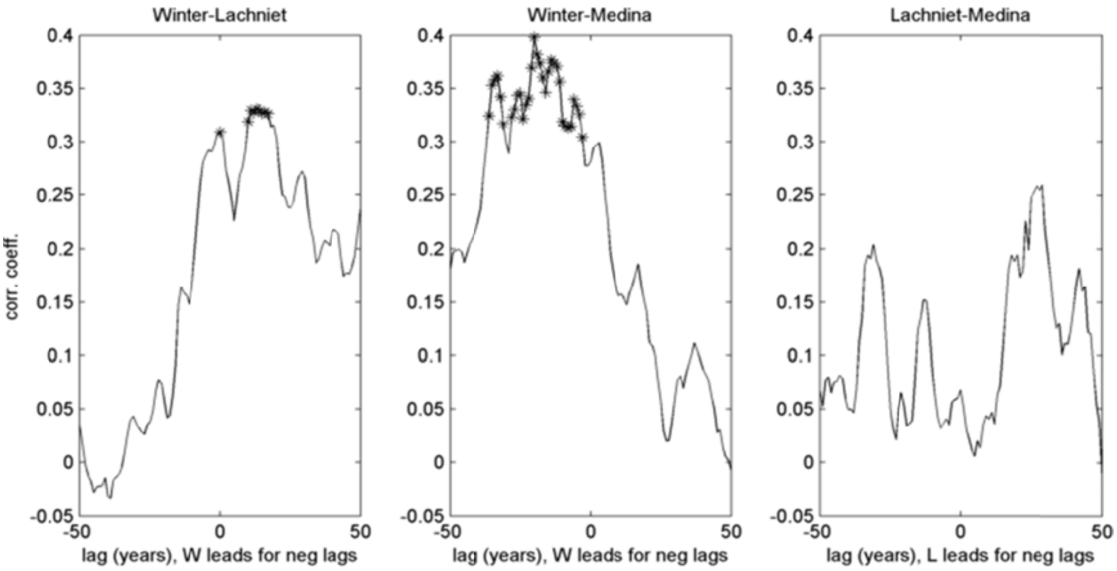
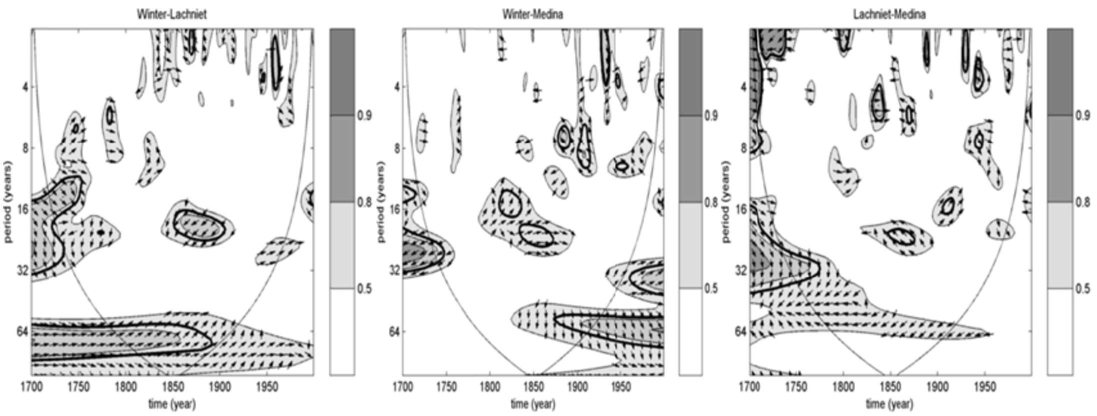
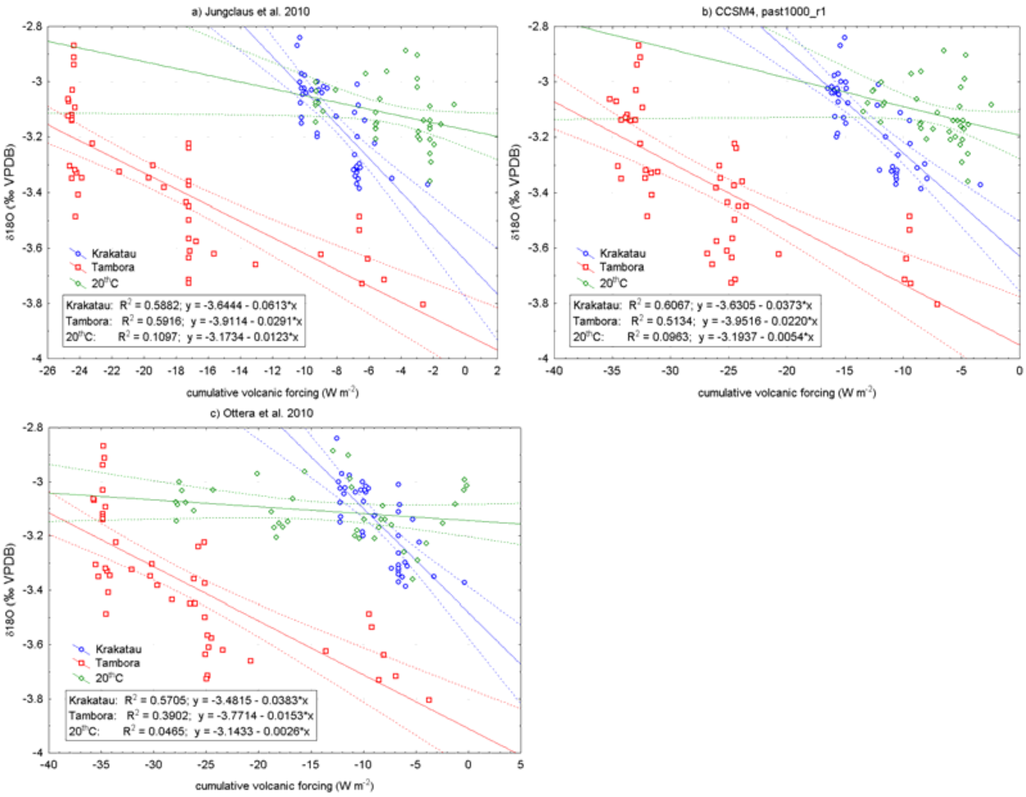


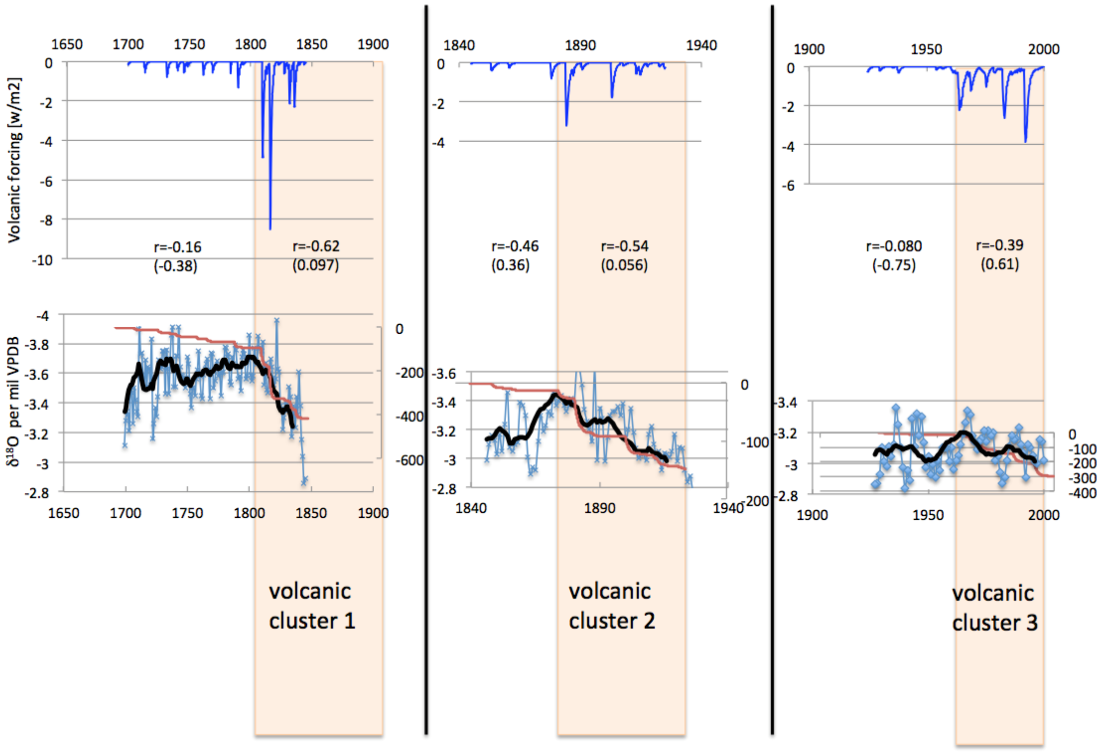
Supplementary Figure 1. Cross-correlations between different reconstructions of Mesoamerican precipitation. Reconstructions are those shown in Fig. 6. Correlations are calculated on annual-average time series obtained with spline interpolation of original data from June 1700 to June 1999. Asterisks mark correlations that are significant at 95% confidence accounting for autocorrelation in the data (using method by[1]). Cross-correlation profiles on annual data identify the following significant statistics (p-value in brackets): Winter-Lachniet: r=0.3310 (0.0370) when Winter lags Lachniet by 13 years; Winter-Medina: r=0.3980 (0.0082) when Winter leads Medina by 20 years.



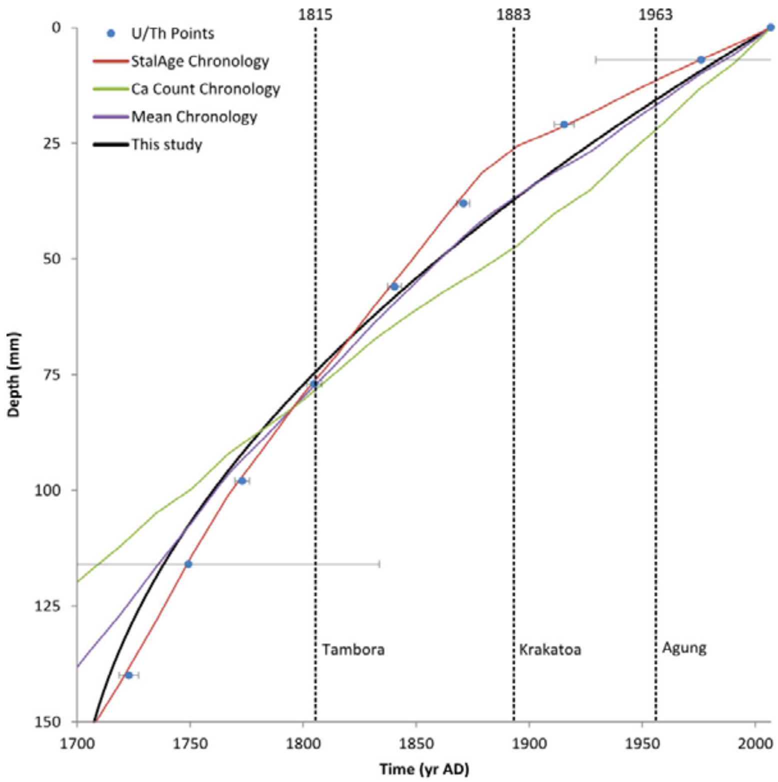
Supplementary Figure 2. Wavelet coherences between different reconstructions of Mesoamerican precipitation. Reconstructions are those shown in Fig. 6. Data as for cross-correlations in Supplementary Fig. 1. Interpretation and method as for Fig. 7.



Supplementary Figure 3. Scatterplots of cumulative volcanic forcing versus δ^{18}O data for three volcanic clusters. The different panels show three different estimates of volcanic forcing from **a**[2], **b**[3], and **c**[4] (the same used in Fig. 5, see methods). Reported are the linear regression lines with 95% confidence bands and the regression equations. The raw δ^{18}O time series has been homogenized to annual data by linearly interpolating the original data at June of each year. Considered periods for the three clusters are: Tambora: 1809-1857 (1809-1856 for panel **b**); Krakatau: 1883-1924 (1883-1923 for panel **c**); 20^{th} century: 1963-1999.



Supplementary Figure 4. δ^{18}O and cumulative volcanic forcing before and during volcanic clusters. Top panels: volcanic forcing[4] (dark blue); bottom panels: stable isotopes (blue) and 11-point running average (black) compared to cumulative volcanic forcing[4] (CVF, red). The numbers are the correlation coefficients r and associated p-values for statistical significance accounting for autocorrelation[1] between CVF and δ^{18}O data before and during each volcanic cluster (see Supplementary Note 1). Note all scales among clusters are the same except CVF, which has been adjusted to match the isotope running average.



Supplementary Figure 5. Different age models that apply to GU-Xi-1. Methods include StalAge, Ca count, the average between StalAge and the Ca count methods, and the method used in this study. See main text for details.

Supplementary Table 1. Description of the nine U/Th dates.

Sample ID	Weight g	Depth mm	^{238}U ppb		^{232}Th ppt		$[^{230}Th/^{232}Th]$ ppm[d]		$\delta^{234}U$ measured[a]		$[^{230}Th/^{238}U]$ activity[c]		Age uncorrected		Age corrected[c,e]		$\delta^{234}U_{initial}$ corrected		Years AD
GUA3	0.1054	7.0000	2407	± 7	105	± 6	173.4	± 241.0	481.6	± 3.6	0.00046	± 0.00063	33.7	± 46.8	32.8	± 46.8	481.7	± 3.6	1976.20
GUA13	0.0701	21.0000	3202	± 5	819	± 17	86.7	± 2.9	489.7	± 1.9	0.00134	± 0.00004	98.5	± 2.6	93.5	± 4.4	489.8	± 2.0	1915.54
GUA12	0.0787	38.0000	2998	± 4.3	225	± 5	414.9	± 11.7	492.8	± 1.8	0.00188	± 0.00004	137.8	± 2.6	138.0	± 2.8	493.0	± 1.8	1871.00
GUA11	0.0641	56.0000	3226	± 6	209	± 5	589.7	± 16.3	492.4	± 2.2	0.00232	± 0.00004	169.7	± 2.9	168.5	± 3.0	492.6	± 2.2	1840.54
GUA10	0.0670	77.0000	3341	± 5.1	216	± 5	711.4	± 19.0	499.5	± 1.8	0.00279	± 0.00004	203.1	± 3.2	204.0	± 3.3	499.8	± 1.8	1805.00
GUA9	0.0765	98.0000	2891	± 4	334	± 7	463.2	± 11.0	487.8	± 1.8	0.00325	± 0.00004	238.1	± 2.8	235.9	± 3.2	488.2	± 1.8	1773.14
GUA2	0.1083	116.0000	1290	± 3	11	± 6	6629.5	± 4185.3	491.5	± 3.6	0.00355	± 0.00115	259.9	± 84.5	259.7	± 84.5	491.9	± 3.6	1749.30
GUA8	0.0698	140.0000	2941	± 5.6	545	± 11	350.8	± 8.2	491.3	± 2.2	0.00394	± 0.00005	288.7	± 3.4	286.0	± 4.3	491.7	± 2.2	1723.00
GUA1	0.1199	174.0000	1140	± 2	28	± 6	3011.9	± 1012.9	490.6	± 2.4	0.00441	± 0.00118	323.2	± 86.9	322.7	± 86.9	491.1	± 2.4	1686.30

Results of ^{230}Th/U-dating on the GU-Xi-1 speleothem.

Supplementary Note 1.

Uncertainty from the volcanic forcing estimates.

Uncertainty from the volcanic forcing estimates is reflected in different regression estimates between cumulative volcanic forcing and $\delta^{18}O$ data (Supplementary Fig. 3). The 95% confidence limits for the regression slopes for the Tambora and Krakatau clusters are, respectively, [-0.0362, -0.0220] and [-0.0777, -0.0449] for the forcing by[2] (Supplementary Fig. 3a), [-0.0283, -0.0156] and [-0.0469, -0.0277] for the forcing by[3] (Supplementary Fig. 3b), and [-0.0209, -0.0097] and [-0.0490, -0.0275] for the forcing by[4] (Supplementary Fig. 3c). However, despite the discrepancies between forcing estimates, there is a robust difference also in the $\delta^{18}O$ response during the two clusters, with stronger response during the Krakatau cluster seen as steepest regression slopes, which we tentatively relate with the different background climate conditions.

For both clusters and different volcanic forcing estimates, the cumulative volcanic forcing explains about 40-60%, i.e., a dominant portion, of the total $\delta^{18}O$ variability. Other external forcing estimates explain less $\delta^{18}O$ variability. These include, for instance for the forcing estimate by[2], the annual volcanic forcing, which yields R^2 values of 0.215 and 0.019 for the Tambora and Krakatau clusters, respectively; the total solar irradiance (TSI, here it is the weakly-varying TSI estimate in[2]) yields R^2 values of 0.416 and 0.012 for the Tambora and Krakatau clusters, respectively; total (volcanic plus solar) yields R^2 values of 0.326 and 0.024 for the Tambora and Krakatau clusters, respectively. A cumulative forcing estimate based on a simple lag-1 autoregressive process of type $X(t)=0.95*X(t-1) + FTA(t)$, where the 0.95 coefficient corresponds to an e-folding time of about 21 years (1/e=0.3679) and FTA is the anomalous total forcing (volcanic plus solar), yields, again for the forcing estimate by[2], R^2 values of 0.2756 and 0.117 for the Tambora and Krakatau clusters, respectively. The linear trend component explains 70.3% and 54.2% of the total $\delta^{18}O$ variability for the Tambora and Krakatau clusters, respectively. However, the R^2 value for cumulative volcanic forcing, still from[2], and the Tambora cluster rises to 0.741 for an imposed 8-year lag in the $\delta^{18}O$ response, beating the trend component.

If the two 19th century clusters (Tambora and Krakatau, periods 1809-1857 and 1883-1924, respectively) are considered together, using for each cluster the $\delta^{18}O$ anomalies with respect to its first value in the cluster, correlations are consistently highly significant accounting for autocorrelation[1] across the different forcing estimates (p-values in parenthesis): r=-0.791 (0.0064) for[2], r=-0.624 (0.0401) for [3], and r=-0.7006 (0.0240) for [4].

The periods used for the correlation analysis in Supplementary Fig. 4 are defined as follow: Before and *after* cluster 1 (C1), cluster 2 (C2), and cluster 3 (C3) respectively: C1 (1760-1808) *(1809-1857)*; C2 (1841-1882) *(1883-1924)*; C3 (1926-1962) *(1963-1999)*. Using the same time periods but comparing instead to[2] gives these correlation statistics: C1 r=0.16087 (0.4634), *r=0.76918 (0.23082)*; C2 r=-0.46581 (0.35182), *r=-0.76695 (0.026371)*; C3 r=-0.036935 (0.89198), *r=-0.3312 (0.6688)*. Comparing to[3] before and *after* C1 r=-0.32142 (0.13478), *r=-0.44704 (0.26677)*; C2 r=-0.42296 (0.40339), *r=-0.56301 (0.045139)*; C3 r=-0.051885 (0.81863), *r=-0.31039 (0.61125)*.

Supplementary References

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