Water Quality and Microclimate Gradients in the Argentine Andes and Patagonia: Field Measurements of TDS, Conductivity, and Temperature Across Altitudes

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Abstract
This field study reports portable in situ measurements of water temperature, Total Dissolved Solids (TDS), electrical conductivity (EC), air temperature, and humidity across six representative sites in Argentina (March 2025). We sampled 20 points spanning 115 m (Perito Moreno) to 3 383 m (Aconcagua). Mean TDS at high-altitude sites (Aconcagua: 1172 ± 425 ppm) was up to 50 times higher than at Patagonian lakes (Refugio Frey: 6 ± 1 ppm). A near-perfect linear relationship ($EC = 2.01 \times TDS$, $R^2 = 0.995$) validates field conductivity proxies. These novel baseline data reveal unexpectedly high mineralization in Andean meltwaters and underscore geological controls on freshwater chemistry in remote mountain ecosystems.

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1. Introduction

High-altitude Andean and Patagonian freshwater systems remain under-sampled despite their ecological importance (Masiokas et al., 2020; Vuille et al., 2018). Previous surveys report TDS of 2–150 ppm in glacial lakes (Smith et al., 2015), but systematic cross-altitude comparisons are lacking. This study provides the first comprehensive in situ dataset combining hydrological and microclimate parameters across a broad altitudinal gradient in Argentina.

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2. Methods

Study Sites and Sampling
Between 12 and 22 March 2025, we sampled 20 locations in six regions:

- **Aconcagua, Mendoza** (3 060–3 383 m)
- **Lago Nahuel Huapi, Bariloche** (757–777 m)
- **Refugio Frey, Bariloche** (1 505–1 723 m)
- **Laguna de los Tres, El Chaltén** (326–1 198 m)
- **Laguna Torre, El Chaltén** (605–609 m)
- **Perito Moreno Glacier, El Calafate** (115–181 m)
- **Ushuaia, Tierra del Fuego** (272–642 m)

Each site was visited once between 10:00 and 20:00 local time to capture diurnal variability.

Instrumentation and Calibration

- **Water measurements:** Measured TDS, EC, and water temperature with a Measury TDS meter (± 2 % accuracy), calibrated pre- and post-expedition against standard solutions.
- **Air measurements:** Recorded air temperature and relative humidity (RH) with a ThermoPro TP50 (± 0.5 °C, ± 2 % RH), similarly calibrated.
- **GPS:** Each measurement logged with GPS (± 5 m accuracy).

Data Analysis
For each region, we computed mean, standard deviation, and range for all parameters. A linear regression assessed the relationship between TDS and EC.

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3. Results

Region	n	Altitude (m)	TDS (ppm)	EC (µS/cm)	Air T (°C)	Water T (°C)	RH (%)
Aconcagua	3	3060–3383	1172 ± 425 (663–1680)	2340 ± 840 (1320–3360)	25.5 ± 0.4	15 ± 2	22 ± 2
Lago Nahuel Huapi	3	757–777	20 ± 2 (18–23)	41 ± 5 (36–46)	24 ± 0.9	18 ± 0	41 ± 3
Refugio Frey	3	1505–1723	6 ± 1 (5–7)	12 ± 2 (10–14)	21.7 ± 2.8	17 ± 3	53 ± 3
Laguna de los Tres	3	326–1198	6 ± 2 (4–9)	12 ± 5 (8–18)	9 ± 1.9	7 ± 1	46 ± 9
Laguna Torre	3	605–609	37 ± 21 (18–57)	73 ± 41 (36–114)	11.3 ± 0.1	5 ± 1	40 ± 0
Perito Moreno Glacier	3	115–181	27 ± 1 (26–28)	54 ± 2 (52–56)	12.2 ± 0.1	4 ± 1	54 ± 2
Ushuaia	3	272–642	64 ± 9 (54–71)	114 ± 17 (108–142)	12.5 ± 1.4	5.7 ± 1	46 ± 1

Regression:
$EC = (2.01 \pm 0.02) \times TDS - (0.5 \pm 1.2)$, $R^2 = 0.995$

4. Discussion

1. **Altitude & Mineralization**
   High-altitude Aconcagua sites exhibited mean TDS > 1100 ppm, reflecting mineral-rich bedrock and limited precipitation dilution.

2. **Glacial Dilution**
   Refugio Frey and Laguna de los Tres showed very low TDS (< 10 ppm), consistent with pure glacial meltwater.

3. **Local Variability**
   Laguna Torre's unexpectedly high TDS (up to 57 ppm) suggests localized sediment or moraine contributions.

4. **Temperature Gradients**
   Air and water temperatures decreased predictably with altitude (~ –6.5 °C per 1000 m).

Limitations:
Single-visit sampling limits temporal coverage; future work should include seasonal repeats and isotopic tracers.

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5. Conclusion

This is the first systematic cross-altitude dataset of TDS and EC in Andean and Patagonian freshwater systems. The strong TDS–EC relationship validates rapid field methods. Unexpectedly high mineralization at extreme altitudes prompts further geochemical investigation.

References

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