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Supplement of

Multi-century lake area changes in the Southern Altiplano: a tree-ring-based reconstruction

M. S. Morales et al.

Correspondence to: M. S. Morales (mmorales@mendoza-conicet.gob.ar)

Supplement

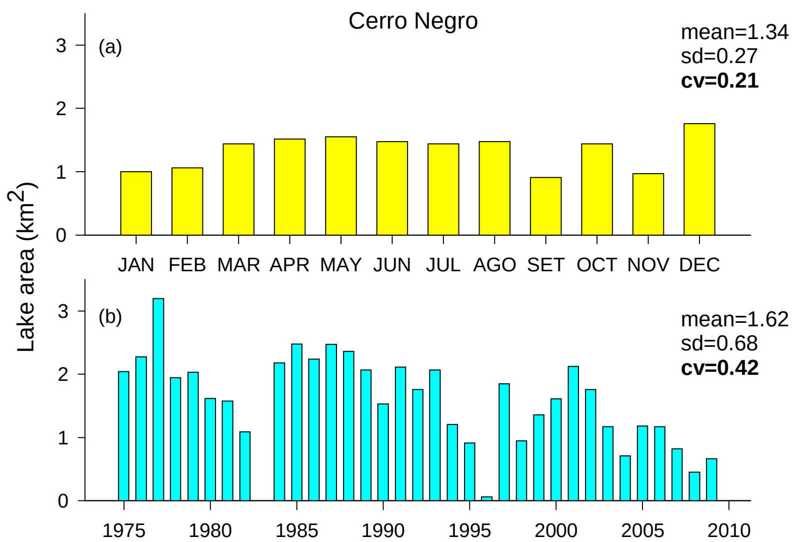
S1. Dates of LANDSAT Images used to calibrate the lake area reconstruction model. LANDSAT MSS 1975-1984, LANDSAT TM 1986-2009.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975												X
1976										X		X
1977				X				X				X
1978					X			X			X	
1979					X			X				X
1980								X				X
1981					X							X
1982	X											
1983												
1984										X		
1985					X			X				
1986			X		X			X		X		
1987												X
1988							X			X		
1989							X	X	X			
1990							X	X				
1991					X			X				
1992						X			X			
1993					X				X			
1994				X	X			X				
1995					X				X		X	
1996									X	X		
1997								X				
1998					X			X				
1999				X				X				
2000			X					X				
2001				X				X				
2002		X										
2003						X				X		
2004					X			X				
2005	X		X	X	X	X	X	X	X	X		
2006		X	X	X	X			X	X	X	X	X
2007	X	X	X	X	X	X**	X	X	X			
2008	X	X*	X	X				X	X		X	X
2009		X	X	X	X	X	X	X		X	X	X

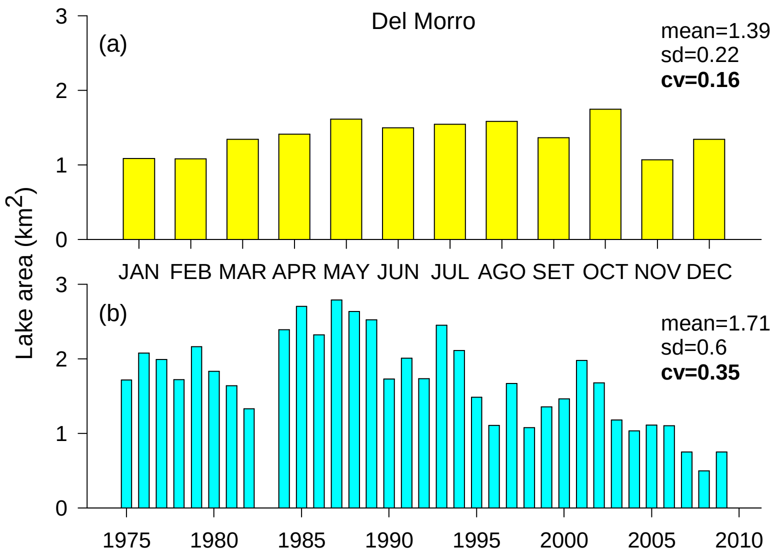
*data for Chojlla lake only, ** data for Coruto lake only

S2. Comparison between intra- and inter -annual variation in lake area records

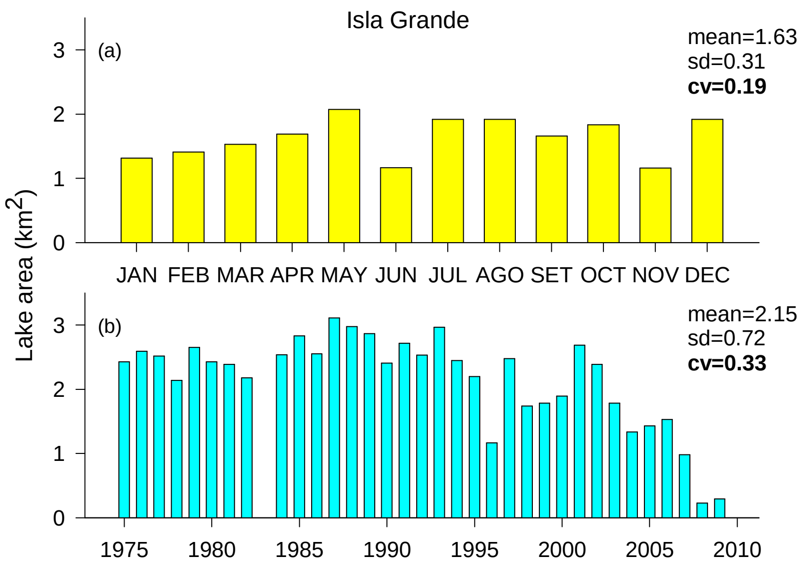
In order to validate the assumption that intra-annual variation was negligible, and justified the use of the averaged annual data for lake area, we compared for each one of the nine lakes the coefficient of variation at both, intra- and inter- annual time scale from 1975 to 2009 period. In all cases inter-annual variation was higher than intra-annual.



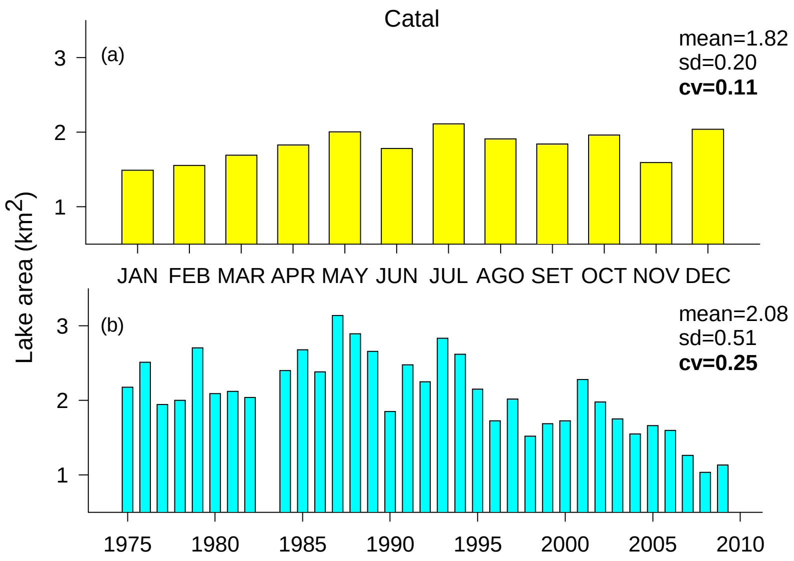
S2.1. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



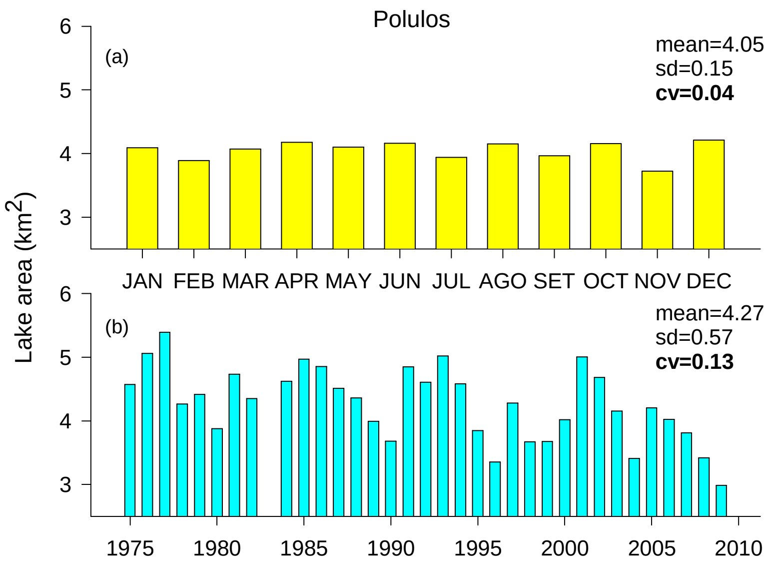
S2.2. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



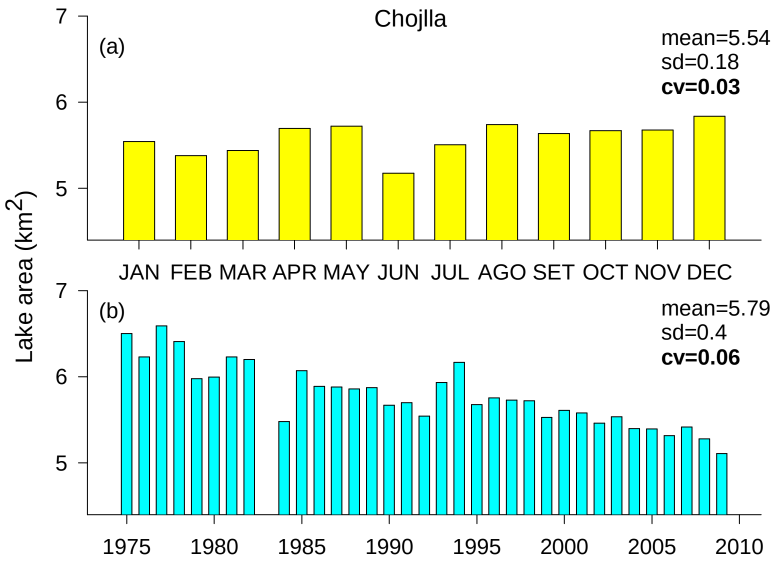
S2.3. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



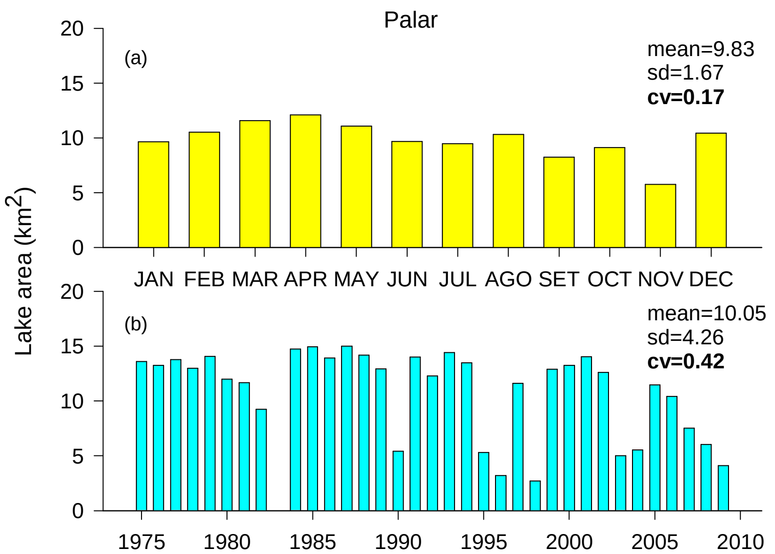
S2.4. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



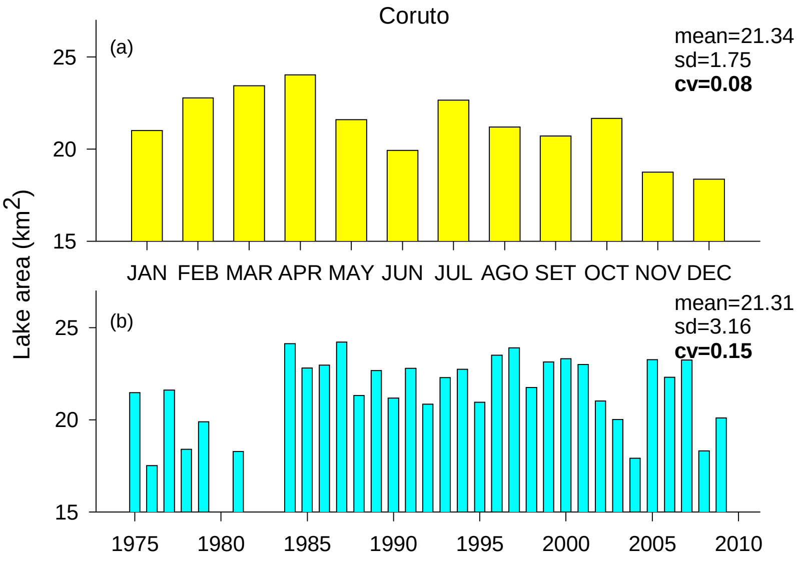
S2.5. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



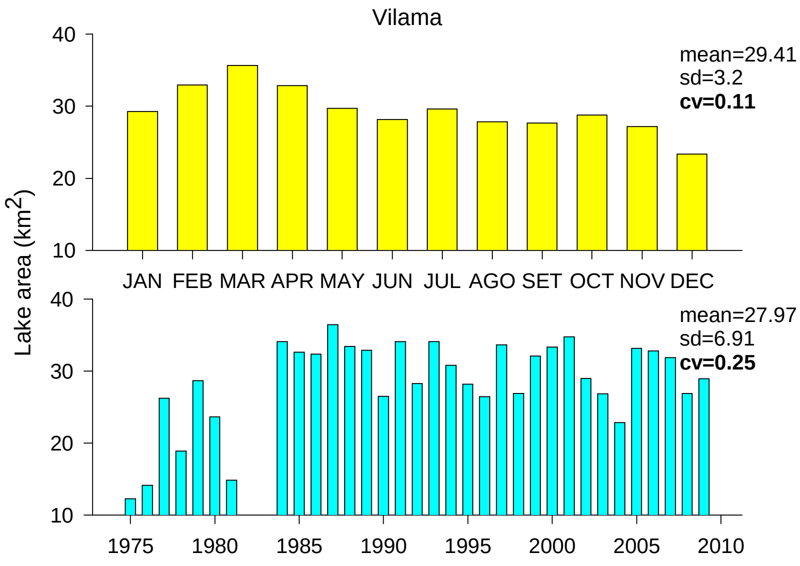
S2.6. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



S2.7. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



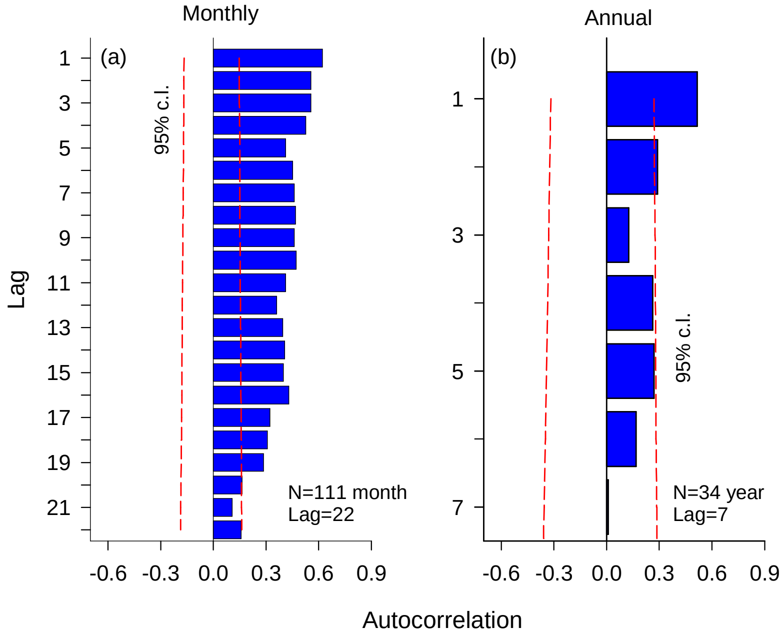
S2.8. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.



S2.9. (a) Monthly and (b) annual (Jan-Dec) mean lake area records from 1975 to 2009 period. Intra-annual and inter-annual mean, standard deviation (sd) and the coefficient of variation (cv) are indicated in both panels.

S3. Monthly and annual persistence

Autocorrelation analyses were applied to determine persistence in the monthly and annual time series averaged for the nine lakes from 1975 to 2009 period. This analysis show strong 19 months persistence in the monthly series, while two years persistence was found in the annual series. This analysis was performed using the AnClim program (Stepánek, 2008).



S3. Autocorrelation of the (a) standardized monthly and (b) mean annual (Jan-Dec) lake area record averaged for the nine lakes from 1975 to 2009. Red short dashed lines represent the 0.05 provability level. Number of lag was defined as 20% of the length of the series (20%N).

S4. Average of the inter-annual area fluctuation for the nine lakes for the 1975 to 2009 period. Minimum and maximum mean monthly (intra-annual range) and mean annual (inter-annual range) lake area records with respect to (wrt) 1975-2009 period. These values were obtained from the figures of intra-annual and inter-annual lake area variability in S2.

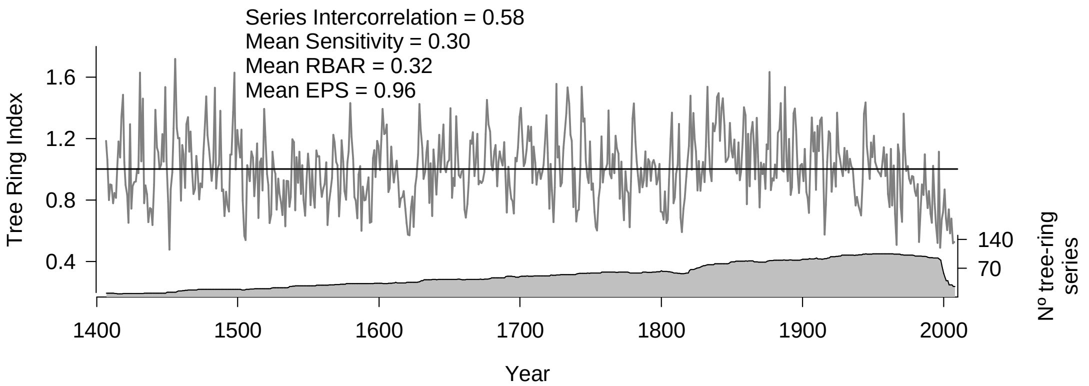
Lakes	Average area (km^2) wrt 1975-2009 period	Area range (km^2)	
		Intra-annual	Inter-annual
Cerro Negro	1.62	0.91 – 1.76	0.06 – 3.19
Del Morro	1.71	1.07 – 1.75	0.50 – 2.79
Isla Grande	2.15	1.16 – 2.07	0.23 – 3.11
Catal	2.08	1.49 – 2.11	1.03 – 3.14

Polulos	4.27	3.72 – 4.17	2.89 – 5.39
Chojlla	5.79	5.17 – 5.84	5.11 – 6.59
Palar	10.05	5.76 – 12.1	3.21 – 15.0
Coruto	21.31	21.00 – 24.02	13.30 – 24.22
Vilama	27.97	27.16 – 35.64	14.15 – 36.43

S5. List of precipitation stations used to estimate the 1983 mean annual lake area from the Vilama-Coruto region.

Station	Lat S / Long W	Elevation (m)	Period
Visviri	17º 37’ / 69º 28’	4080	1968-2007
Oruro	17º 57’ / 67º 08’	3706	1943-2009
Alcerreca	17º 59’ / 69º 41’	3900	1971-2008
Cota Kotani	18º 11’ / 69º 13’	4550	1963-2007
Putre	18º 11’ / 69º 33’	3545	1970-2007
Parinacota	18º 12’ / 69º 16’	4420	1933-2006

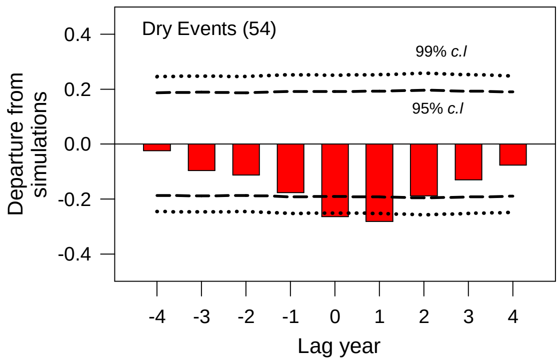
S6. Regional *Polylepis tarapacana* tree-ring chronology



S6. Regional signal free chronology of *Polylepis tarapacana* and number of tree ring series for the Northwest Argentina and Southwest Bolivia. The regional chronology covers the period AD 1407-2008 (N > 10 tree-ring series). Standard chronology statistics (series intercorrelation; mean sensitivity, mean RBar, mean EPS) are in the figure.

S7. Comparison between dry events from an historical precipitation reconstruction and the tree-ring lake area reconstruction.

Superposed epoch analysis (SEA), a nonparametric technique, was used to determine the relationships between the tree-ring lake area reconstruction and dry events from an historical document based reconstruction of precipitation from Potosí, Bolivia, over the period 1585-1807 (Gioda and Prieto, 1999). In this analysis, the lake area records were used as the background time series and the dates of dry years in the historical series as event years. For each event, a 9-year lake area window, consisting of the event year as the central value plus 4 years before and after the event, was selected. The 9-year lakes areas were averaged for each event to produce a mean lake area pattern related to historical dry event. The mean lake area pattern for the selected years was statistically evaluated for significance (95% confidence interval) by performing 1,000 Monte Carlo simulations (Mooney and Duval, 1993) from the lake area record.
This analysis showed significant below average lake area conditions during the dry event (year 0) and the following year (lag year 1). The annual dry events of the historical series and lake area reductions were consistently related on inter-annual variations during the common period.



S7. Superposed epoch analysis (SEA) comparing reconstructed lake area deviations during the dry events of the historical precipitation reconstruction from Potosí, Bolivia, from 1585 to1807 period (Gioda and Prieto, 1999). The X-axis represents a 9-year window, starting 4 years previous and ending 4 years after the dry event (year 0). The time interval used to run SEA analysis was 1585–1807. Short dashed and dotted lines represent 95% and 99% confidence interval.

S8. References

Gioda, A., Prieto, M. R.: Histoire des sécheresses andines: Potosi El Niño et le Petit Age Glaciaire, La Météorologie, 8, 33–42, 1999.

Mooney, C. Z., Duval, R. D.: Bootstrapping: a nonparametric approach to statistical inference, Sage University paper series on quantitative applications in the social sciences, Sage University, Newbury Park, 1993.