical Research Letters*
- Characterizing the spatial correlation of daily streamflows (2017a) Betterle, Schirmer, Botter, *Water Resources Research*
- Flow dynamics at the continental scale: Streamflow correlation and hydrological similarity (2019) Betterle, Schirmer, Botter, *Hydrological Processes*