Features and controlling factors of drainage networks in the Tibetan Plateau

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Introduction

- Drainage networks in the Tibetan Plateau vary in shapes and features due to complex climatic and geomorphic conditions.
- Studying the features and controlling factors of drainage networks is important to understand **evolution processes of Tibetan Plateau** and can provide comprehensive insights into **flood behavior** and **landscape evolution models**.
- The goal of our study is to **test the postulates of the self-similar networks (RSN) model on 30 mid-sized basins** and explore **the features and controlling factors of drainage networks** in the Tibetan Plateau.

Background

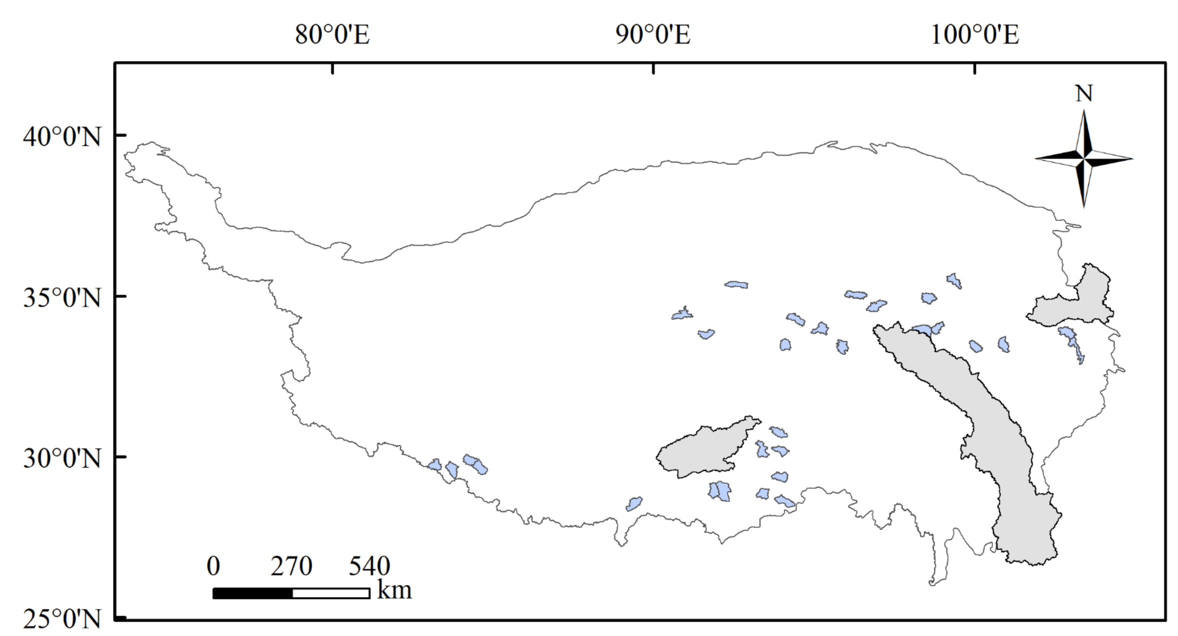

Fig.1 Study area

- 3 typical river basins (filled with grey in Fig.1) in the Tibetan Plateau
- 30 mid-sized basins (filled with blue in Fig.1) located in the Tibetan Plateau

River Network Extraction and Selection :

- Extract river networks in the Tibetan Plateau using DEMRiver developed by Tsinghua University.
- 3 typical basins have been chosen because their climate conditions (in terms of aridity index) and tectonic activities backgrounds are different.
- For each of 30 basins selected in the Tibetan Plateau, basin area is about 1000 km^2 and Strahler level is 6 (critical source area is 40).
- 30 basins have been chosen to cover a wide range of climates which are identified by aridity index.

Dataset

- 90-m-resolution SRTM DEM
- Aridity Index(**AI**) from Global Aridity Index and Potential Evapo-Transpiration Climate Database

Methodology

Detailed analysis for 3 typical basins

Horton's laws

Bifurcation ratio

$$R_b(\omega) = N_{\omega-1} / N_{\omega}, \omega = 2,3,\ldots\Omega$$

Length ratio

$$R_L(\omega) = \bar{L}_{\omega} / \bar{L}_{\omega-1}, \omega = 2,3,\ldots\Omega$$

- N Number of streams
- L Average length of streams
- Ω The highest order of streams in a basin

(Horton et al., 1945)

Normalized concavity index of profile

$$NCI = \text{median}[(E_L - Y_L) / H]$$

- E_L Elevation of point at distance L
- Y_L Elevation of point at distance L on the straight line fitted through the profile endpoints
- H Topographic relief of river profile

(Chen et al., 2010)

Regression analysis for 30 mid-sized basins

Geometric distribution for generators of RSN models

$$P[L = k] = p(1-p)^k, k = 0,1,2,\ldots$$

- L The number of interior nodes in interior generators or exterior generators

Generalized linear model

$$\log \mu_{\alpha jk} = \kappa + \delta_{\alpha} + \tau_j + \varphi_k + (\delta\varphi)_{\alpha k} + (\tau\varphi)_{jk}$$

- $\mu_{\alpha jk}$ Mean of L
- κ Intercept
- δ_{α} Generator type effect
- τ_j Level effect
- φ_k Basin effect
- $(\delta\varphi)_{\alpha k}$ Type-basin interaction
- $(\tau\varphi)_{jk}$ Level-basin interaction

(Mantilla et al., 2010)

Generalized linear mixed model

$$\log \mu_{\alpha jk} = \kappa + \delta_{\alpha} + \varphi_k + (\delta\varphi)_{\alpha k} + \beta z_k$$

- φ_k Random variables
- $(\delta\varphi)_{\alpha k}$ Random variables
- β coefficient
- z_k The logarithm of aridity index

(Mantilla et al., 2010)

Results and Discussion

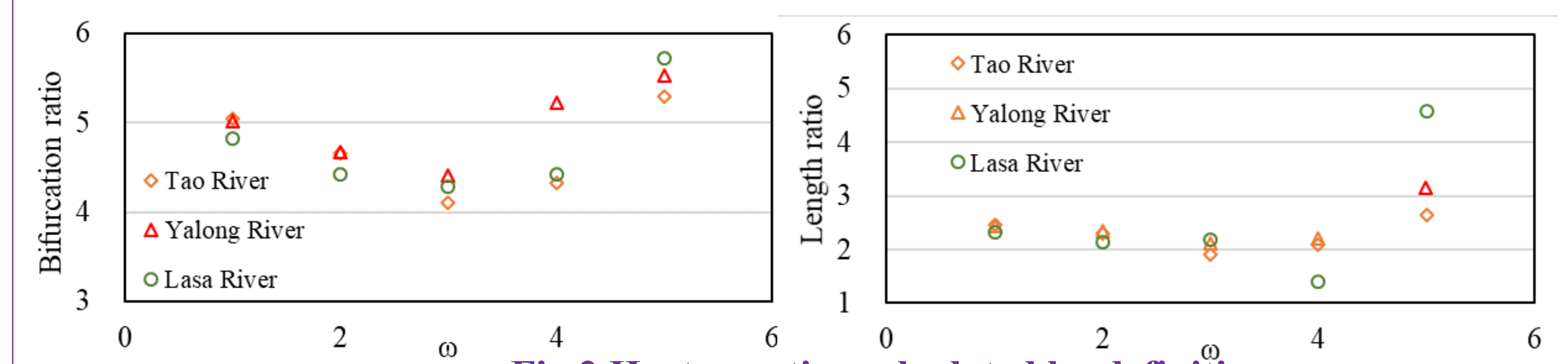

Fig.2 Horton ratios calculated by definition

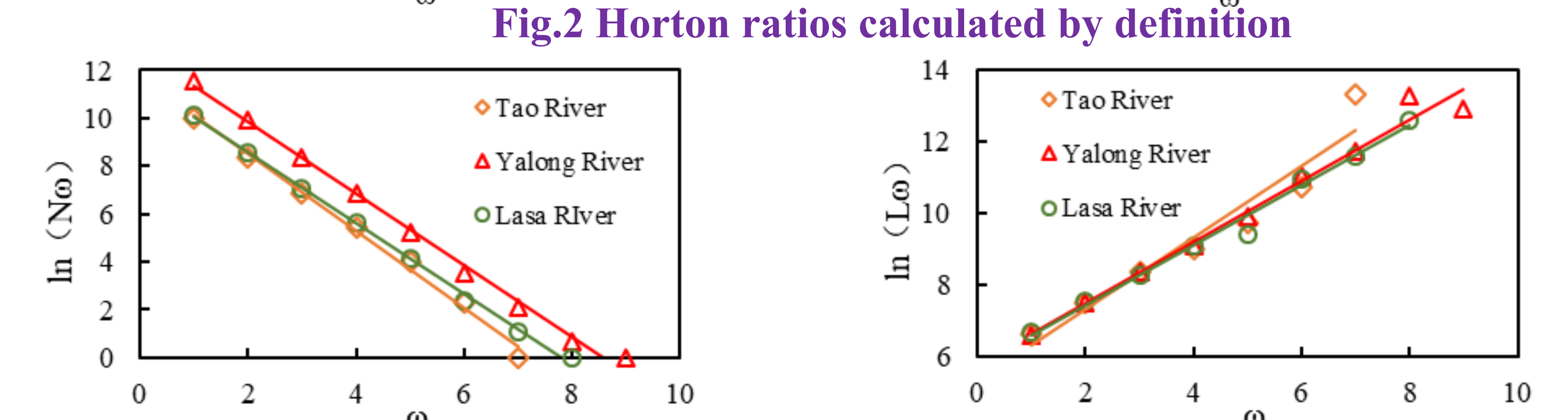

Fig.3 Horton ratios obtained by fitting method

Horton's laws and NCI for 3 typical basins

- For 3 typical basins, bifurcation ratios and length ratios range from 4.10 to 5.73 and from 1.90 to 3.14 respectively(Fig.2).
- For Yalong River, Tao River and Lasa River, bifurcation ratios are 4.46, 5.00 and 4.37 while the length ratios are 2.35, 2.71 and 2.30(Fig.3).
- NCI values demonstrate that profiles of Tao River and Lasa River are **concave-up** and that of Yalong River is **convex-up.**
- Comparing the Horton ratios obtained by the original definition and the fitting method, **the climate effect** is reflected in the structure of the **low-level river network** and **tectonic activities** probably control the structure of **high-level network**.

Geometric distribution examination for generators

- Plots like Fig.4 for all 30 basins indicate that the **geometric distribution** is a good approximation for all the basins.
- Interior and exterior generators are geometrically distributed with parameters $p_i \in [0.33, 0.49]$ and $p_e \in [0.43, 0.52]$.

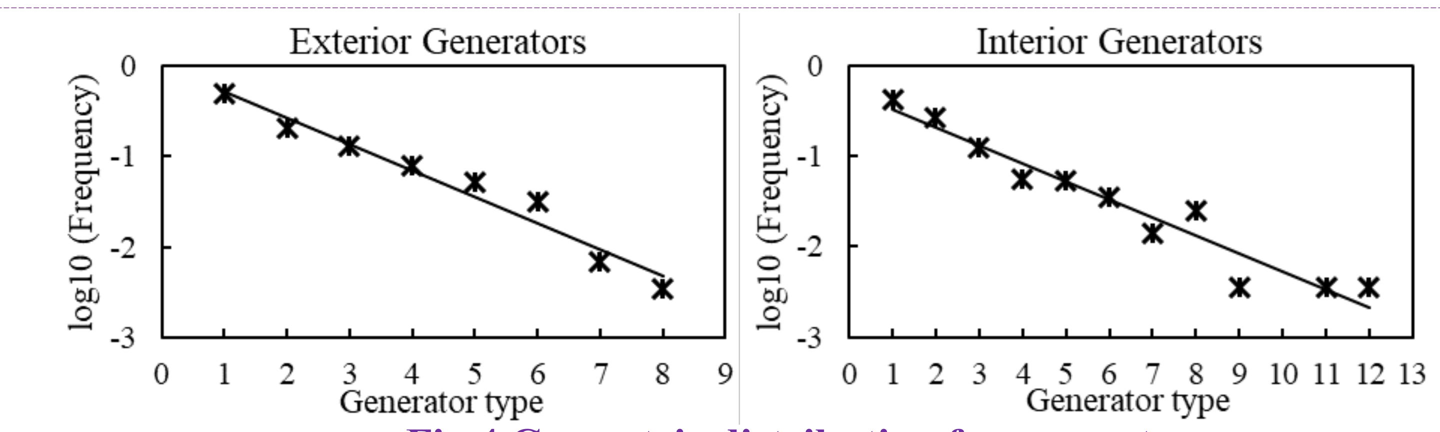

Fig.4 Geometric distribution for generators

Results for generalized linear model

- There are highly significant difference between interior and exterior generator properties.
- Significance level for **type and basin interaction** shows that basin-to-basin variability is different for interior and exterior generators.

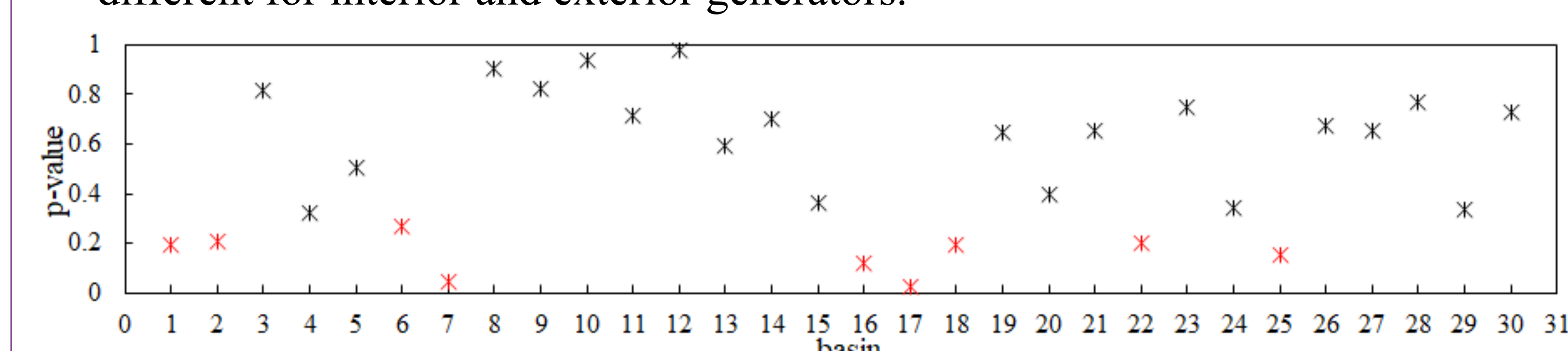

Fig.5 p-values for testing hypothesis of no level differences

Table 1 Factors' Significance

factor	p-value	
	30 basins	21 basins
type	2.20E-16	2.20E-16
level	4.32E-06	0.0674
basin	0.0003	4.44E-05
type : basin	0.0022	0.0068
level : basin	0.9907	0.9997

- It is necessary to remove a total of 9 basins (marked by red crosses in Fig.5) in order to be able to accept the null hypothesis of **scale invariance**.

Results for generalized linear mixed model

- The climate term is not significant at the 5% level (because p-value =0.472 > 0.05).

Conclusions and future work

- Detailed analysis for **three typical basins** in Tibetan Plateau demonstrates that **high-level rivers** tend to be affected mainly by **tectonic activities**.
- Generators of RSN model obey a **geometric distribution** and **self-similarity holds in a statistical sense** in 21 of 30 basins in Tibetan Plateau.
- Though some indication of **climatic influence** on parameters of **low-level rivers** is detected, this influence on the generators is **not statistically significant**.
- **Future work**: 1) Explore factors contributing to basins' **deviation from scale invariance**; 2) Quantitatively analyze the impact of other factors (e.g., tectonic controls) on the drainage networks.