Supplemental Materials:
Multi-scale temporal variability in meltwater contributions in a tropical glacierized watershed

Figures

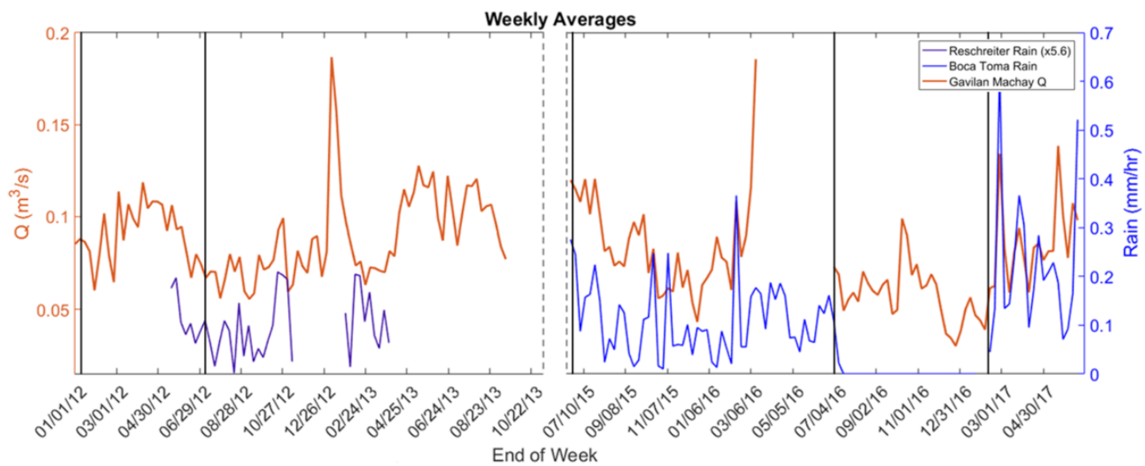

Figure S1. Comparison of average weekly discharge (m^3/s) at Gavilan Machay and rainfall (mm/hr) at Boca Toma. Vertical black dashed lines indicate weeks where sampling occurred. Despite gaps in data, it can be seen that precipitation was higher in the time surrounding the 2015 sampling campaign than in the times surrounding the other campaigns.

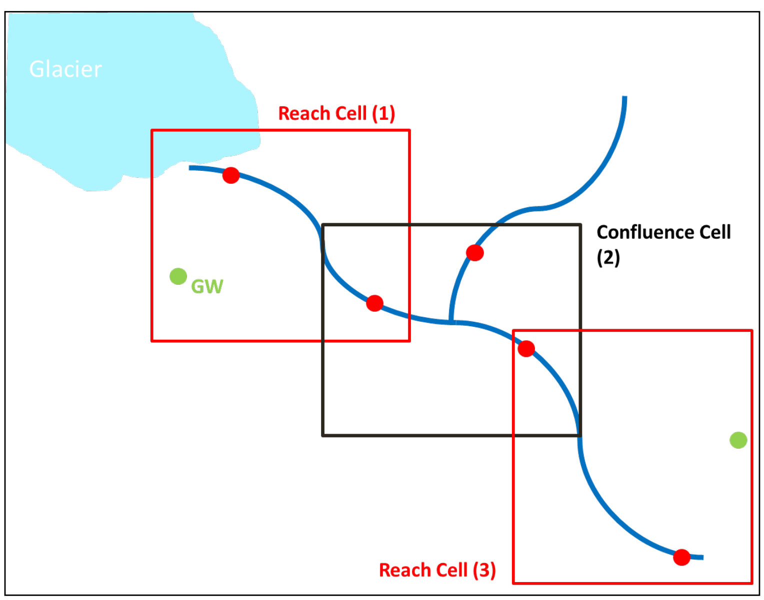

Figure S2. The reach and confluences cells relative to a stream system.

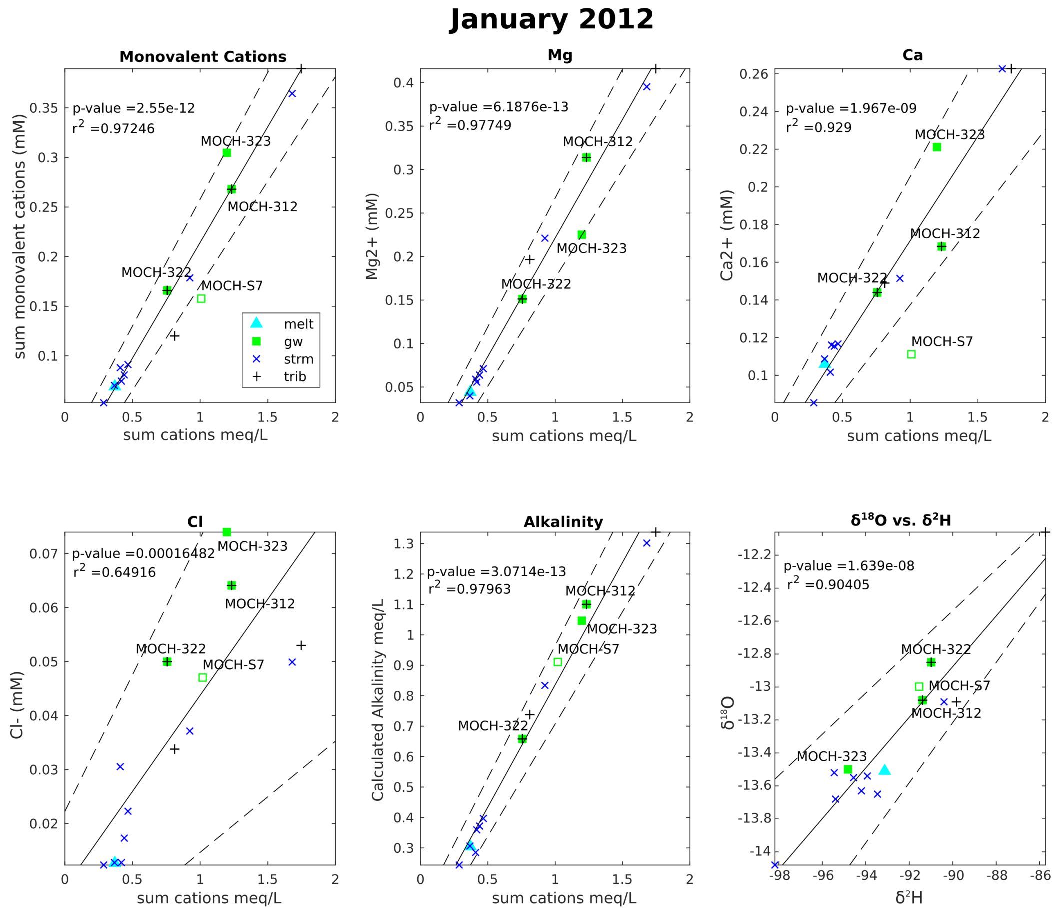

Figure S3. Bivariate diagrams of tracers selected for January 2012 analysis. The solid black lines represent linear regressions through all samples and dashed black lines indicated the regressions' 95% confidence intervals. Samples from the main Rio Mocha channel before and after the Gavilan stream joins it (filled green circles) consistently plot outside or away from the mixing line created between groundwater and meltwater. MOCH-S7 was not considered in the analysis (shown with hallow square). These samples are also responsible for the poor R2 and p-values of sulfate and chloride.

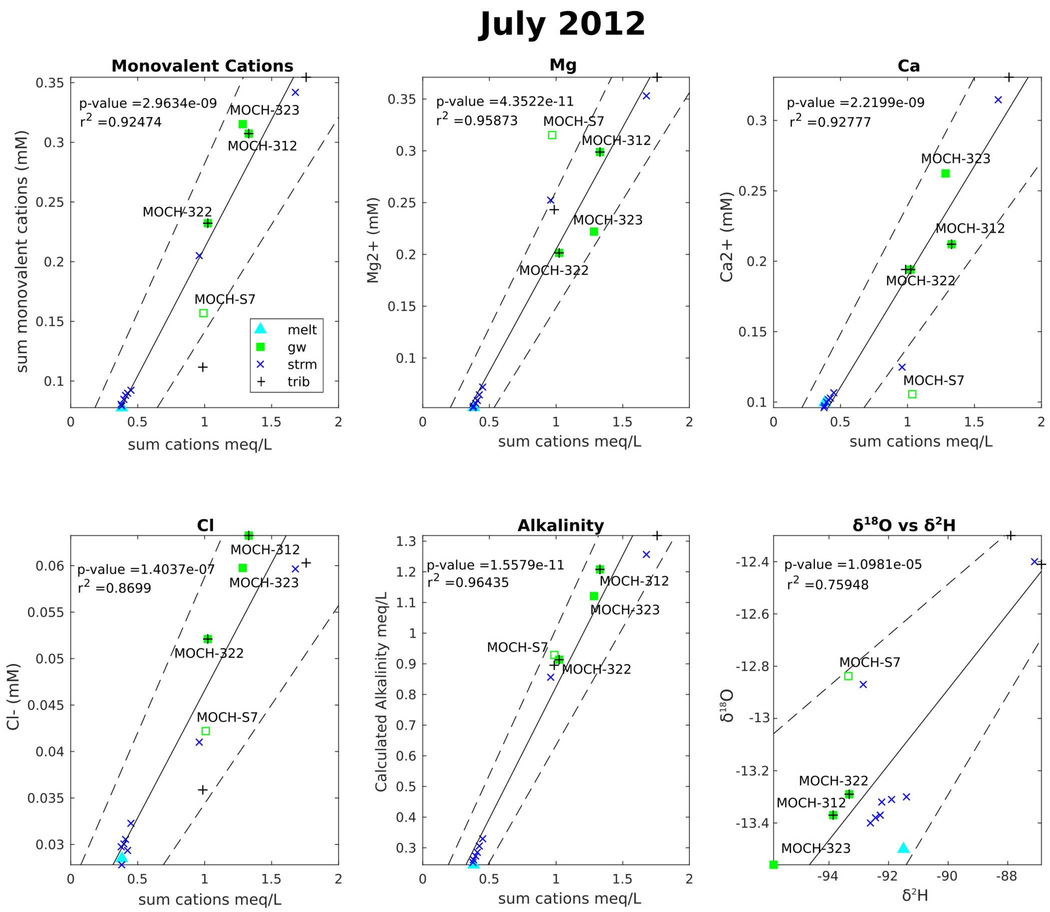

Figure S4. Bivariate diagrams of tracers selected for July 2012 analysis. The solid black lines represent linear regressions through all samples and dashed black lines indicated the regressions' 95% confidence intervals. Samples from the main Rio Mocha channel before and after the Gavilan stream joins it (filled green circles) consistently plot outside or away from the mixing line created between groundwater and meltwater. MOCH-S7 was not considered in the analysis (shown with hollow square). These samples are also responsible for the poor R2 and p-values of sulfate and chloride.

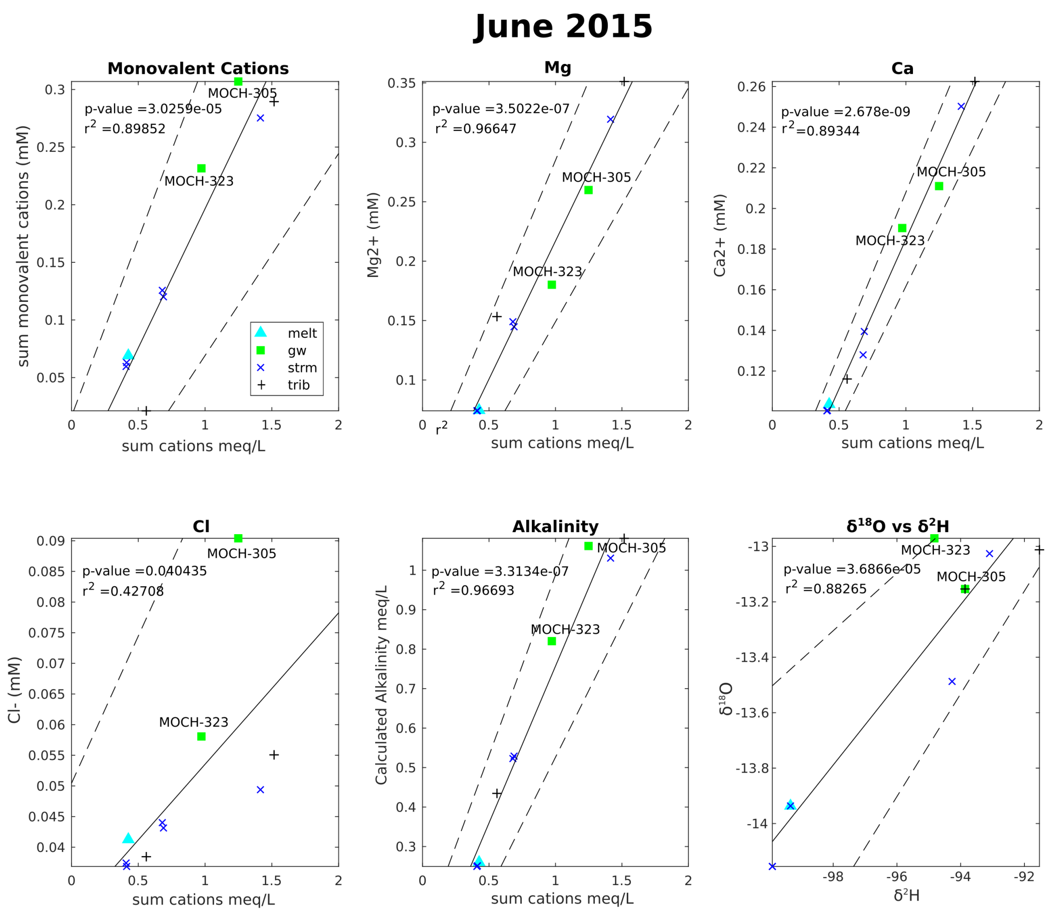

Figure S5. Bivariate diagrams of tracers selected for June 2015 analysis. The solid black lines represent linear regressions through all samples and dashed black lines indicated the regressions' 95% confidence intervals. Samples from the main Rio Mocha channel before and after the Gavilan stream joins it (filled green circles) consistently plot outside or away from the mixing line created between groundwater and meltwater. MOCH-S7 was not considered in the analysis (shown with hallow square). These samples are also responsible for the poor R2 and p-values of sulfate and chloride.

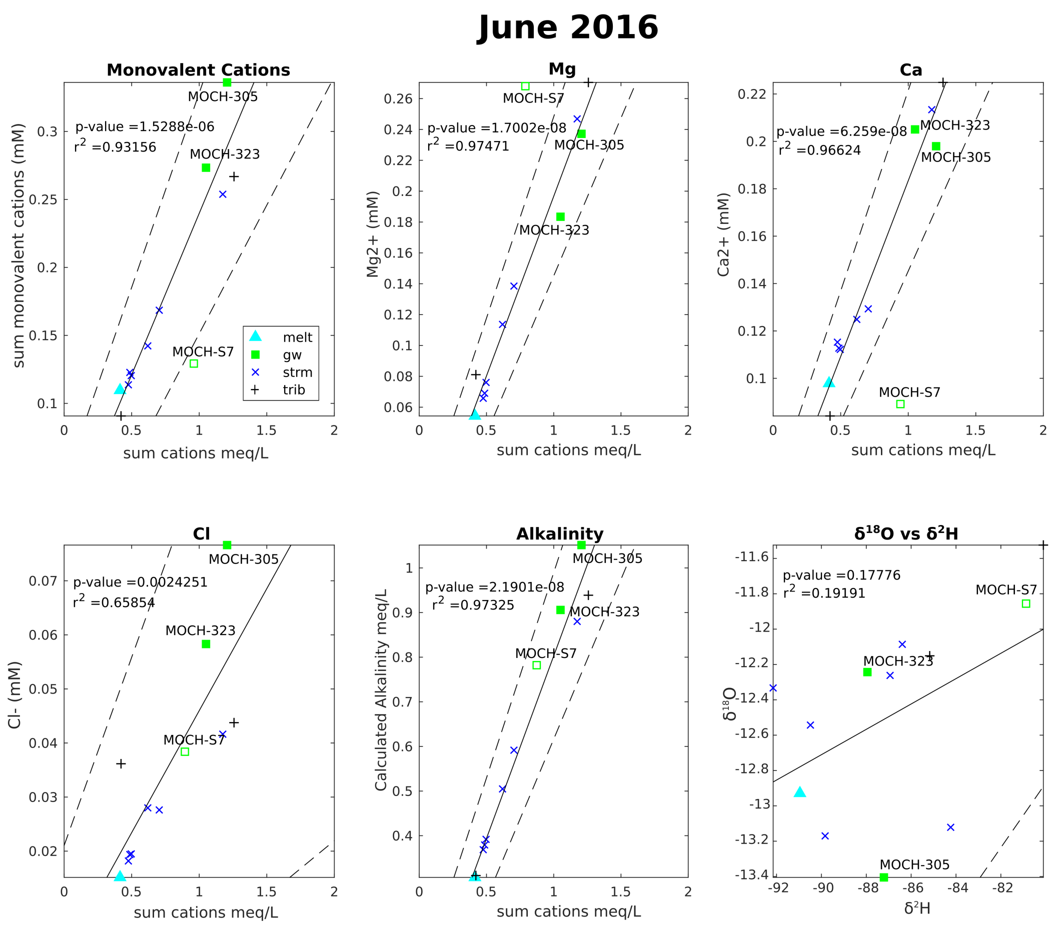

Figure S6. Bivariate diagrams of tracers selected for June 2016 analysis. The solid black lines represent linear regressions through all samples and dashed black lines indicated the regressions' 95% confidence intervals. Samples from the main Rio Mocha channel before and after the Gavilan stream joins it (filled green circles) consistently plot outside or away from the mixing line created between groundwater and meltwater. MOCH-S7 was not considered in the analysis (shown with hallow square). These samples are also responsible for the poor R2 and p-values of sulfate and chloride.

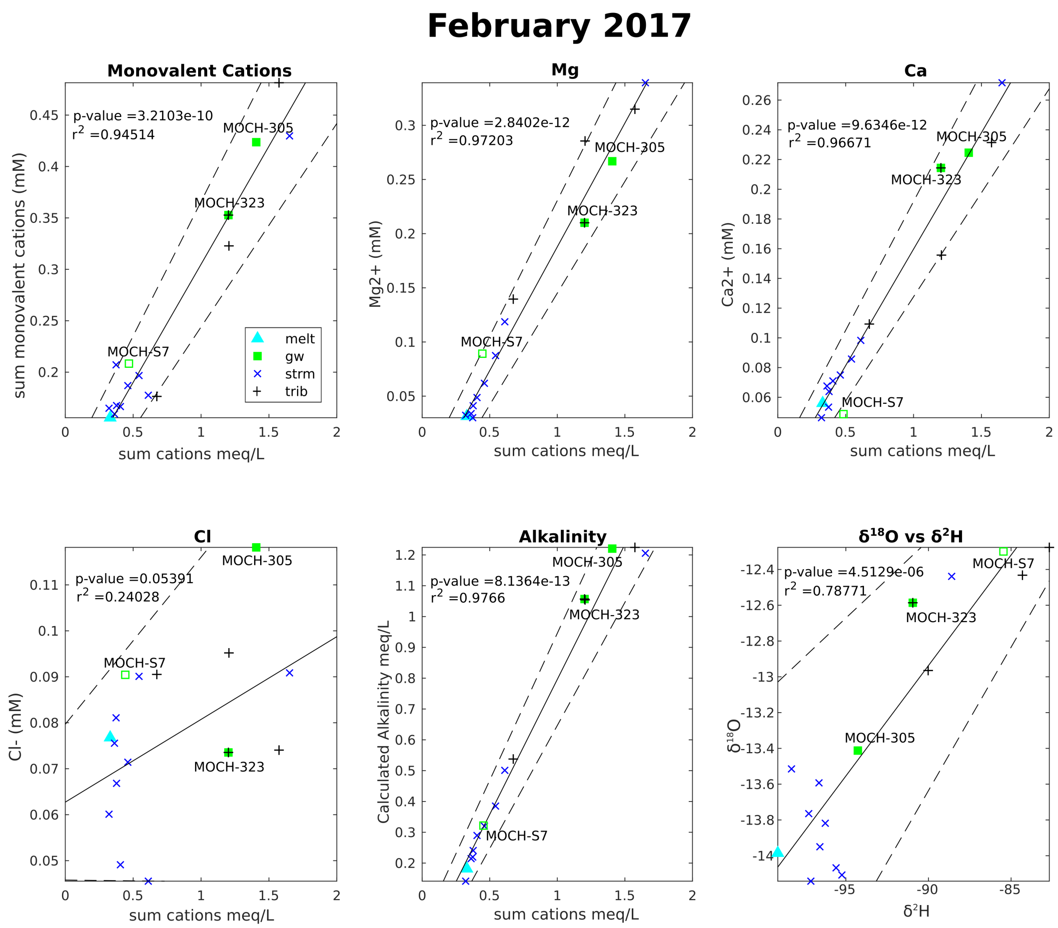

Figure S7. Bivariate diagrams of tracers selected for February 2017 analysis. The solid black lines represent linear regressions through all samples and dashed black lines indicated the regressions' 95% confidence intervals. Samples from the main Rio Mocha channel before and after the Gavilan stream joins it (filled green circles) consistently plot outside or away from the mixing line created between groundwater and meltwater. MOCH-S7 was not considered in the analysis (shown with hallow square). These samples are also responsible for the poor R2 and p-values of sulfate and chloride.

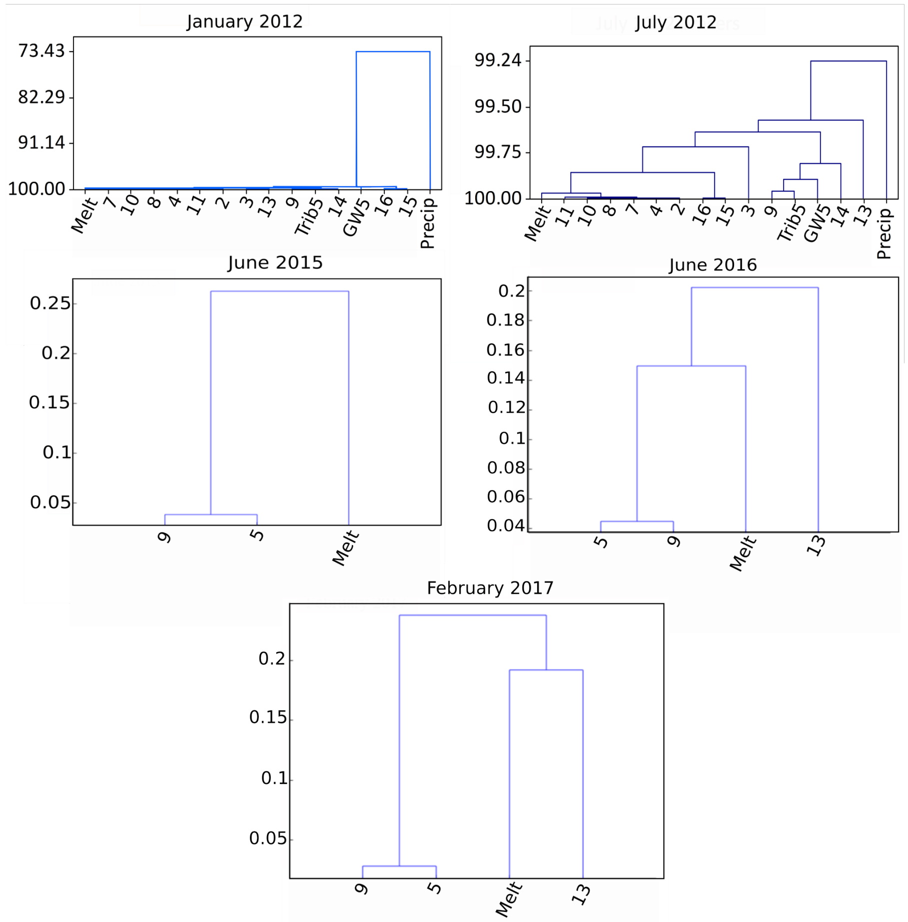

Figure S8. Hierarchical cluster analysis dendrograms for tracers used in HCBM for January 2012, July 2012, June 2015, June 2016, and February 2017. Sample grouping verifies effectiveness of selected tracers in distinguishing between source waters, as groundwater samples (GW) cluster separately from melt water (Melt) samples. GW-7 is considered an outlier, and is suspected to be a mixed source sample or to originate from a unique geology.

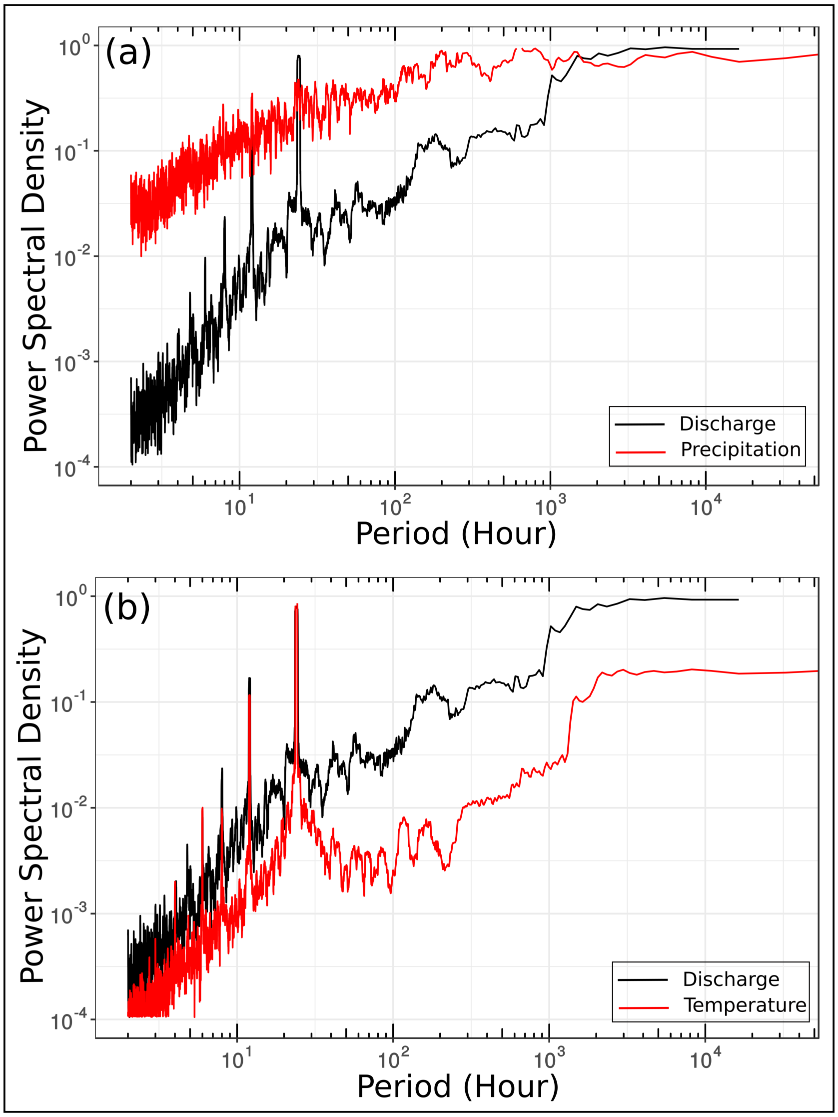

Figure S9. Power spectral density of **(a)**discharge and temperature, **(b)** discharge and precipitation

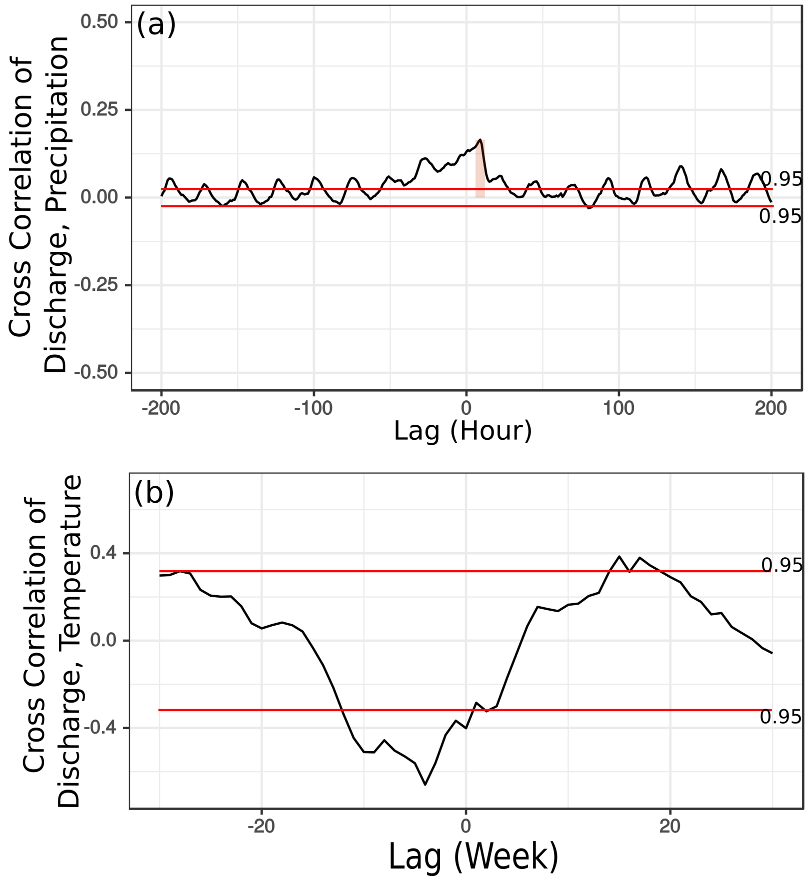

Figure S10. Cross-correlation of **(a)**hourly discharge and precipitation, **(b)** weekly discharge and temperature

Hydrochemical Basin Characterization Model (HBCM)

The following set of mass-balance equations for J tracers applies to each HBCM cell:

$$C_{tot_j} = \frac{\sum_{i=1}^{I}(C_{i,j} * Q_i) + \epsilon_j}{Q_{tot}} \tag{S1}$$

Where:

j: index for a specific natural tracer, 1 through J

i: index for a specific source to the cell (ice, tributary, or groundwater), 1 through I

C_{tot_j}: concentration of tracer j at the cell outlet

$C_{i,j}$: concentration of tracer j in source i

Q_{tot}: Total discharge at cell outlet

Q_i: Contribution to discharge from source i

ϵ_j: residual error between the observed and predicted concentration flux out of the cell for tracer j

HBCM solves for the unknown relative contributions of each source (Q_i/Q_{tot}) by minimizing the sum of the residual errors:

$$\sum_{j=1}^{J} \epsilon_j \tag{S2}$$

In order to over-constrain the problem, the model requires $J = I$ tracers and, preferably, $J > I$ tracers should be utilized in order to avoid the possibility of correlated tracers that do not independently constrain the problem. HBCM checks that a tracer is conservative within each cell via three tests:

1. A tracer value in a cell outflow cannot be outside the range bracketed by the possible contributors;
2. The tracer value at the cell outflow, along with that of at least one input component, must be greater than the detection limit of the analytical methods (confirmed by user); and
3. There must be a minimum 5% difference between the concentration of a tracer from each source.

If any of these requirements is not met, HBCM will reject the tracer for use in the cell.

Tables

Table S1. HBCM analysis result for January 2012 to February 2017 with different cell configurations. – See the spreadsheet "HBCM Table".

	Observed				Flux-PIHM pedotransfer function results						
	Sand (%mass)	Silt (%mass)	Clay (%mass)	OC (%mass)	KINF (m/s)	KSATV (m/s)	KSATH (m/s)	SMCMAX (-)	SMCMIN (-)	ALPHA (1/m)	BETA (-)
Podwojewski et al. 2002, Pantano 60-80	26	41	8	12	4.52E-07	6.44E-07	6.44E-06	0.479	0.05	1.908	1.157
Patano 80-95+	33	39	14	8	1.47E-06	1.58E-06	1.58E-05	0.481	0.05	3.491	1.136
Humid páramo 0-15	26	44	7	10	6.24E-07	1.03E-06	1.03E-05	0.48	0.05	2.267	1.173
Humid páramo 15-30	32	41	8	7	1.51E-05	6.76E-06	3.05E-05	0.418	0.05	5.34	1.26
Dry páramo 0-15	30	43	8	7	8.28E-05	3.71E-05	6.96E-05	0.493	0.05	5.82	1.22
Dry páramo 15-30	35	33	20	5	8.28E-05	3.71E-05	6.96E-05	0.493	0.05	5.82	1.22
Minaya (2016), Low Elev.	20.28	31.98	6.24	22	3.71E-08	8.42E-08	8.42E-07	0.482	0.05	0.327	1.144
Minaya (2016), Middle Elev.	26.07	30.81	11.06	21	6.13E-08	1.03E-07	1.03E-06	0.479	0.05	0.466	1.124
Minaya (2016), Highest Elev.	23.4	39.6	6.3	10	4.28E-07	1.70E-07	1.70E-06	0.465	0.05	1.442	1.1

Table S2. Páramo soil measurments applied into pedo transfer functions (Podwojewski et al., 2002; Minaya, 2016)