

Evaluation of inter-annual to decadal changes in tropical Andean stream chemistry below debris-covered glaciers

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INTRODUCTION

Changing cryospheric conditions in the tropical Cordillera Blanca, Peru have lasting impacts on downstream water resources. By assessing isotopic signatures of  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  in glacial streams, how do debris-covered glacier (DCG) outflows chemically differ from those of debris-free glaciers?

METHODS

Fieldwork

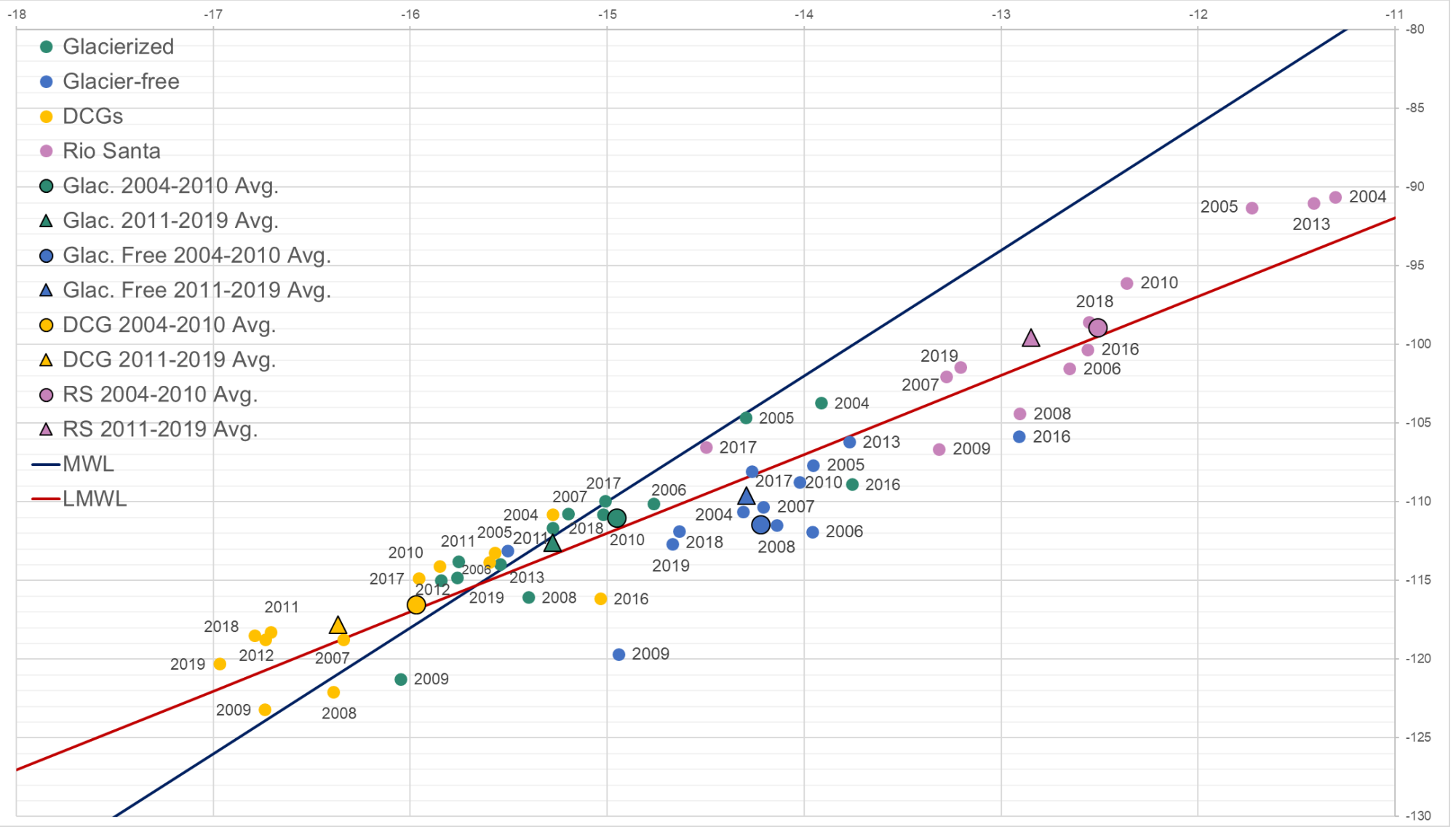
- 48 sampling locations across 20 catchments
  - 3 catchments contain DCG
- 15 years of synoptic sampling during dry season
- Began to focus on DCG outflow over past 2 years

Processing

- Picarro Isotope Analyzer and Ion Chromatography

RESULTS

- DCG  $\delta^{18}\text{O}$  signal consistently lighter than debris-free glaciers
- DCG outflows also contain fewer ions
- All glacial sources in the Cordillera Blanca show a general depletion over a decadal time scale.



DISCUSSION

- Post-depositional enrichment of  $\delta^{18}\text{O}$
- Less evaporation below debris than clean ice
- Findings show similar trends to the central Andes, but differ from the Himalaya (see table)

Further Analysis

- PCA, mixing models to determine contributions

Study Reference	Outflow Site Name	Location	Elevation	D18O
Wilson et al., 2016	Khimsum Glacier Post-monsoon median	Himalaya	4166	-19.94
	Lirung DCG Post-monsoon median	Himalaya	3754	-15.47
Crespo et al., 2017	Mean DCG outflow value	Mendoza Andes	N/A	-20.20
	Mean Glacier outflow value	Mendoza Andes	N/A	-19.37
	Mean from downstream rivers	Mendoza Andes	N/A	-18.01
This study	Kinzi DCG median	Cordillera Blanca	4250	-16.34
	Yanamarey Glacier median	Cordillera Blanca	4031	-15.24
	Broggi Glacier median	Cordillera Blanca	3905	-15.90

REFERENCES

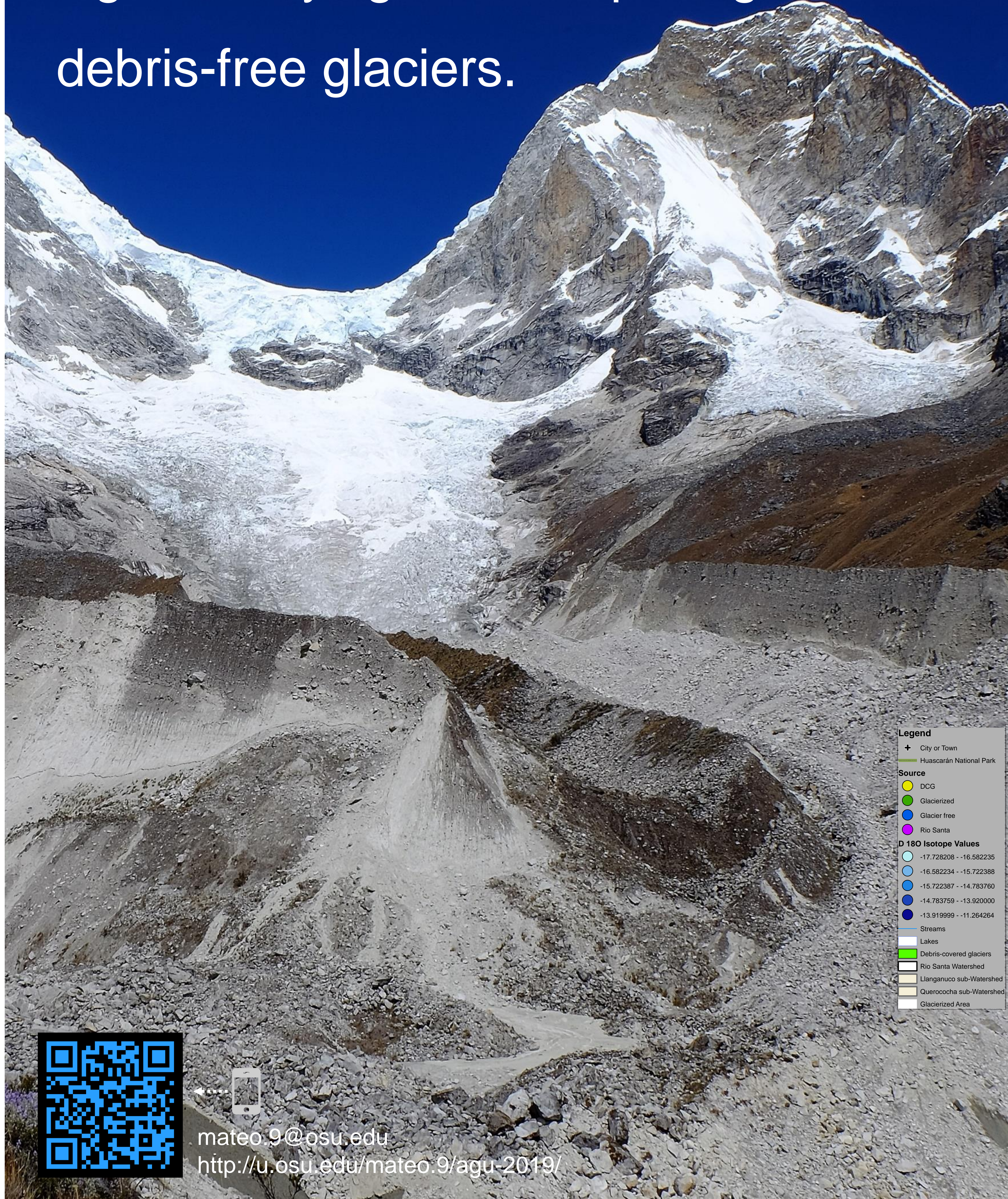
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Debris-covered glaciers display a significantly lighter isotopic signal than debris-free glaciers.



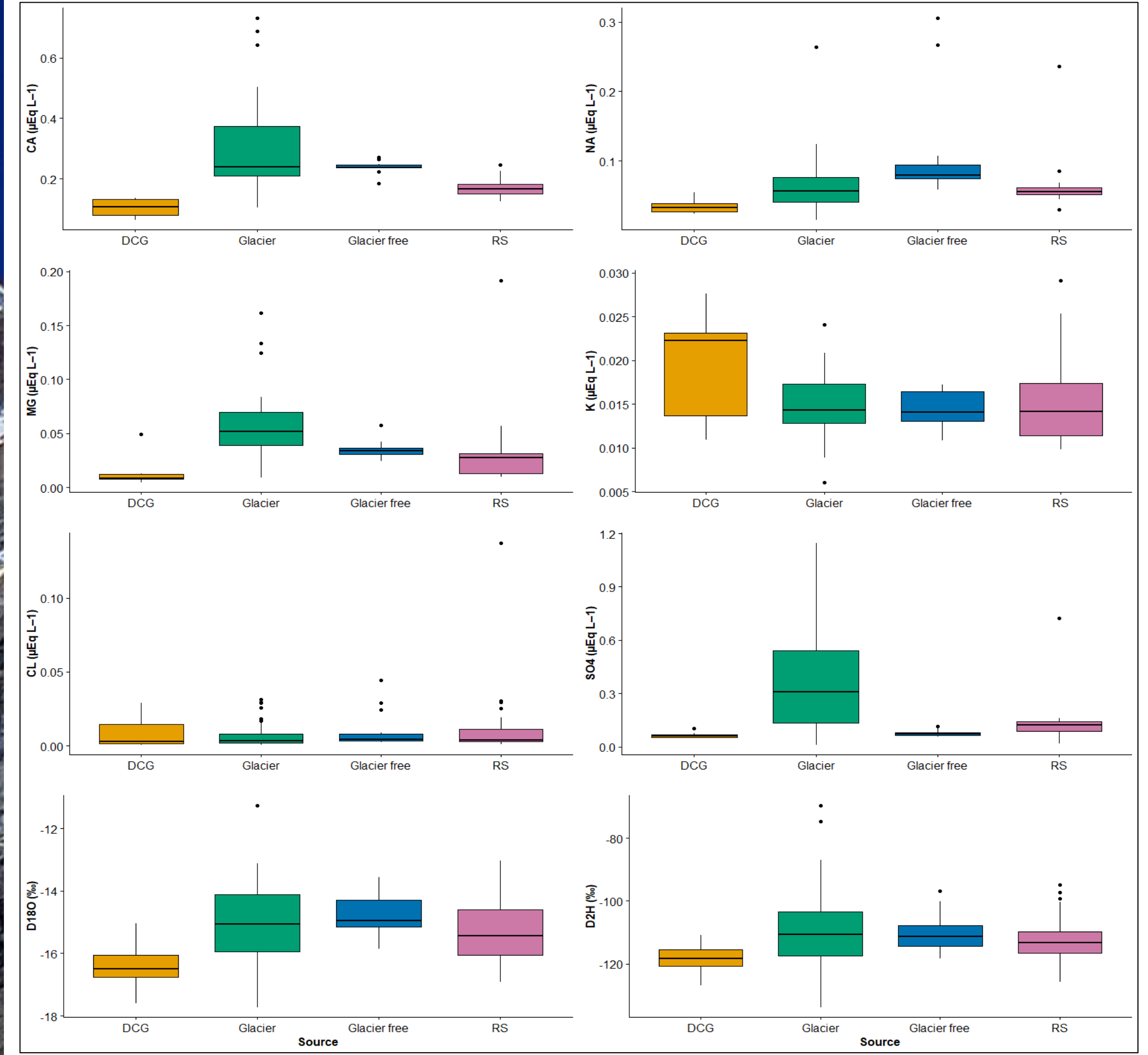
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Source	count	mean	sd	max	min	pval
DCG	26	-16.57489	0.600963	-17.60208	-15.82182	2.94549
Glacier	63	-16.05023	1.281296	-15.26426	-17.73821	6.46344
Glacier free	22	-14.80705	0.652101	-13.55653	-15.84643	2.20115
RS	47	-15.24202	1.0482454	-13.03509	-16.91000	3.47096

Comparison	D18O	SDH	d.excess	Ca	Na	Mg	K	Cl	SO4
Glacier - DCG	0.0001	0.0088	0.1565	0.0002	0.3505	0.0046	0.0442	0.9921	0.0011
Glacier Free - DCG	0.0003	0.0085	0.2028	0.0006	0.3648	0.0048	0.0465	0.9986	0.0013
RS - DCG	0.0020	0.1124	0.0889	0.0307	0.4852	0.4545	0.1405	0.9424	0.0775
Glacier Free - Glacier	0.0378	0.9996	0.4964	0.3872	0.0161	0.1302	0.9895	0.9310	0.0001
RS - Glacier	0.0000	0.7399	0.5265	0.0001	0.9986	0.0103	0.9342	0.4551	0.0001
RS - Glacier Free	0.9929	0.8800	0.8139	0.2803	0.0225	0.9953	0.9908	0.9238	0.8200

Above: Descriptive statistics and p-values from the Tukey HSD test for multiple mean comparisons



Above: Boxplots comparing geochemical (µEq/L) and isotopic tracers (‰) in tributaries to the Rio Santa separated by end-member source (Debris-covered glacier (DCG), Rio Santa (RS))

Below: Map of the Rio Santa Watershed with water sample locations

