

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

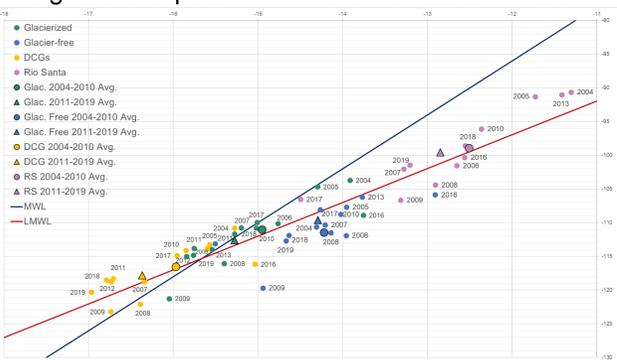
- 48 sampling locations across 20 catchments
 - 3 catchments contain DCG
- 15 years of synoptic sampling during dry season
- Began to focus on DCG outflow over past 2 years

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	D180
Wilson et al., 2016	Khimbung Glacier Post-monsoon median	Himalaya	4166	-15.94
	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

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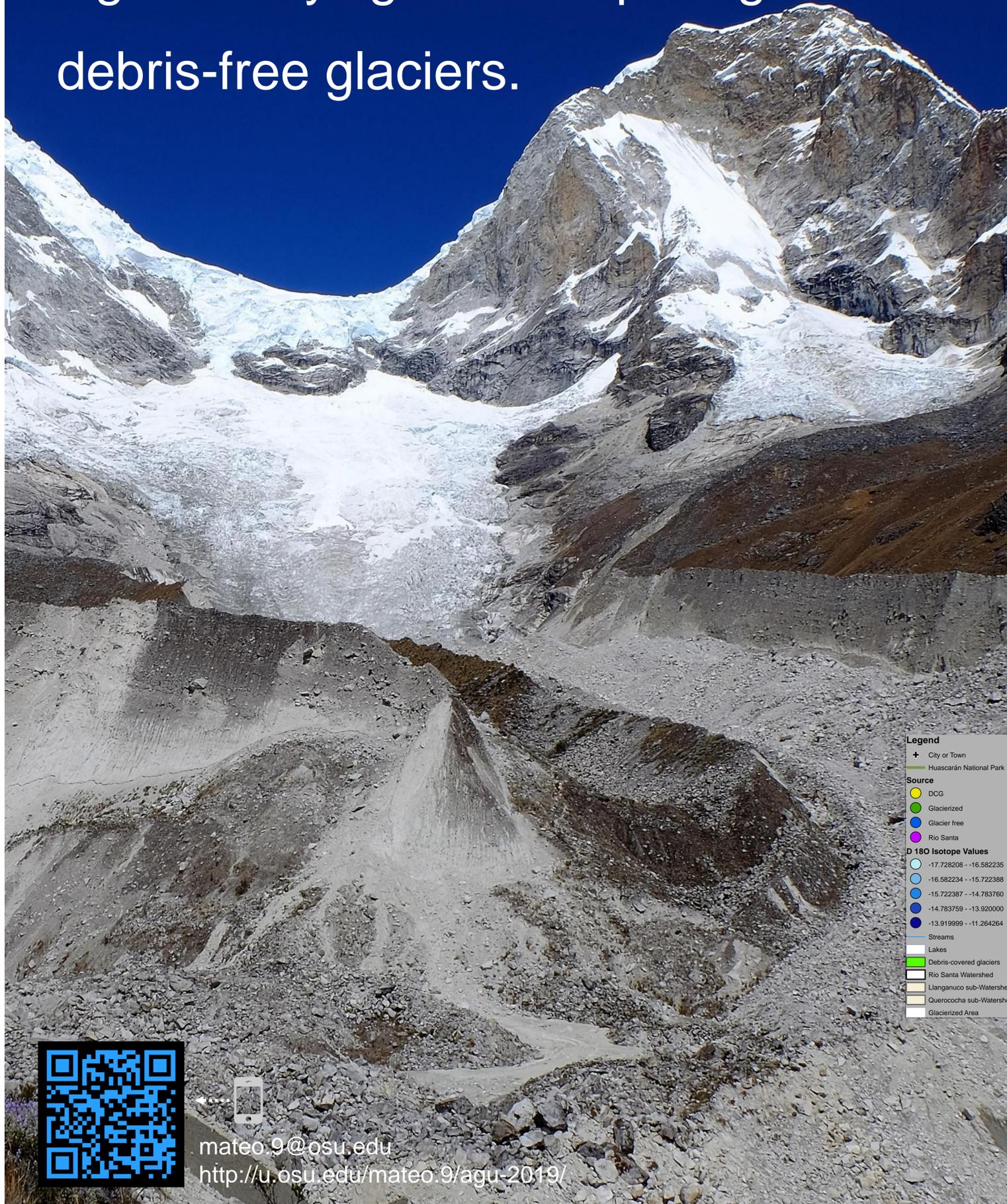
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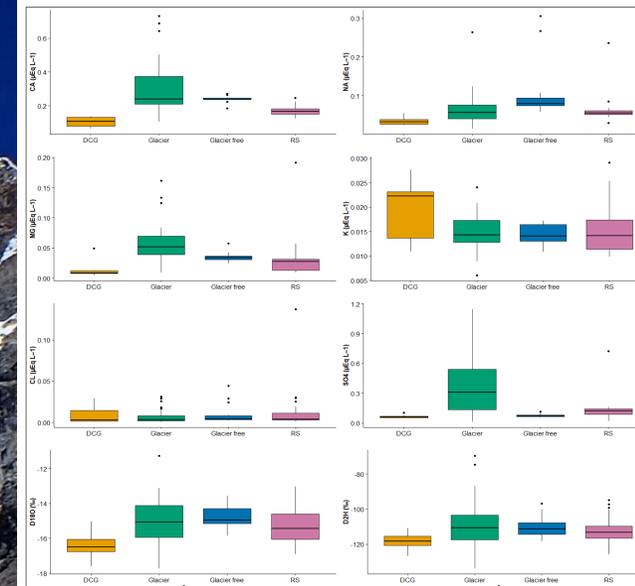
Debris-covered glaciers display a significantly lighter isotopic signal than debris-free glaciers.



Source	count	mean	sd	min	max	range
DCG	21	-16.37489	0.620963	-17.02028	-15.69142	2.32886
Glacier	83	-15.95903	1.291296	-15.36426	-17.73021	6.36594
Glacier free	22	-14.80705	0.621011	-15.55652	-14.04643	2.20013
RS	47	-15.24202	1.048244	-13.93969	-16.91000	3.97036

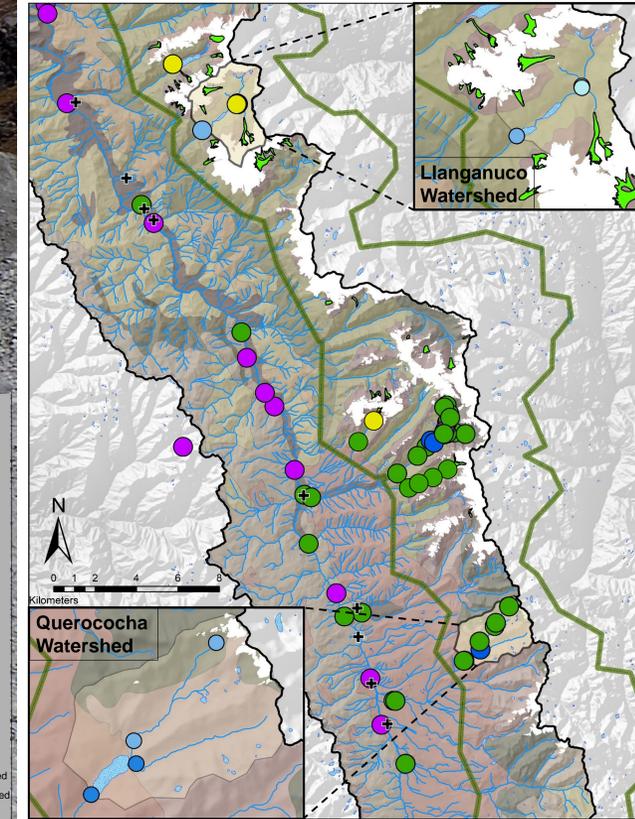
Comparison	D180	SDH	c excess	Ca	Na	Mg	K	Cl	SO4
Glacier - DCG	0.0001	0.0088	0.1969	0.0002	0.3609	0.0046	0.0442	0.0021	0.0011
Glacier Free - DCG	0.0002	0.0088	0.0228	0.0048	0.4648	0.0008	0.0008	0.0008	0.0001
RS - DCG	0.0020	0.1254	0.0089	0.0007	0.4852	0.0049	0.0409	0.0404	0.0070
Glacier Free - Glacier	0.0376	0.0996	0.4964	0.0072	0.0191	0.1302	0.0095	0.0010	0.0001
RS - Glacier	0.0020	0.7359	0.0285	0.0001	0.0985	0.0103	0.0342	0.4663	0.0001
RS - Glacier Free	0.0029	0.8800	0.0139	0.0003	0.0228	0.0003	0.0008	0.0028	0.0001

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



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