

EVALUATION OF LITTLE ICE AGE COOLING IN WESTERN CENTRAL ANDES SUGGESTED BY PALEOELAS, IN CONTRAST WITH GLOBAL WARMING SINCE LATE 19th CENTURY DEDUCTED FROM INSTRUMENTAL RECORDS

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This paper attempts to evaluate climate cooling (°C) during the glacial expansion phases using the product GTV•ΔELA, where GTV is the vertical air temperature gradient (°C/m) and ΔELA (m) the difference in level observed between the Equilibrium Line Altitude (ELA) reconstructions for current and past glaciers.

With this aim the Area x Altitude Balance Ratio-(AABR) method was used to produce reconstructions of present ELAs (2002-2010) and paleoELAs corresponding to the last glacier advance phase. The reconstructions were produced in three study areas located along a N-S transect of the western cordillera in the Central Andes: the south-western sector of the Nevado Hualcán (9°S, 77°W; Giráldez 2011); the southern slope of the Cordillera Pariaqaga (12°S, 76°W; Quirós, 2013) and the NW, NE, SE and SW quadrants of the Nevado Coropuna (16°S, 72°W; García 2013; Úbeda 2011; Campos, 2012).

The three mountains exceed 6000 m altitude, their summit areas are covered by glaciers, and on their slopes there are existing well-conserved moraines deposited by the last advances near the present front of the ice masses. Although there are no absolute dates to confirm this hypothesis, it has been assumed that the last glacial advances occurred during the Little Ice Age (LIA), which the oxygen isotopes of the Nevado Huascarán (9°S, 77°W) date to the period 1500-1890.

For the Hualcán and Pariaqaga the mean global value of the Earth's air temperature lapse rate (ATLR=6.5°C/km) was used, considered valid for the Tropics. On the Coropuna a ATLR=8.4°C/km was used, based on high resolution sensors installed in situ since 2007 (Úbeda 2011). This gradient is approaching the upper limit of the dry adiabatic gradient (9.8°C/km), as the Coropuna region is more arid than the other case study areas. The climate cooling estimates deduced from the product ATLR•ΔELA were compared with the global warming shown by the 1880-2012 series, ΔT=0.85°C, and 1850/1900-2003/2012, ΔT=0.78°C.

The differences are small (averaging 0.05 and 0.12 °C) suggesting that the product ATLR•ΔELA may be a good indicator of climate cooling during glacial expansion phases. However, the role played by precipitation has not yet been determined, and this will be examined in future research.

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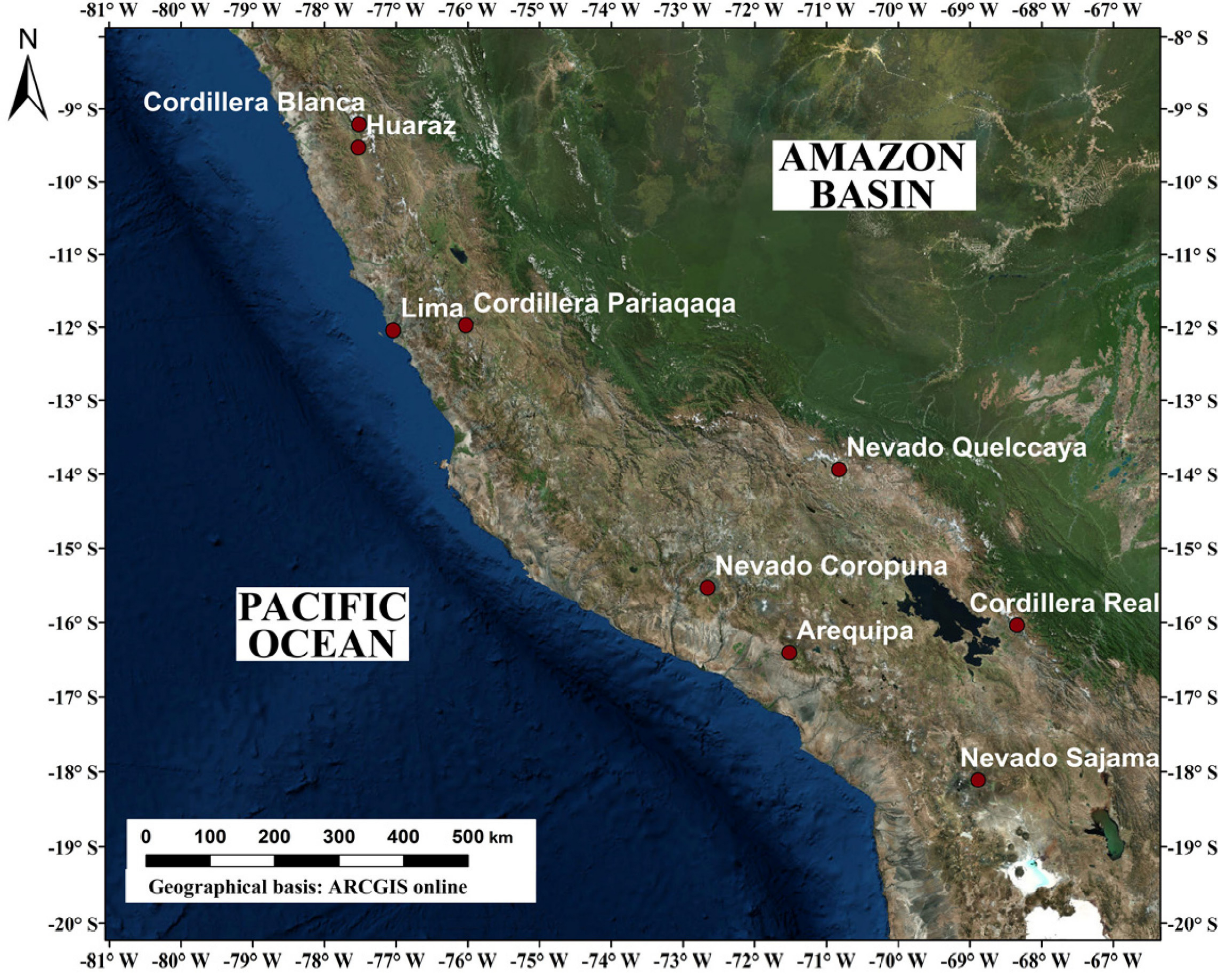


Figure 1: Location of study areas and paleoclimatic proxies

		NEVADO HUALCAN ¹		CORDILLERA PARIQAQA ²		NEVADO COROPUNA			
		9°S	12°S	12°S		NW ³	NE ⁴	SE ⁴	SW ⁵
Latitude		9°S	12°S	12°S					16°S
Air Temperature Lapse Rate (°C/km)		6.5	6.5						8.4
Year of the geographical basis (satellite images)									
PRESENT	ELA (m)	5124	5138	6034	5968	5862	5992		
	BR	1.0	1.0	3.0	1.0	1.0	2.0		
	σ	90	132	36	73	136	80		
LITTLE ICE AGE	ELA (m)	4994	4998	5936	5886	5776	5823		
	BR	1.0	3.0	3.0	1.0	1.0	1.0		
	σ	124	161	61	93	166	39		
	ΔELA (m)	130	140	98	82	86	169		
	ΔT(°C)	-0.85	-0.91	-0.82	-0.69	-0.72	-1.42		
Differences respect to ΔT series	ΔT=0.85°C (1880-2012)	0.01	0.06	0.03	0.16	0.13	0.57	0.05	
	ΔT=0.78°C (1850/1900-2003/2012)	0.06	0.13	0.04	0.09	0.06	0.64	0.12	

ELAs and paleoELAs: ¹Giráldez (2003); ²Quirós (2013); ³García (2013); ⁴Úbeda (2011); ⁵This work

Global warming trends: 1880-2012 y 1850/1900-2003/2012: IPCC (2013).

Figure 2: Summary table of results from ELAs and its comparison with instrumental data

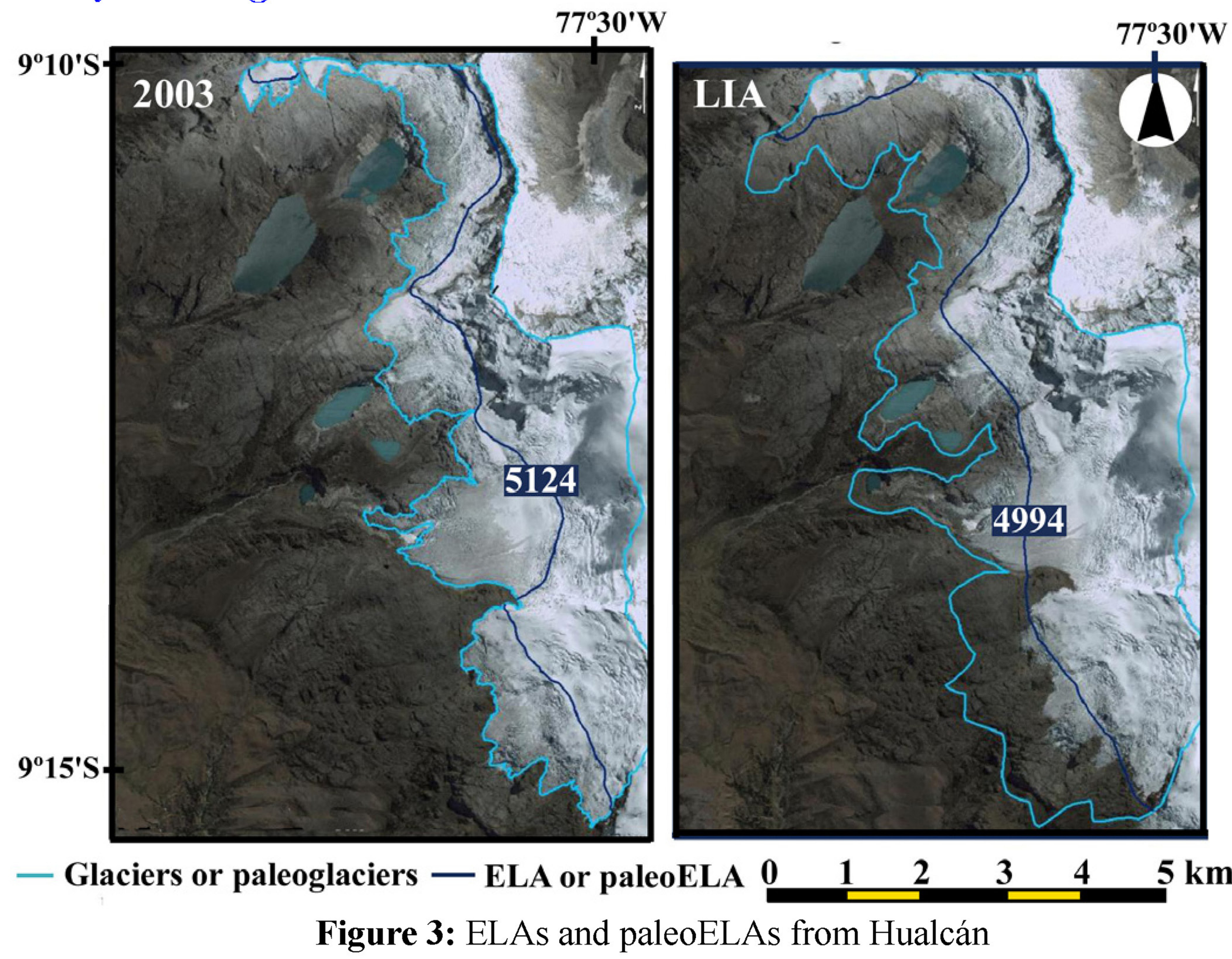


Figure 3: ELAs and paleoELAs from Hualcán

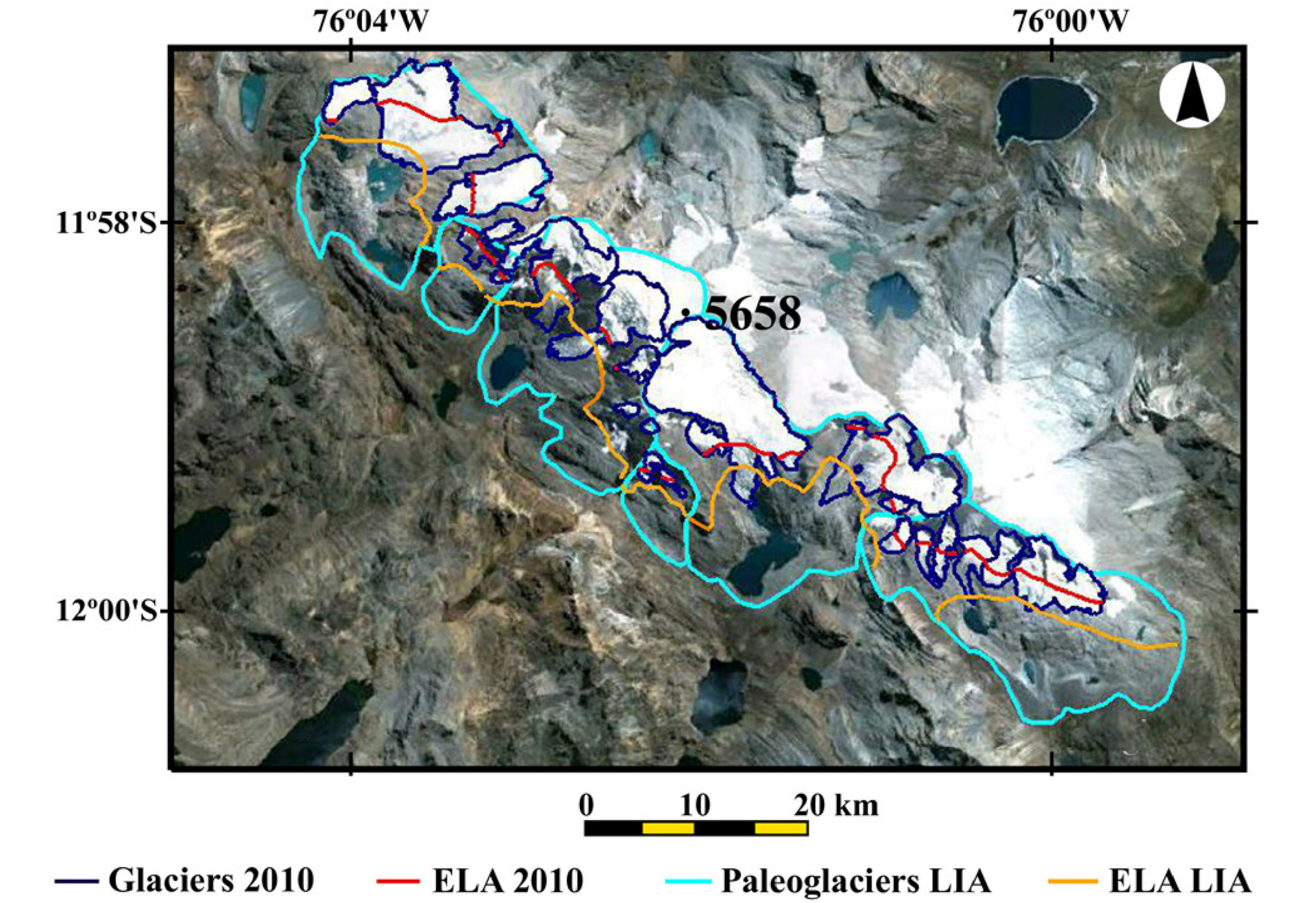


Figure 4: ELAs and paleoELAs from Pariaqaga

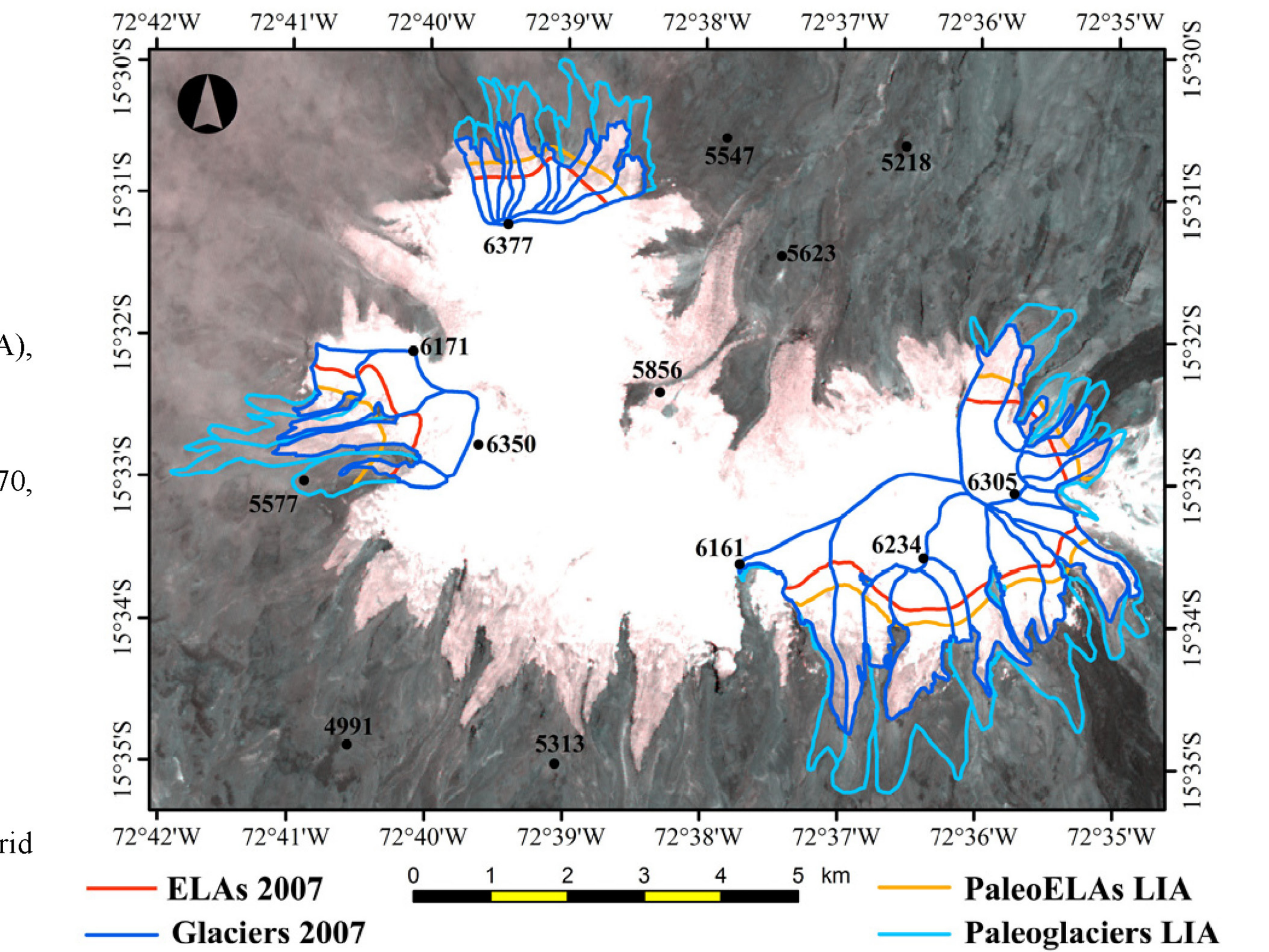


Figure 5: ELAs and paleoELAs from Coropuna

Paleoclimatic context for LIA on Central Andes

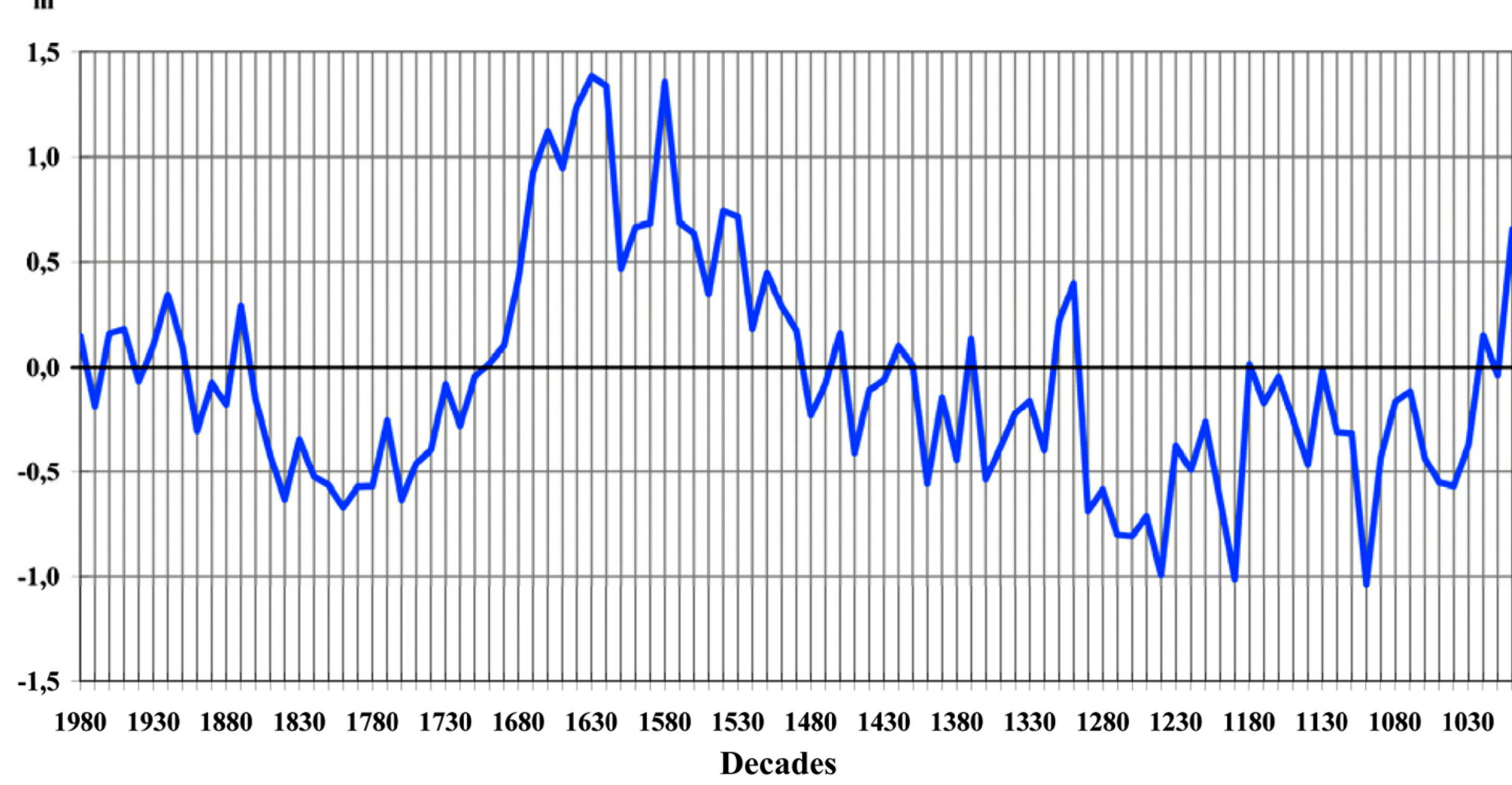


Figure 6: Cumulation in the Quelccaya ice cap (Thompson (1992)). Deviations of decadal means respect to the average 470-1980. The curve shows higher humidity (more positive deviations) in 1490-1700.

CLIMATE:		Cooling	Aridity	Humidity	MORAINES:		Maximum advances	Minor advances	
		ICE CORES			LICHENOMETRY OF MORAINES		POLLENS		
		Quelccaya Huascarán Thompson et al (2000) Rate δO ¹⁸	Quelccaya 13°56'S · 70°50'O Thompson et al (1986) Cumulation	Huascarán 9°06'S · 77°30'O Thompson et al (1995) Cumulation	C. Blanca (Perú) 9°28'-54'S-77°13'-28'O Solomina et al (2007) <i>Rhizocarpon</i> sp.	C. Real (Bolivia) 15°-16'S · 67°-68'O Rabatel et al (2008) <i>Rhizocarpon</i> sp.	N. Sajama (Bolivia) 18°06'S-68°58'O Liu et al (2005) <i>Asteraceae/Poaceae</i>		
Year									
1910	LITTLE ICE AGE (δO ¹⁸ very negative)		ARIDITY (lower cumulation)			ADVANCES			
1900									
1890									
1880			HUMIDITY (greater cumulation)						
1870									
1860							ADVANCES		
1850						ADVANCES			
1840									
1830									
1820									
1810					ARIDITY (lower cumulation)		ADVANCES	ARIDITY abundance of <i>Asteraceae</i>	
1800									
1790									
1780									
1770									
1760									
1750									
1740							MAXIMUM ADVANCES		
1730									
1720									
1710									
1700							MAXIMUM ADVANCES		
1690									
1680									
1670									
1660						MAXIMUM ADVANCES		HUMIDITY abundance of <i>Poaceae</i>	
1650									
1640									
1630									
1620				HUMIDITY (greater cumulation)					
1610									
1600									
1590									
1580									
1570									
1560									
1550									
1540									
1530									
1520									
1510									
1500									

Figure 7: Paleoclimatic proxies for cooling, aridity and humidity in andean altiplano