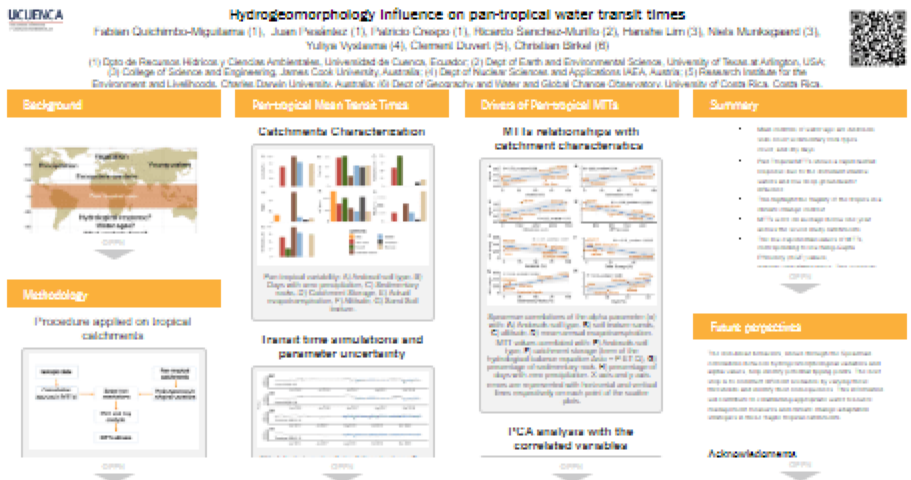
Hydrogeomorphology influence on pan-tropical water transit times



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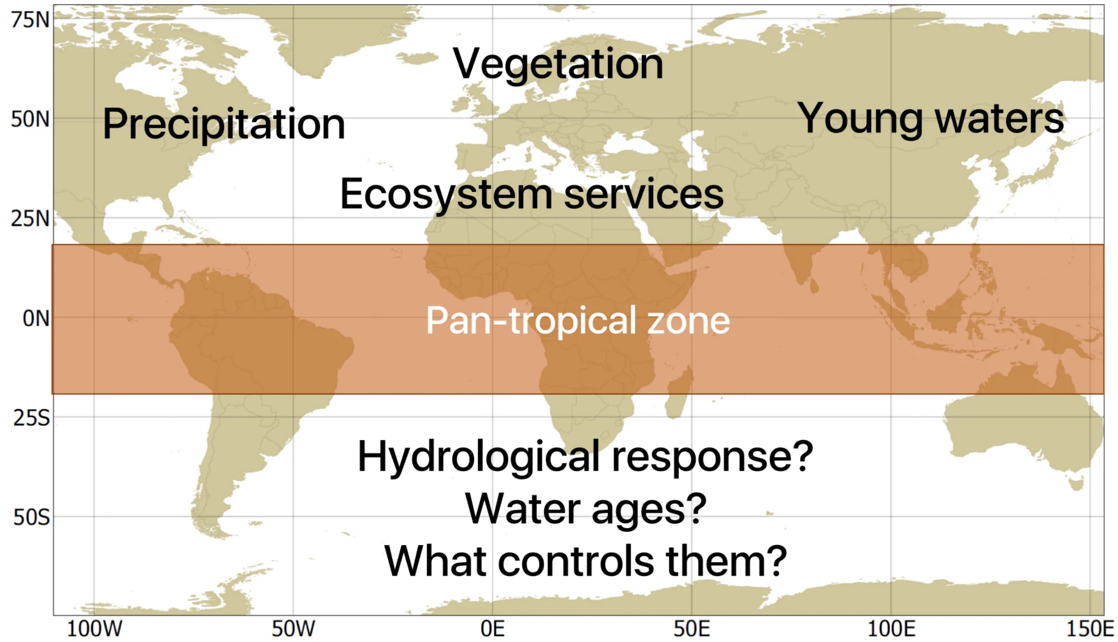
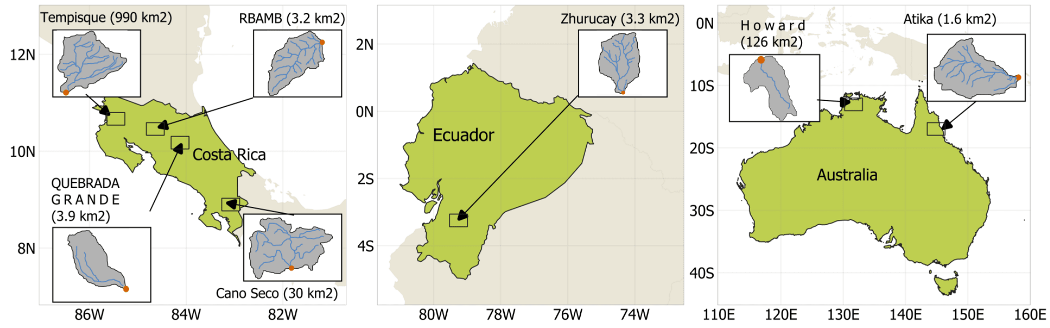
PRESENTED AT:

BACKGROUND



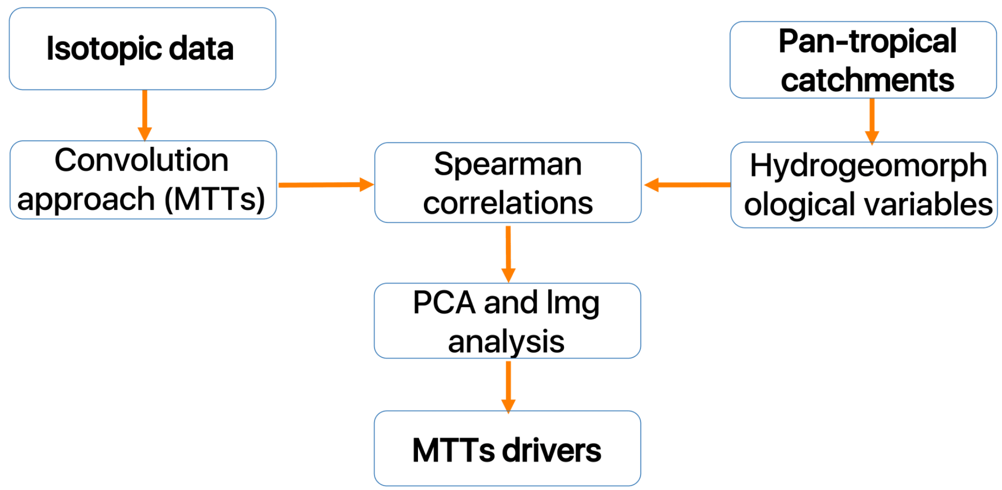
Tropical hydrological processes remain relatively unknown compared to other extratropical environments. This work aims to provide more details about these processes through the estimation of Mean Transit Times (MTTs) using daily isotopic datasets. We applied a simple convolution approach to identify hydrogeomorphological controls on their distributions.



General outline of Pan-tropical research

METHODOLOGY

Procedure applied on tropical catchments

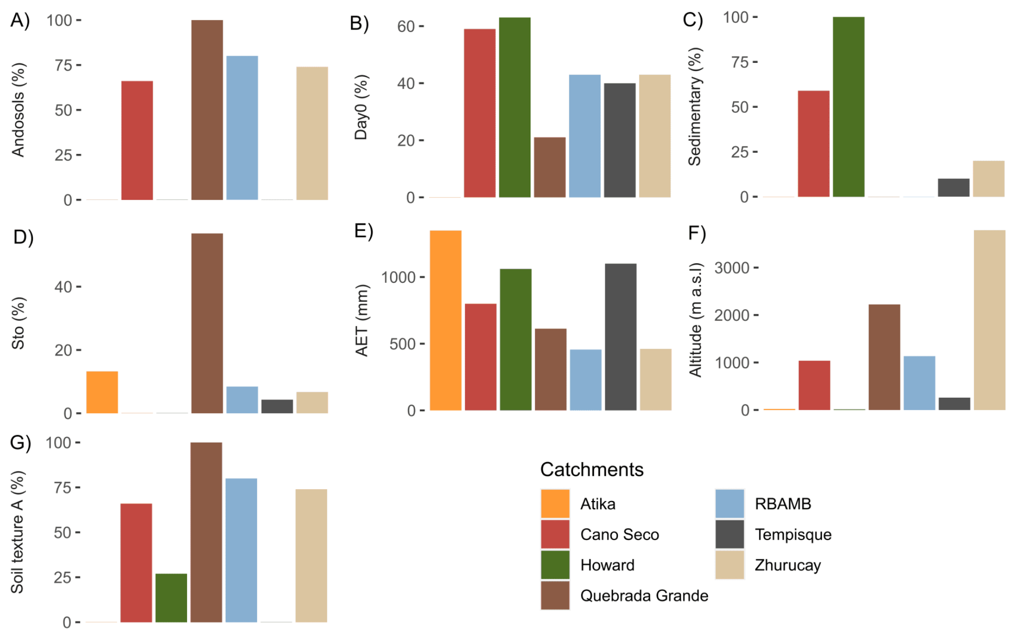


Flowchart

- Catchment characterization (landscape variables, geological variables, hydrometeorological variables).
- Transit time estimations (Convolution approach with exponential and gamma models as transfer functions).
- Statistical Analysis (Non-parametric Spearman's rank correlations).
- Principal Component Analysis (PCA).
- Ranking relative importance of variables (using Lendeman, Merida, and Gold-lmg metrics).

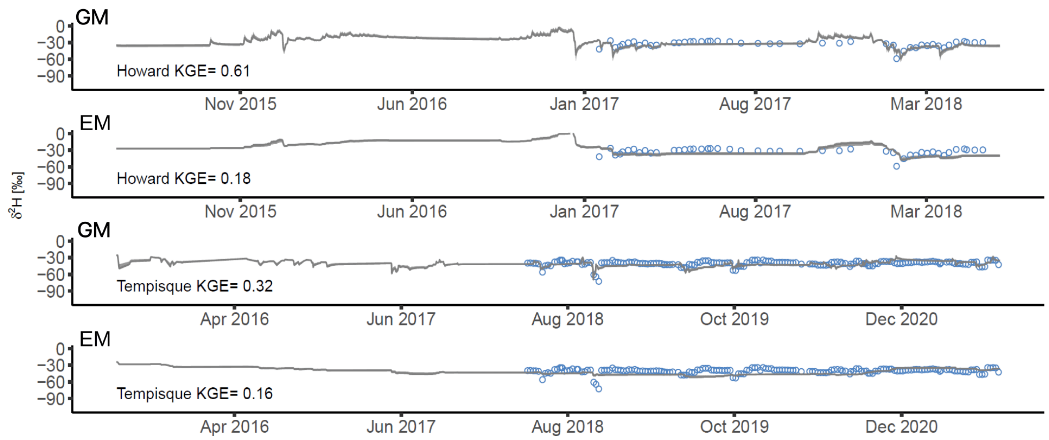
PAN-TROPICAL MEAN TRANSIT TIMES

Catchments Characterization



Pan-tropical variability: A) Andosol soil type, B) Days with cero precipitation, C) Sedimentary rocks, D) Catchment Storage, E) Actual evapotranspiration, F) Altitude, G) Sand Soil texture.

Transit time simulations and parameter uncertainty



Fitted deuterium signal simulations in streamflow using a convolution integral approach with a Gamma model (GM) and Exponential model (EM). Blue points represents the stremflow observations. Gray bands are the simulations, 90% uncertainty, with the retained parameter sets during calibration.

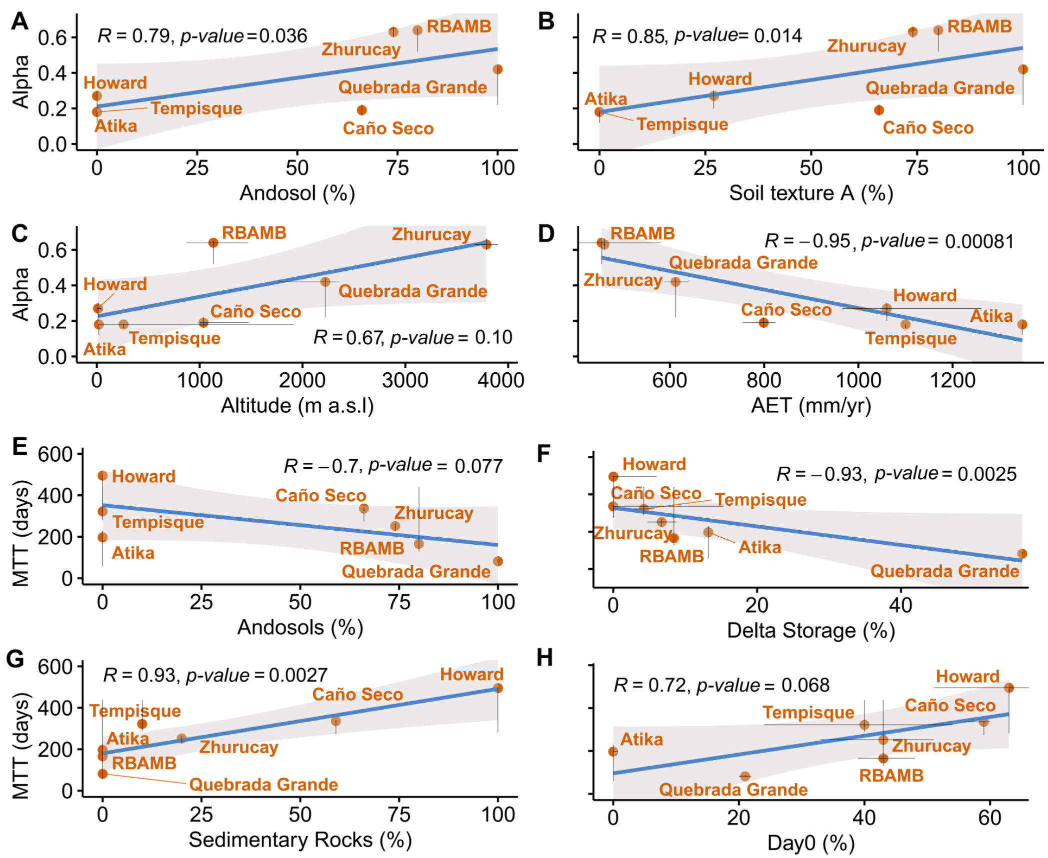
Best MTTs simulations

Catchment	GM				EM		REFERENCES MTT/TT (days)	
	Alpha (Range) calibrated	**Beta (Range) calibrated**	**MTT (Simulated) Best fit**	**KGE**	**MTT (Simulated) Best fit**	**KGE**		
Howard-AUS	(0.2-0.3) 0.27	(944-1825) 1825	(283-497) 494.83	0.61	(113-124) 123.46	0.18	--	--
Atika-AUS	(0.12-0.18) 0.18	(1034-1318) 1115.02	(49 -228) 197.00	0.84	(28-113) 53.37	0.67	--	--
Caño Seco-CRI	(0.16-0.22) 0.20	(1213-1552) 1535	(274-340) 336.70	0.63	(109-113) 104.2	0.38	~213	(Mendez et al., 2016)
Quebrada Grande-CRI	(0.22-0.44) 0.42	(179-389) 195.70	(80-151) 81.74	0.92	(69-113) 72.52	0.88	~87	(Mayer-Anhalt et al., 2022)
RBAMB-CRI	(0.52-0.65) 0.64	(248-323) 259.57	(130-438) 165.69	0.39	(113-157) 156.20	0.37	~162	(Correa et al., 2020)
Tempisque-CRI	(0.16-0.22) 0.18	(1730-1825) 1825	(289-438) 322.19	0.32	(82-113) 85.53	0.16	--	--
Zhurucay-ECU	(0.6-0.66) 0.63	(382-412) 400	(229-264) 252.02	0.76	(113-230) 163.12	0.57	~188	(Mosquera et al., 2016)

The best-fit MTT estimations of all study catchments using two different models. Gamma (GM) and exponential model (EM) with the retained parameter range and median, as well as the best fit MTTs, KGE efficiencies and references. All MTT values are in days.

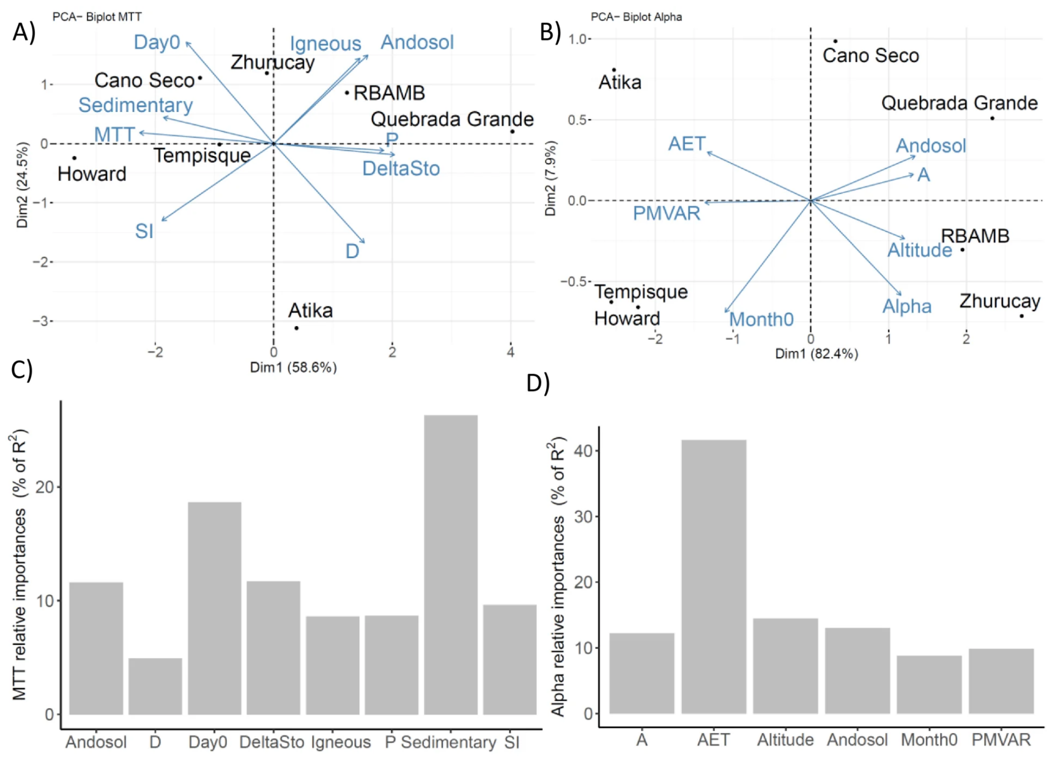
DRIVERS OF PAN-TROPICAL MTTS

MTTs relationships with catchment characteristics



Spearman correlations of the alpha parameter (α) with: **A**) Andosols soil type, **B**) soil texture sands, **C**) altitude, **D**) mean annual evapotranspiration. MTT values correlated with: **E**) Andosols soil type, **F**) catchment storage (term of the hydrological balance equation Δsto = P-ET-Q), **G**) percentage of sedimentary rock, **H**) percentage of days with zero precipitation. X-axis and y-axis errors are represented with horizontal and vertical lines respectively on each point of the scatter plots.

PCA analysis with the correlated variables



PCA analysis and ranked importance variables of correlated variables with MTT **A**), and alpha **B**) as target variables, respectively. Relative importance for MTT **C**), and alpha **D)**.

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SUMMARY

- Main controls of water age are Andosols soils cover,sedimentary rock types cover, and dry days.

- Pan Tropical MTTs shows a rapid rainfall response due to the dominant shallow waters and low deep groundwater influence.
- This highlight the fragility of the tropics in a climate change context.
- MTTs were on average below one year across the seven study catchments.
- The low exponential values of MTTs, corresponding to low Kling-Gupta Efficiency (KGE) values, indicate underfitting times. This suggests that EM is too simple to simulate the variability of the current isotopic data.

FUTURE PERSPECTIVES

The non-linear behaviors, shown through the Spearman correlations between hydrogeomorphological variables and alpha values, help identify potential tipping points. The next step is to construct different scenarios by varying those thresholds and identify their consequences. This information will contribute to establishing appropriate water resource management measures and climate change adaptation strategies in these fragile tropical catchments.

Acknowledgments

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Fabian Quichimbo

My field of interest seamlessly bridges the study of both urban and natural catchments, leveraging modeling techniques to achieve a better understanding of hydrological processes and contribute to effective water management strategies. This integrated field of interest positions me at the intersection of science, policy, and practice. I aspire not only to expand our knowledge of hydrological behaviors but also to contribute to the development of strategies that ensure the sustainable coexistence of water resources and human settlements.

TRANSCRIPT

ABSTRACT

The tropics represent one of Earth's most diverse and dynamic regions. Despite their significance, our comprehension of tropical hydrological processes remains a formidable challenge, largely due to limited monitoring. In this study, we harnessed high-resolution daily input-output isotope data from seven tropical catchments, with areas up to 900 km2, situated in Australia, Costa Rica, and Ecuador. Our aim was to estimate and compare streamflow transit times (TTs) while considering various hydrogeomorphological factors. Employing a simple lumped convolution integral model with a Gamma distribution as the transfer function (yielding best-fit Kling Gupta efficiencies up to 0.92), our extensive and unique pan-tropical dataset revealed relatively short TTs ranging 81 to 494 days (equivalent to 0.22 to 1.4 years). Principal Component Analysis (PCA) and the relative importance test highlighted sedimentary rock content (%), precipitation-free days, and water storage capacity as the most crucial factors influencing TT. Moreover, the TT distribution, as indicated by the alpha parameter, was most effectively explained by annual evapotranspiration, altitude, and Andosol soil cover (%). These findings provide crucial insights into the primary controls on TT and its distribution in rapidly responding tropical catchments compared to other climate and geomorphic zones, underscoring the significance of TT as a coherent descriptor about flow pathways, source of water and storage.

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