

# Synoptic Time Scale Variability in Precipitation and Streamflows for River Basins over Northern South America

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## 1. EMD and EEMD methods

### 1.1. Empirical Mode Decomposition (EMD)

Huang et al. (1999, 1998) proposed that a time series  $x(t)$  can be expressed as,

$$x(t) = \sum_j^n (c_j(t)) + \zeta \quad [\text{S. 1}]$$

where  $c_j$  correspond to the IMFs, and  $\zeta$  is the residual of data. The procedure can be summarized as follows [2]: (1) The extreme maximum and minimum values are identified in  $x(t)$ , (2) the maximal values are connected using a cubic spline to find an upper envelope,  $U_{max}(t)$ . A similar procedure is carried out to the minimal values to find a lower envelope  $L_{min}(t)$ , (3) the mean value between  $U_{max}(t)$  and  $L_{min}(t)$  is estimated  $\left[\bar{U}(t) = \frac{U_{max}(t) - L_{min}(t)}{2}\right]$ , (4) the time series  $\bar{U}$  is substrated of  $x(t)$  as  $[d(t) = x(t) - \bar{U}(t)]$ , (5) the time series  $d(t)$  is considered as the new  $x(t)$  and then steps 1-4 are repeated until finding a signal with zero mean that is the first IMF, (6) The IMF is subtracted from the original time series  $x(t)$  and the procedure is repeated to obtain the next IMF, and (7) stop the iterative process when  $d(t)$  has only one maximum or one minimum value, so that it is not possible to extract more IMFs using  $d(t)$ .

### 1.2. Ensemble Empirical Mode Decomposition (EEMD)

As mentioned above, Wu and Huang (2009) proposed the EEMD as a modified version of the EMD method to solve the “mode mixing” problem. The procedure can be summarized as follows: (1) add white noise series to the original data  $x(t)$ , (2) apply the EMD method to  $x(t)$  with added noise to find the IMFs, (3) repeat steps (1) and (2) several times and, (4) calculate the (ensemble) mean for each IMF, until finding stable values of the IMF for a given error level  $\epsilon$ .

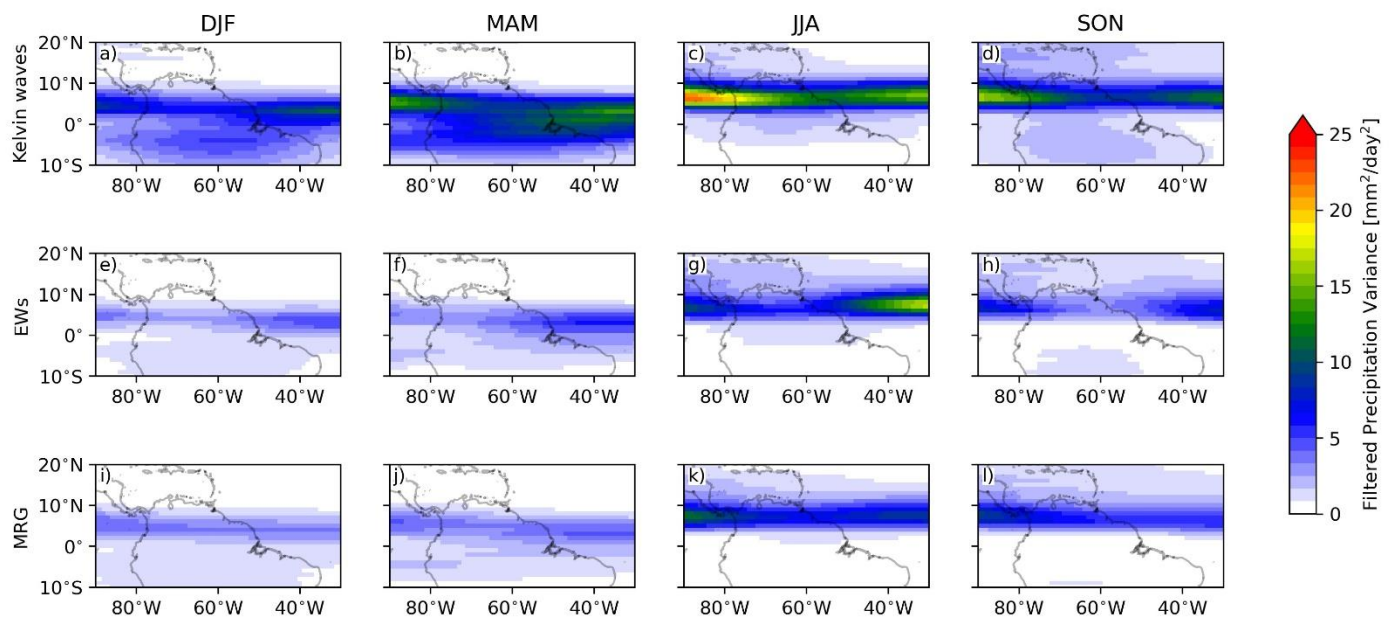
Finally, the added noise series cancel out each other and the mean IMFs remains within the natural dyadic filter windows significantly reducing the chance of mode mixing and preserving the dyadic property [3–5]. This method is counter-intuitive because it uses multiple noise realizations added to a single time series to mimic a scenario of multiple trials of observations which are averaged for the corresponding IMFs allowing to extract scale-consistent signals [5].

## 2. Supplementary tables

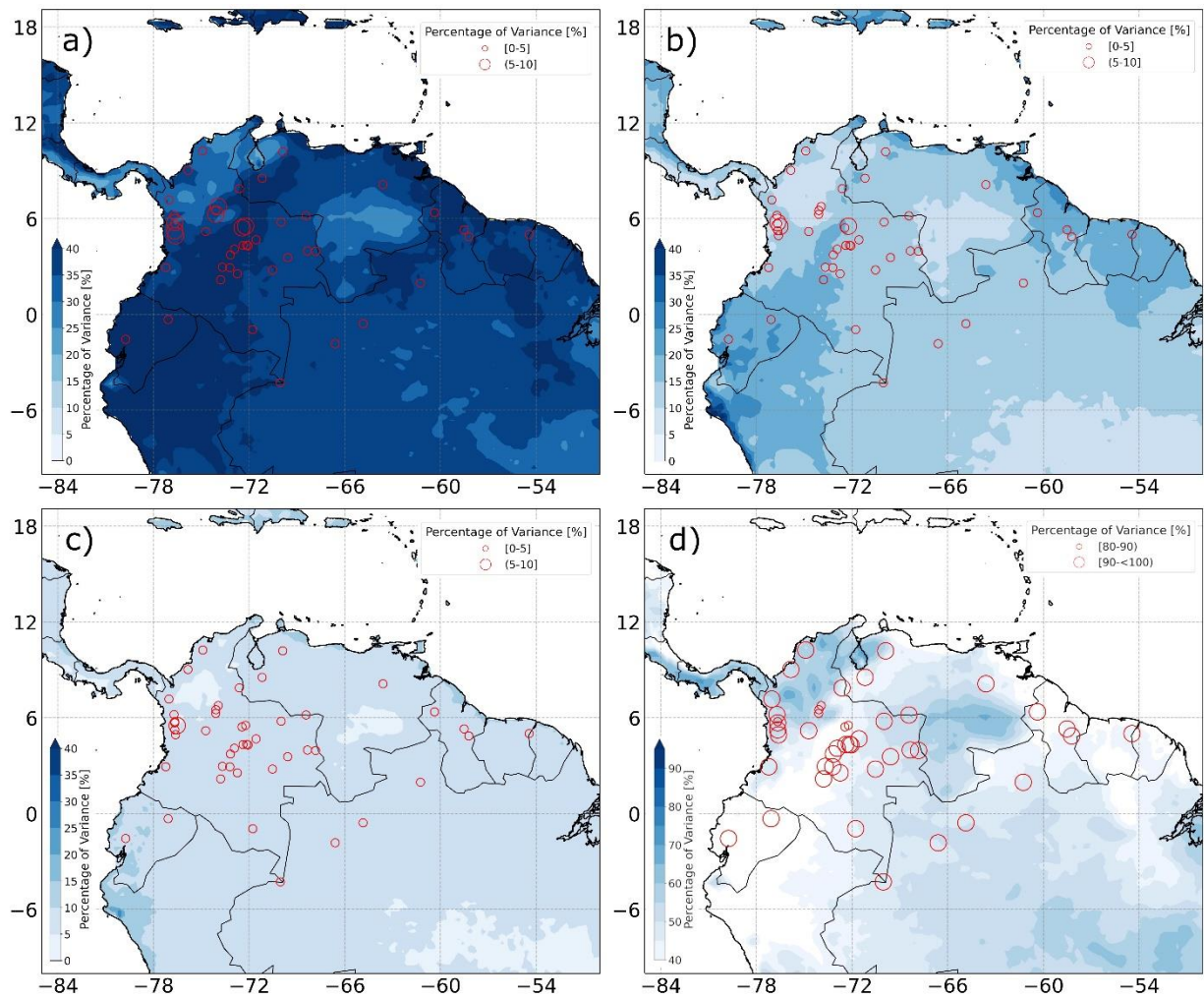
**Table S1.** Streamflow gauges from IDEAM, SO-HYBAM, and GRDC.

ID	Station	Code	Dataset	Area (km <sup>2</sup> )	Latitude	Longitude
1	Puente	11037020	IDEAM	1652.9	5.52	-76.52
2	Quibdo	11047020	IDEAM	4708.8	5.70	-76.66
3	Bajira	11147020	IDEAM	5384.9	5.76	-76.67
4	Belen	11047010	IDEAM	5384.9	6.22	-76.72
5	Tado	54017040	IDEAM	22932.1	7.18	-77.03
6	Calamar	29037020	IDEAM	270895.5	10.25	-74.91
7	Macarena	32037030	IDEAM	13868.2	2.19	-73.79
8	Puerto AR	32107010	IDEAM	35530.0	2.57	-72.75
9	Mapiripana	32157010	IDEAM	52436.0	2.80	-70.53
10	Barranco	32157060	IDEAM	72209.1	3.57	-69.59
11	Cejal	32207010	IDEAM	83633.1	3.99	-68.35
12	Guavare	31097010	IDEAM	134887.1	3.96	-67.83
13	Puente la Cabana	35217030	IDEAM	1034.7	5.44	-72.46
14	Puente Lleras	35017020	IDEAM	8617.1	4.10	-72.94
15	Sabana Nueva	13077010	IDEAM	10061.4	9.03	-75.85
16	Arrancaplumas	21237020	IDEAM	54714.8	5.20	-74.73
17	Puente Ferrocarril	23147020	IDEAM	1758.4	6.77	-73.94
18	Puerto Araujo	23127020	IDEAM	5404.2	6.53	-74.09
19	Santa Rosa	23127060	IDEAM	4936.0	6.29	-74.1
20	Aceitico	35257040	IDEAM	106252.7	6.18	-68.44
21	Aguaverde	35267080	IDEAM	76596.5	5.79	-69.99
22	Camp Yucao	35127020	IDEAM	2352.7	4.34	-72.16
23	Humapo	35117010	IDEAM	26314.7	4.33	-72.39
24	La Estacion	35217020	IDEAM	4310.0	4.69	-71.56
25	Playon El	35217060	IDEAM	1440.3	5.54	-72.23
26	El Barro	35017040	IDEAM	2370.1	3.75	-73.18
27	Piñalito	32077070	IDEAM	2377.5	2.97	-73.68
28	Puerto Gaitan	35127010	IDEAM	9919.7	4.31	-72.08
29	Puerto Rico	32077080	IDEAM	6523.0	2.94	-73.21
30	Quilla La	46077010	IDEAM	17583.7	-0.93	-71.78
31	Ciudad Bolivar	40800000	SO-HYBAM	836000.0	8.14	-63.6
32	Langa	30030000	SO-HYBAM	60930.0	5.03	-54.45
33	Caracarai	14710000	SO-HYBAM	124980.0	1.98	-61.26
34	Serrinha	14420000	SO-HYBAM	279950.0	-0.57	-64.86
35	Francisco	10080900	SO-HYBAM	12440.0	-0.31	-77.08
36	Tabatinga	10100000	SO-HYBAM	880250.0	-4.26	-70.05
37	San Javier	3104500	GRDC	1579.0	7.88	-72.62
38	Tado	3141300	GRDC	1661.0	5.25	-76.66
39	Mampi	3141310	GRDC	1226.0	4.95	-76.62
40	Angosura	3141800	GRDC	2511.0	2.95	-77.23
41	Eiido	3205220	GRDC	1064.0	8.55	-71.19
42	Puente Torres	3205300	GRDC	3590.0	10.20	-69.9
43	Apaikwa	3308300	GRDC	14000.0	6.38	-60.38
44	Great Falls	3309300	GRDC	2460.0	5.31	-58.53
45	Itabru Falls	3309400	GRDC	5100.0	4.88	-58.23
46	Acanaui	3621200	GRDC	242259.0	-1.82	-66.6
47	Vinces-DCP	3844450	GRDC	4400.0	-1.55	-79.75

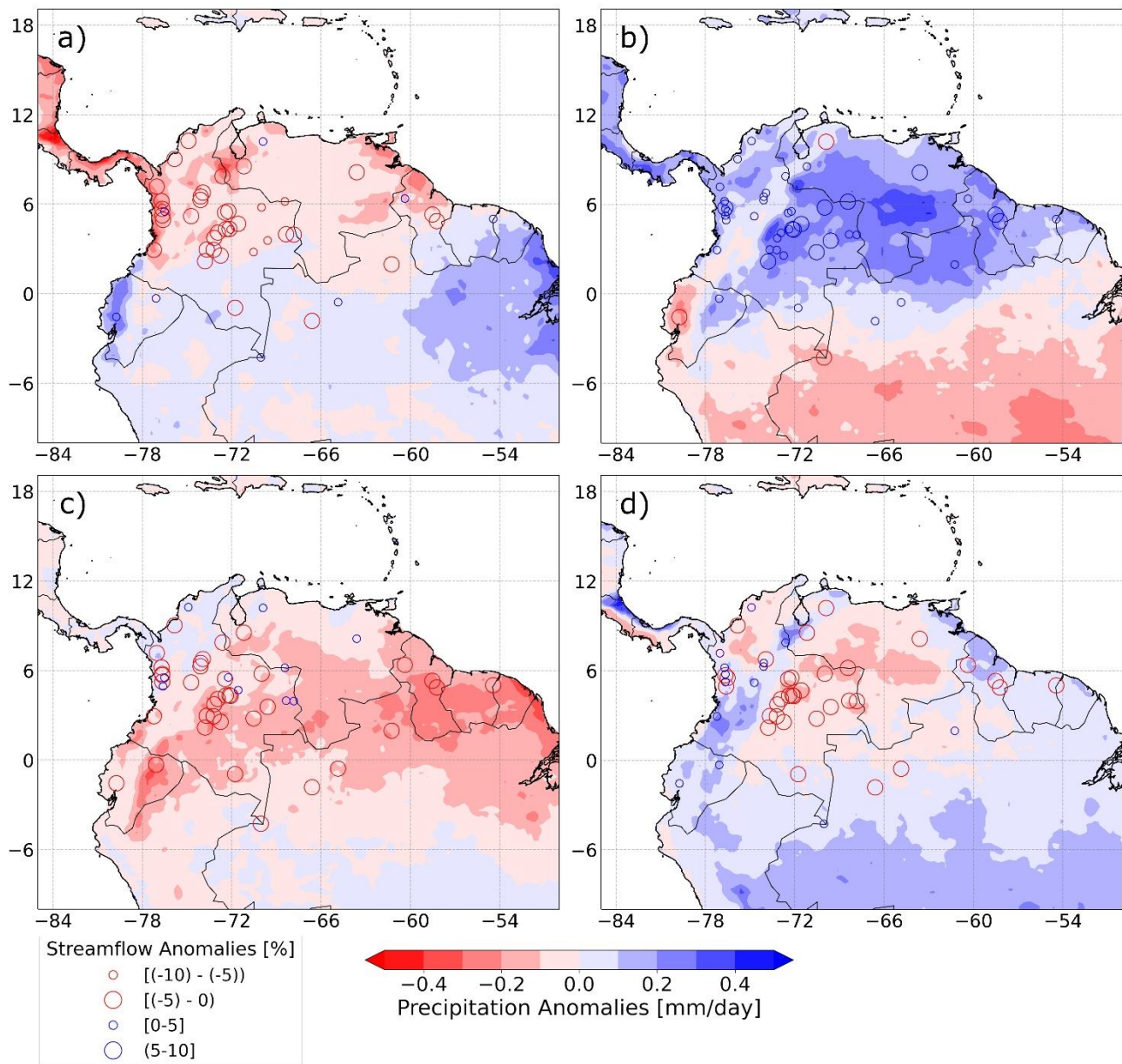
### 3. Supplementary Figures



**Figure S1.** Geographical distribution of ERA5 precipitation variance for the seasons DJF (first column), MAM (second column), JJA (third column) and SON (fourth column) for a,b,c,d) Kelvin waves, e,f,g,h) Easterly waves (EWs) and i,j,k,l) mixed Rossby-gravity (MRG) waves.



**Figure S2.** Percentage of the total variance explained by the synoptic modes of variability for daily precipitation over the region of study, and streamflows of each catchment (red circles). a) IMF 1; b) IMF 2; c) IMF 3; d) Variance explained by the other frequency bands.



**Figure S3.** Seasonal synoptic anomalies of precipitation (colors) and streamflows (circles), over theregion of study for the period 1981-2019. a) DJF; b) MAM; c) JJA; d) SON.

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## References

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