Statistical Scaling of the Percentiles of the Daily Flow Duration Curve with the Long-Term Mean Discharge in Colombian Rivers

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1. Introduction:

Estimating different percentiles of daily flow duration curve constitutes a permanent challenge for multiple hydrological purposes. Here, we introduce a new way of facing such task based on the theory of statistical scaling that accounts for the mathematical concept of self-similarity, the property exhibited by a type of sets or objects called fractals, which consists of each of its parts being, either deterministically or statistically, equal to itself on any scale. Those elements and their dynamics can be modeled by the formulation of power laws, which have proven to be a very simple and at the same time a very powerful predictive tool.

2. Objetive:

To estimate any percentile of the daily flow duration curve for rivers of Colombia and the five major hydrological regions of the country (Caribbean, Andes, Orinoco, Amazon and Pacific), during the entire record period, and for the three phases of ENSO: El Niño, La Niña and Normal, given their strong effect on Colombian river flows (Poveda et al., 2010).

3. Data:

We use daily river flows gathered by IDEAM at 634 gauging stations (Figure 1), with record lengths larger than 10 years, between 1940 and 2014, and with less than 40% of missing data.

4. Methodology:

Based on ideas put forward by Poveda et al. (2007), we propose that for each region, a power law represents the relation between the i-th percentile of the daily flow duration curve, $\boldsymbol{Q_i}$, and the long-term mean river discharge, $\boldsymbol{\bar{Q}}$, such that:

$$Q_i = \alpha_i \bar{Q}^{\theta_i},$$

where α_i and θ_i depend on the hydrological region of the country and the phase of ENSO.

We constructed monthly time series by averaging the daily discharge of the months with less than 1/3 of missing data. We estimated the daily flow duration curves by taking the median of all the records for each day of the year. Two thirds of the available gauging stations were randomly chosen and used to calibrate the values of α_i and θ_i. The remaining third was used for validation purposes (Figure 1).

Figure 1. Gauging stations used to calibrate and validate the power laws.

5. Results:

5.1. Calibration of the power laws:

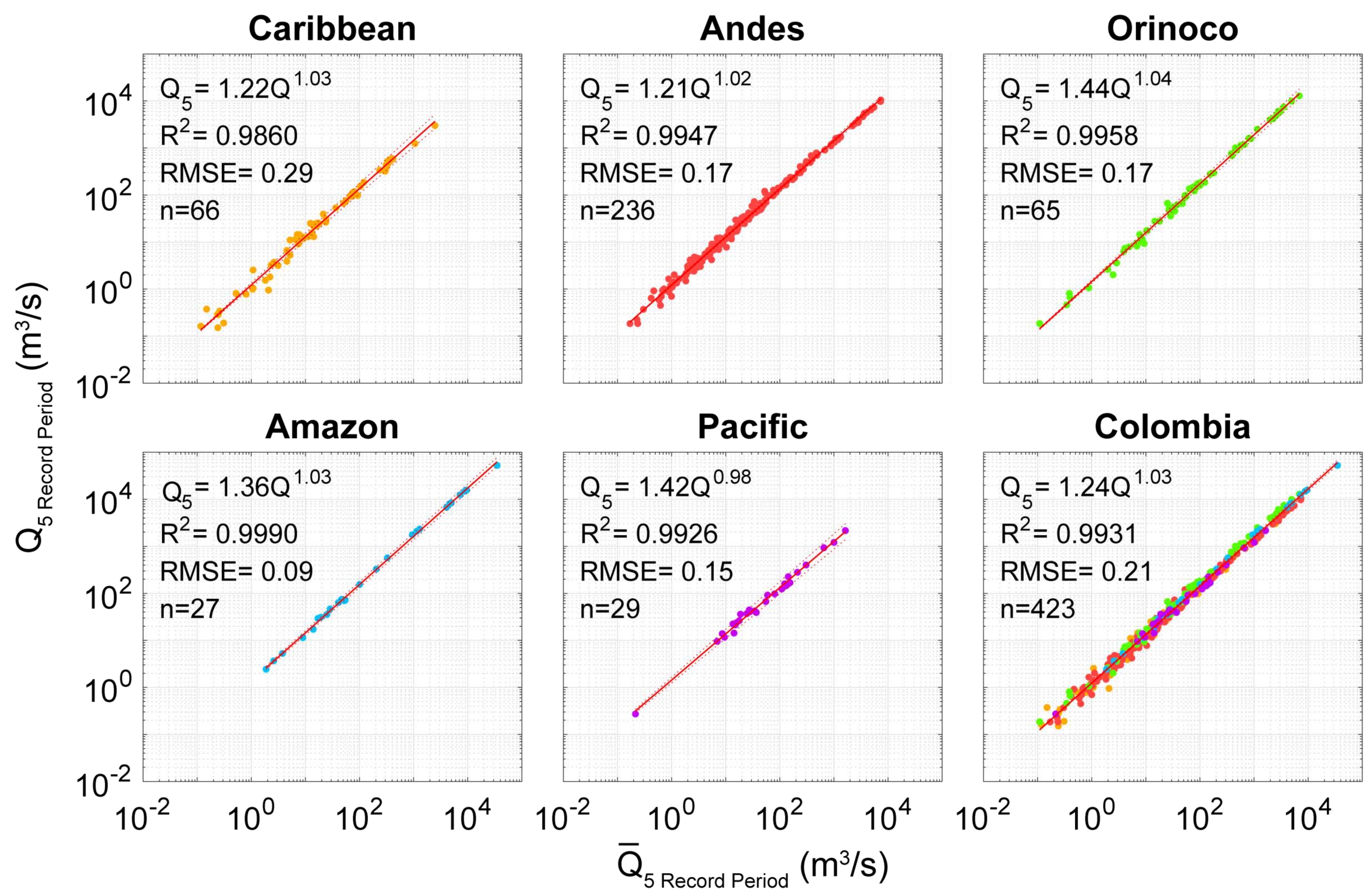

Figure 2. Regional and national calibration of the power laws for the 5-th percentile.

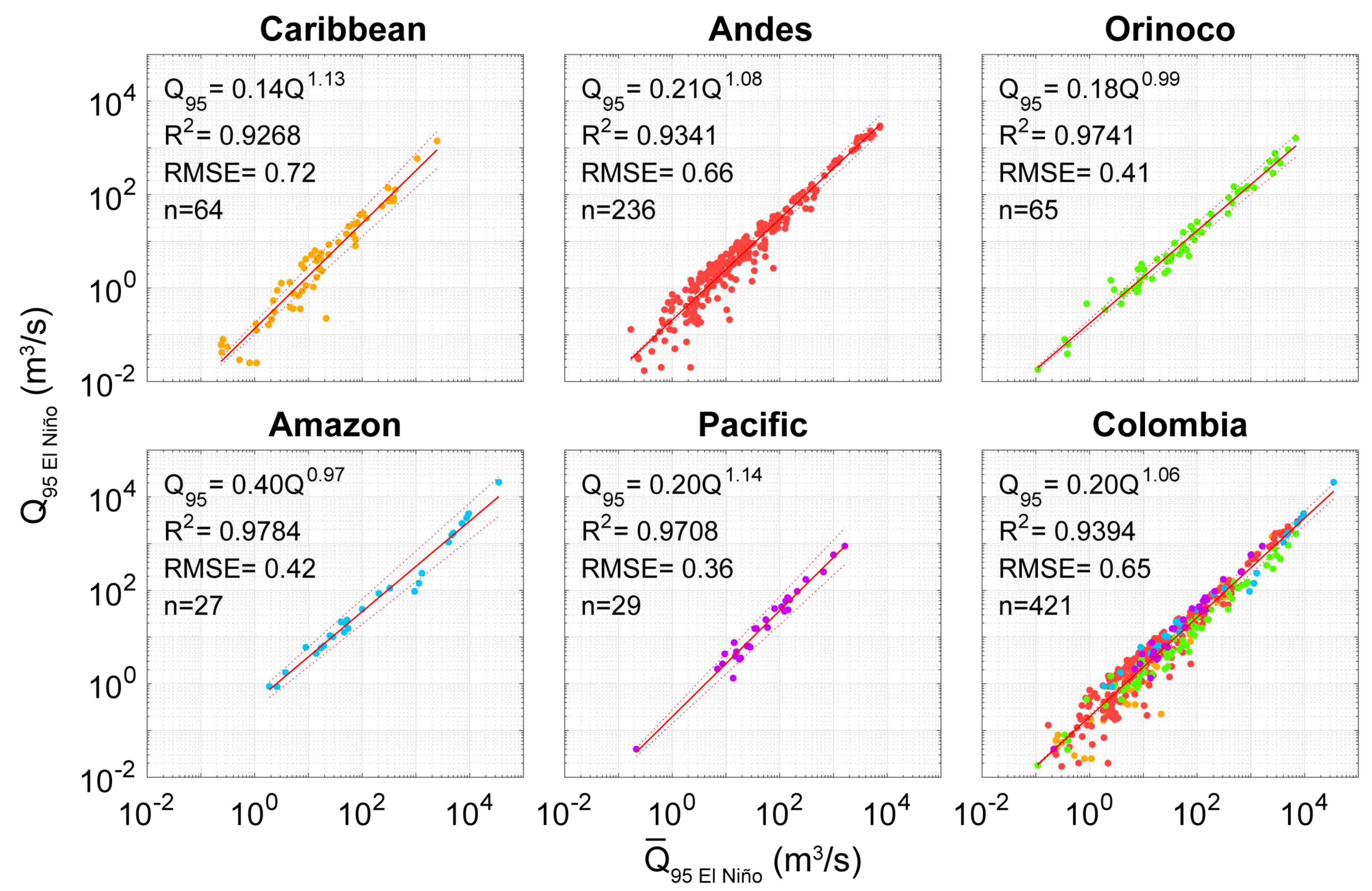

Figure 3. Regional and national calibration of the power laws for the 95-th percentile during El Niño.

5.2. Validation of the power laws:

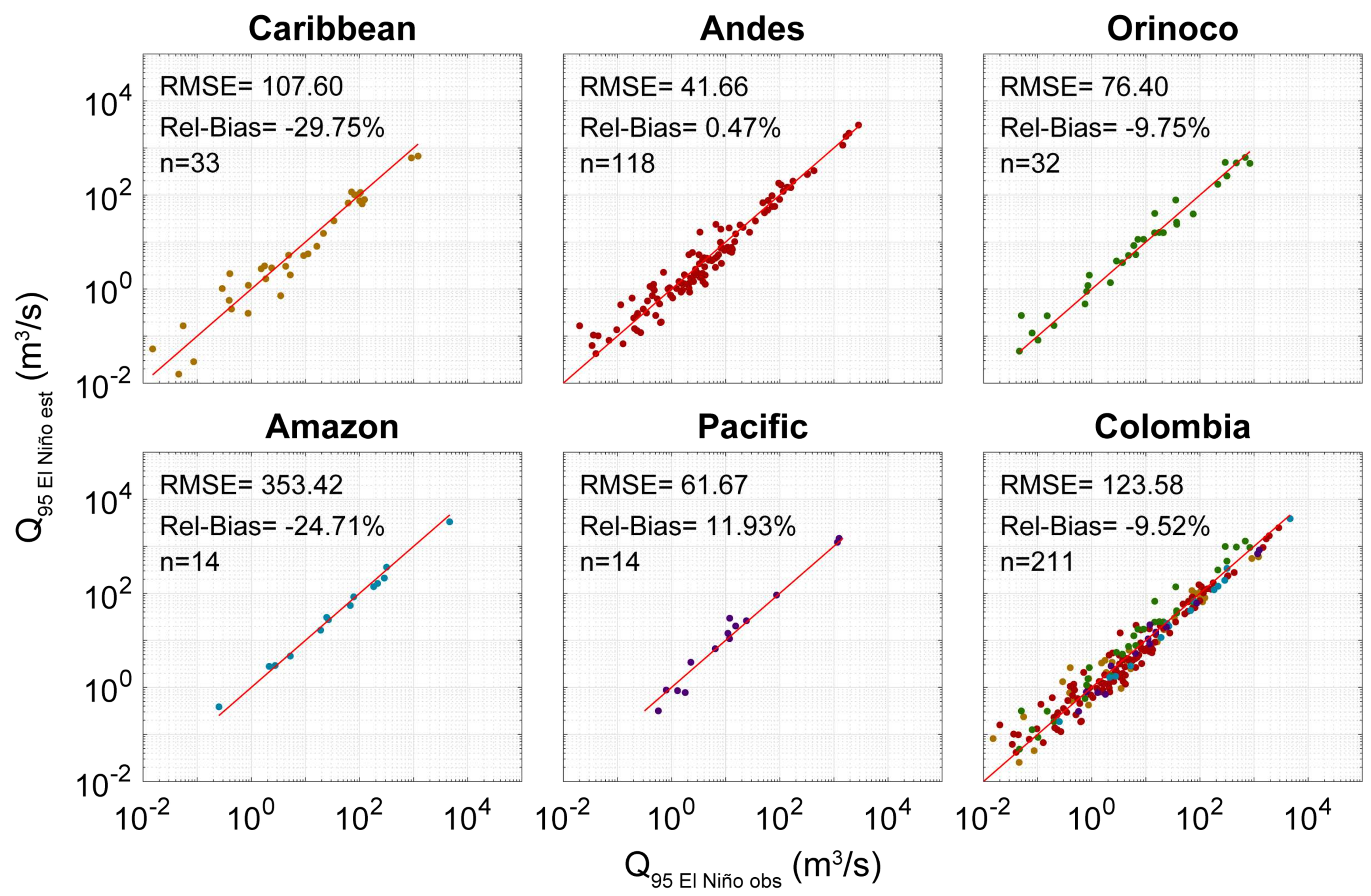

Figure 4. Regional and national validation of the power laws for the 95-th percentile during El Niño.

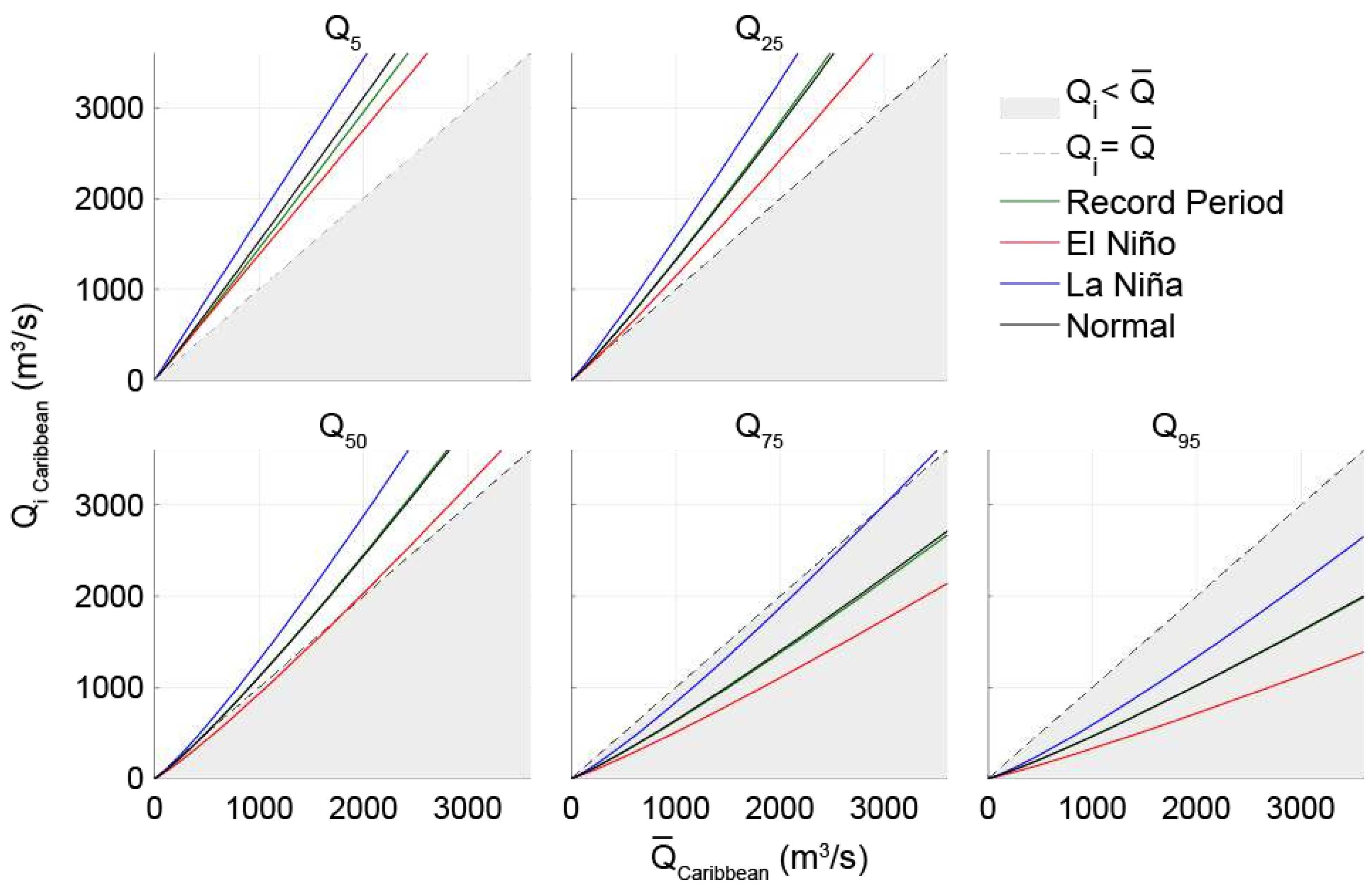

Figure 5. Validation of the power laws for each percentile over the Caribbean region, considering the phases of ENSO.

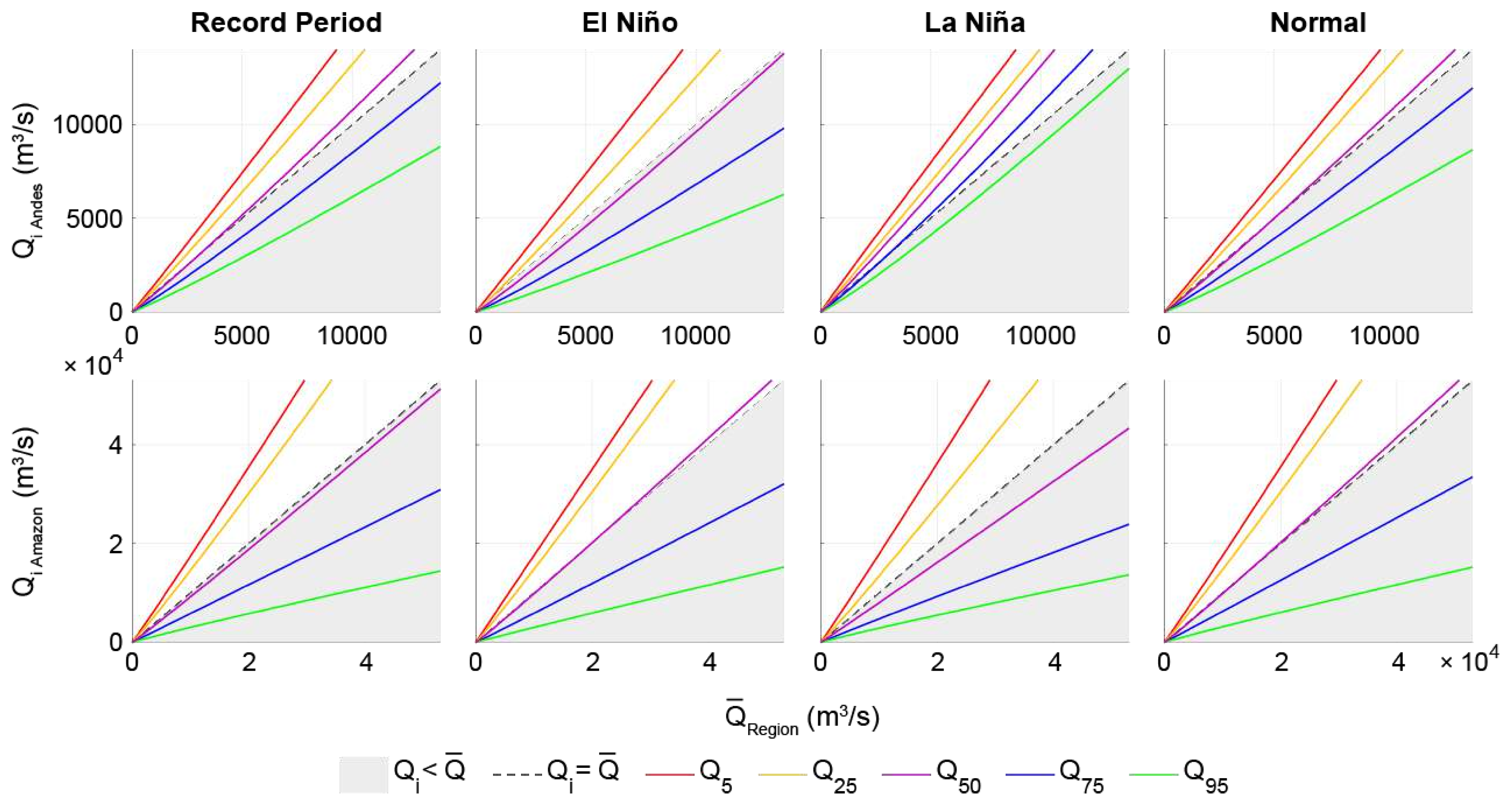

Figure 6. Validation of the power laws for each phase of ENSO over the Andes (**top**) and the Amazon (**bottom**) regions, considering the percentiles.

6. Conclusions:

Clear-cut power laws represent the relations between the percentiles of the daily flow duration curve and the long-term mean discharge in Colombian rivers, for the entire record length and for different phases of ENSO. Our results are quite coherent since the identified power laws are strictly increasingly ordered as greater percentiles are estimated, and are consistent with the expected hydrological behavior of the Colombian regions during the different phases of ENSO.

7. References:

Poveda, G., *et al.* (2007). Linking long-term water balances and statistical scaling to estimate river flows along the drainage network of Colombia. *Journal of Hydrological Engineering*, **12:** 4-13.

Poveda, G., *et al.* (2010). Hydro-climatic variability over the Andes of Colombia associated with ENSO: A review of climatic processes and their impact on one of the Earth's most important biodiversity hotspots. *Climate Dynamics*, **36**, 2233.doi:10.1007/s00382-010-0931-y.

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