Supplementary Information

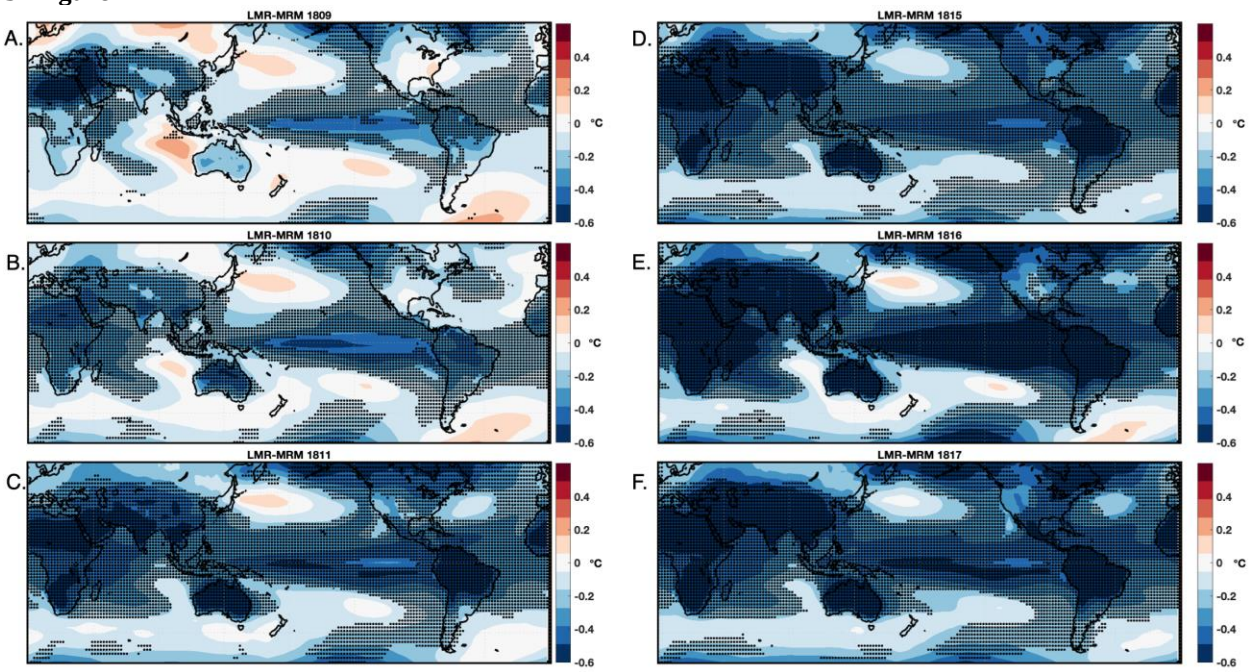
This file contains supplemental information for:

Climate model teleconnection patterns govern the Niño 3.4 response to early 19th century volcanism in coral-based data assimilation reconstructions

Sara C. Sanchez[1], Gregory J. Hakim[2], Casey P. Saenger[1]
1. Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
2. Department of Atmospheric Sciences, University of Washington

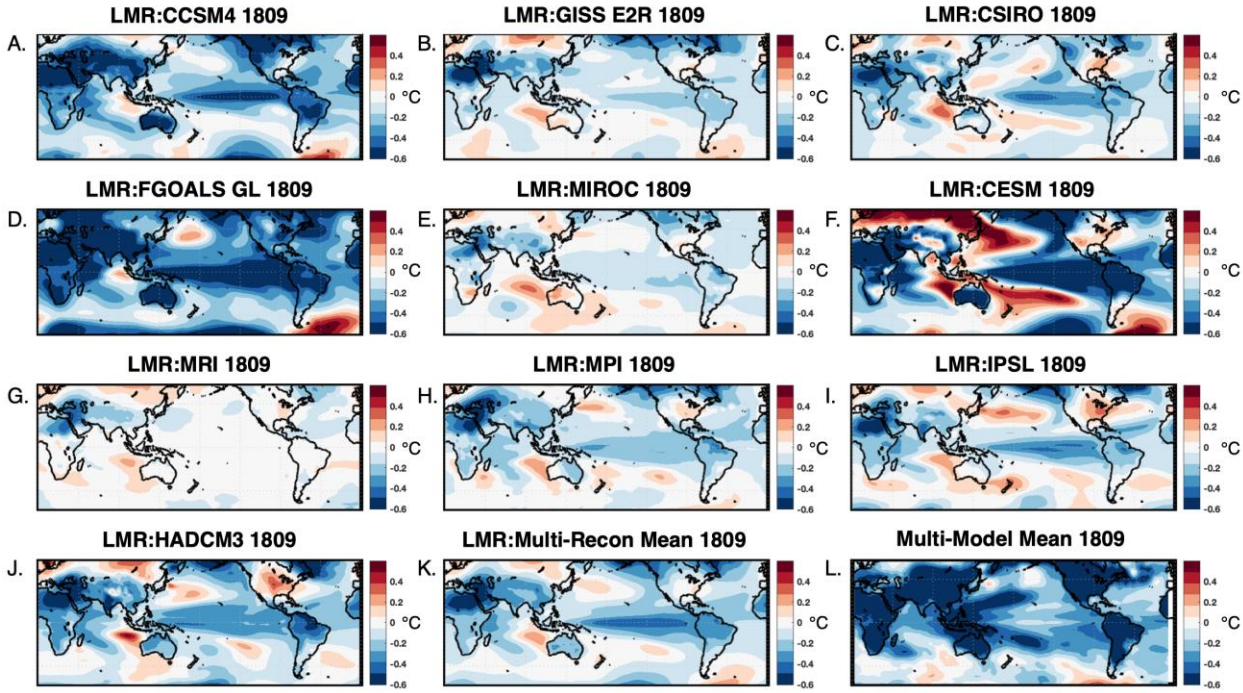
Figures 1-7 illustrate the coral-DA reconstructions of surface temperature response following the Mystery and Tambora eruptions.
Table 1/File 1 describes the coral archives used in this study.
Table 2-6 are the Niño 3.4 validation statistics with different reanalysis products.
Table 7 provides details of temperature reconstructions.

SI Figure 1



SI Figure 1
Multi-reconstruction mean of the Mystery eruption(left) and Tambora eruption (right), created by averaging the reconstructions formed by assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each the 10 individual Past1000 and Last Millennium priors. Stippling indicates all 10 coral-DA reconstructions agree on the sign of the anomaly. A. Year 1809, Mystery eruption +0, B. Year 1810, Mystery eruption +1, C. Year 1811, Mystery eruption +2, D. Year 1815, Tambora eruption +0, E. Year 1816, Tambora eruption +1, D. Year 1817, Tambora eruption +2.

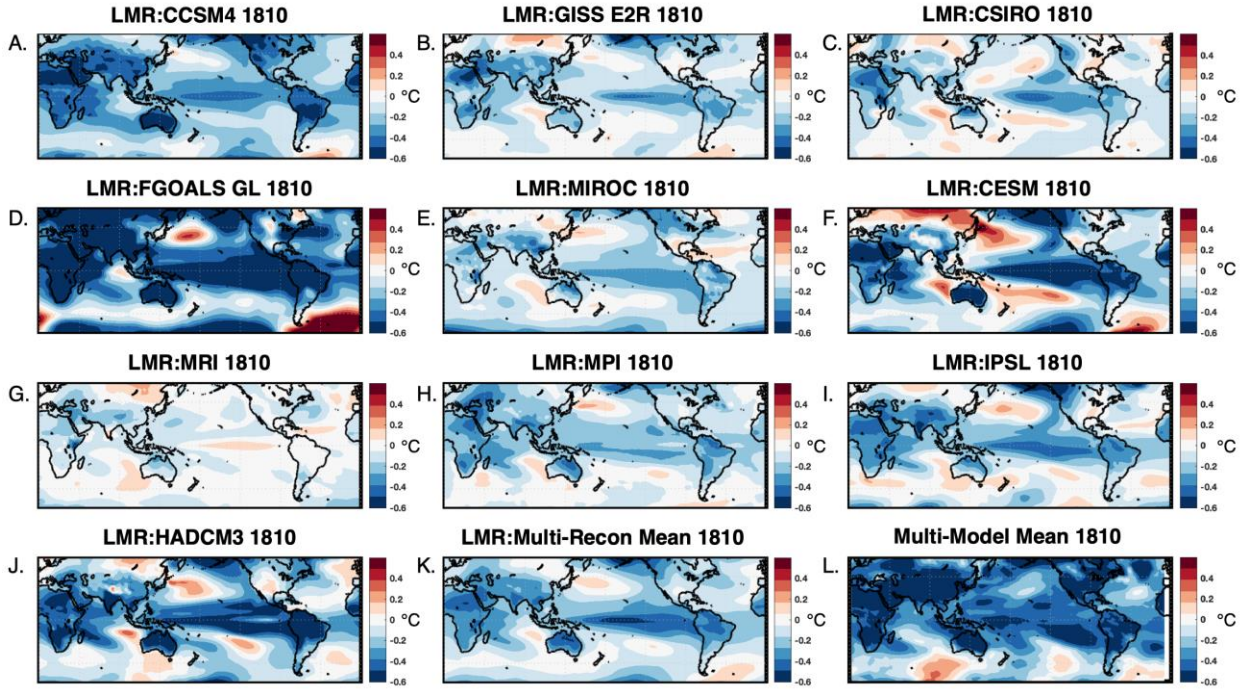
SI Figure 2



SI Figure 2

Individual reconstructions of the year 1809 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1809 shown in SI Figure 1A, L. Multi-model mean of year 1809 averaging the model output of each of the 10 priors used in the reconstructions.

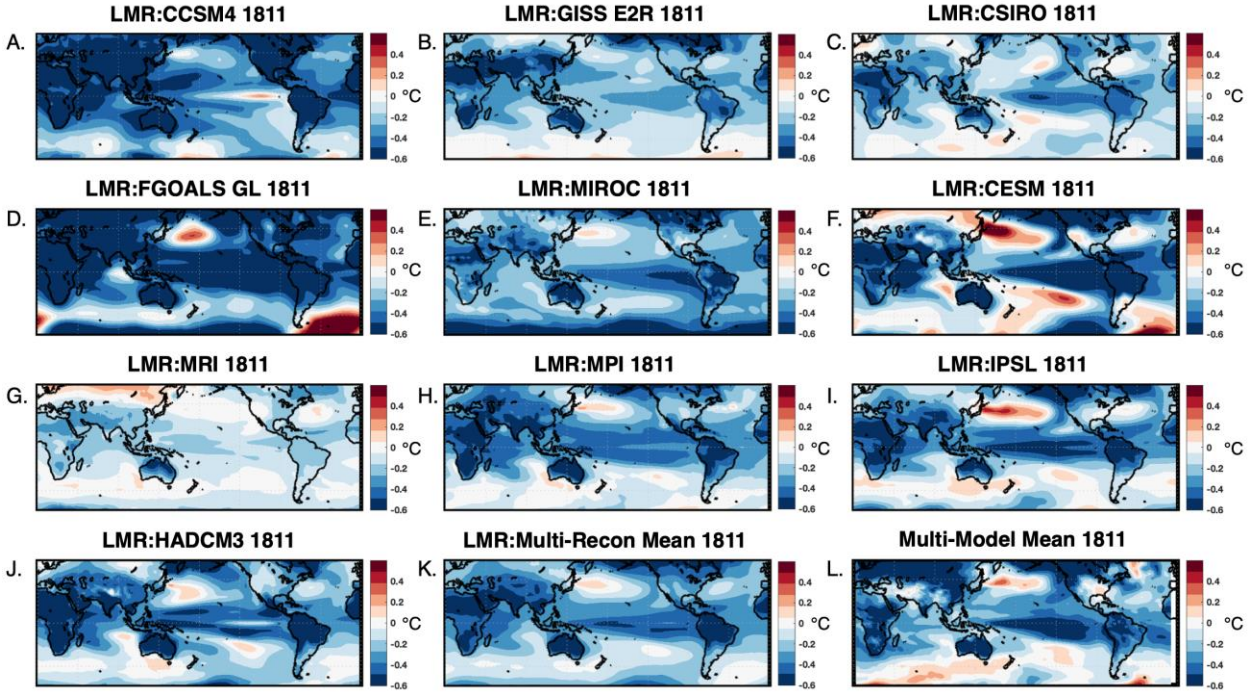
SI Figure 3



SI Figure 3

Individual reconstructions of the year 1810 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1810 shown in SI Figure 1B, L. Multi-model mean of year 1810 averaging the model output of each of the 10 priors used in the reconstructions.

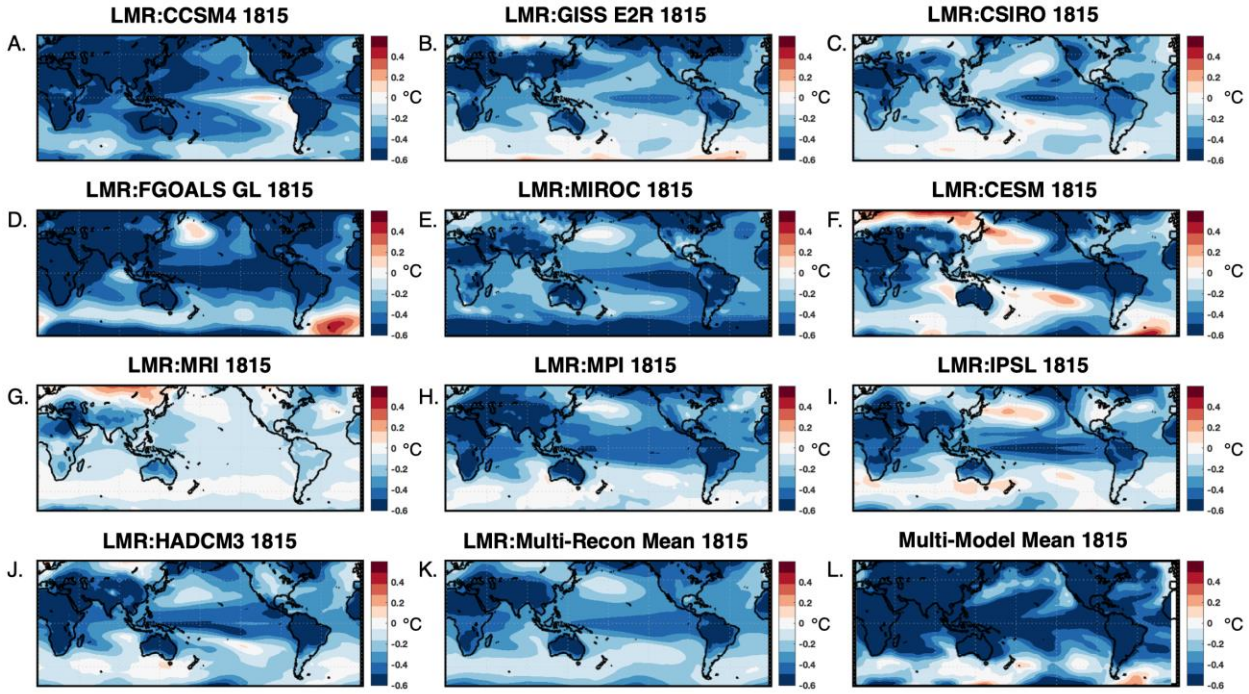
SI Figure 4



SI Figure 4

Individual reconstructions of the year 1811 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1811 shown in SI Figure 1C, L. Multi-model mean of year 1811 averaging the model output of each of the 10 priors used in the reconstructions.

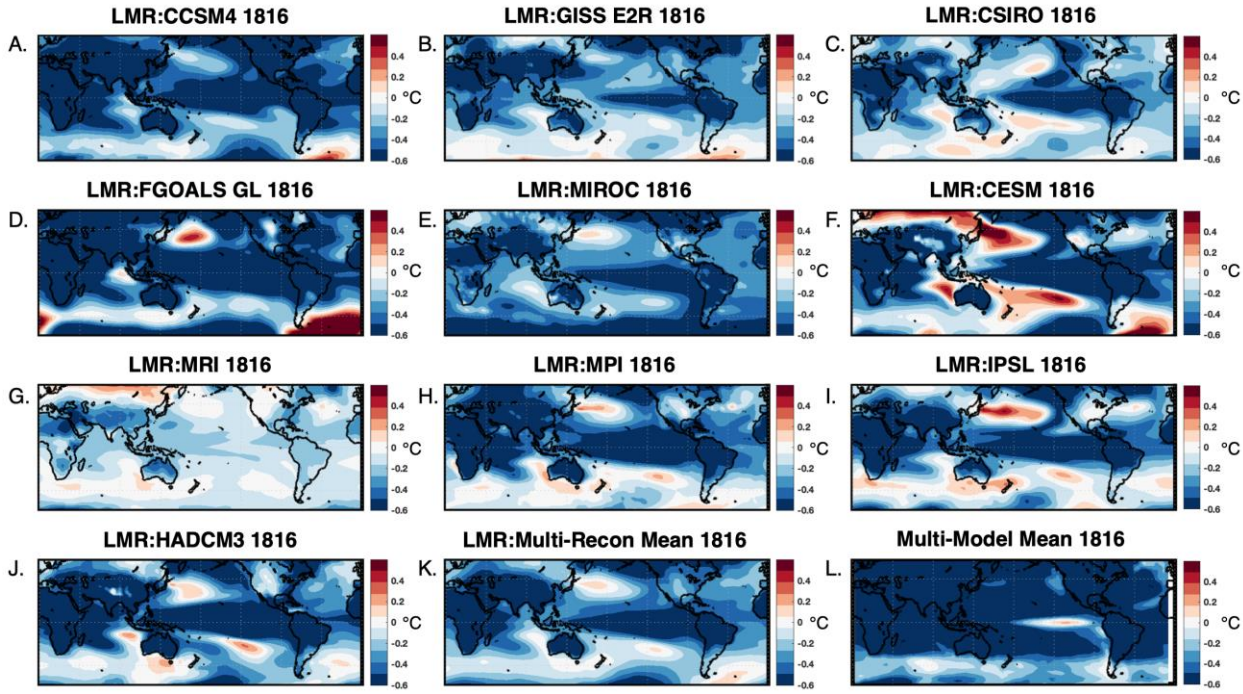
SI Figure 5



SI Figure 5

Individual reconstructions of the year 1815 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1815 shown in SI Figure 1D, L. Multi-model mean of year 1815 averaging the model output of each of the 10 priors used in the reconstructions.

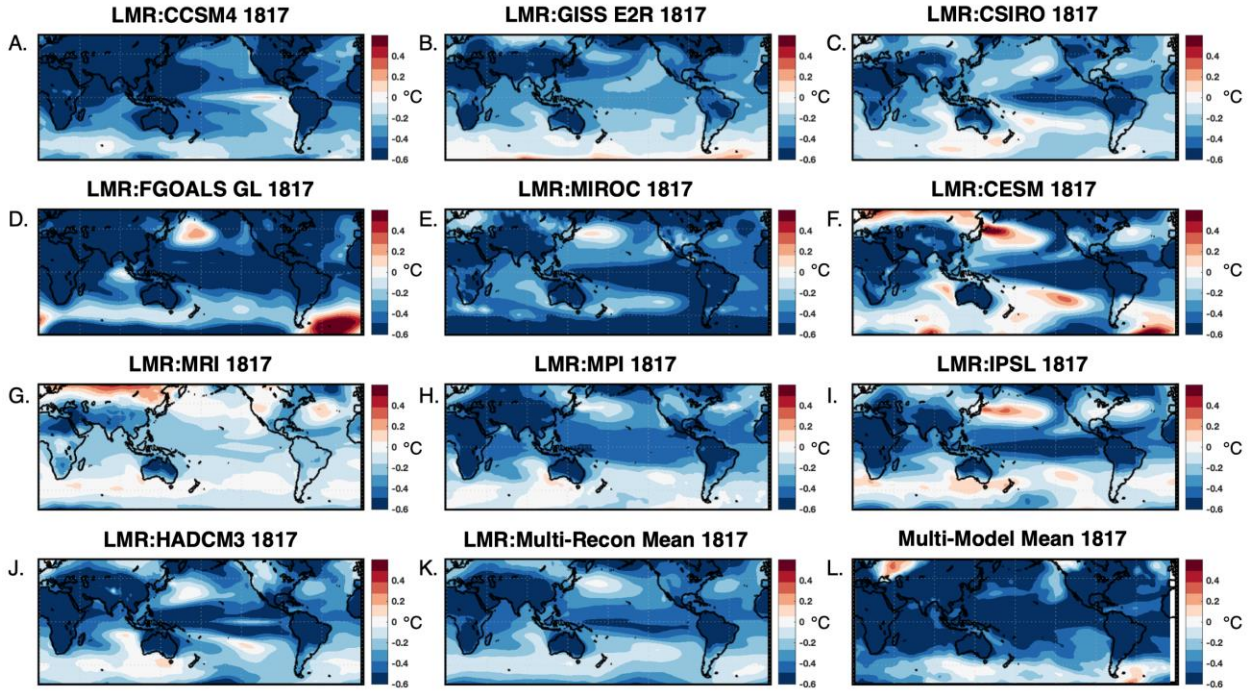
SI Figure 6



SI Figure 6

Individual reconstructions of the year 1816 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1816 shown in SI Figure 1E, L. Multi-model mean of year 1816 averaging the model output of each of the 10 priors used in the reconstructions.

SI Figure 7



SI Figure 7

Individual reconstructions of the year 1817 when assimilating all eastern Pacific, Atlantic, and Indian Ocean-based coral records (n=24) with each of the 10 individual Past1000 and Last Millennium priors. A. LMR coral-DA with NCAR-CCSM4 prior, B. LMR coral-DA with NASA GISS-E2R prior, C. LMR coral-DA with CSIRO prior, D. LMR coral-DA with FGOALS-GL prior, E. LMR coral-DA with MIROC prior, F. LMR coral-DA with NCAR-CESM prior, G. LMR coral-DA with MRI prior, H. LMR coral-DA with MPI prior, I. LMR coral-DA with IPSL prior, J. LMR coral-DA with HadCM3 prior, K. Multi-reconstruction mean of year 1817 shown in SI Figure 1F, L. Multi-model mean of year 1817 averaging the model output of each of the 10 priors used in the reconstructions.

SI Table 1/File 1

Attached, as Sanchezdb1_proxies.xlsx

SI Table 2.
Calibration statistics between the Niño 3.4 from LMR coral-only reconstructions and NOAA ERSST version 5 reanalysis (Huang et al. 2017).

ERSSTv5	r(1950-2000)	CE(1950-2000)	r(1900-2000)	CE(1900-2000)
Prior				
CCSM4	0.86	0.73	0.84	0.68
CSIRO	0.8	0.62	0.79	0.62
MPI	0.86	0.73	0.84	0.71
20CR	0.82	0.67	0.81	0.65
HADCM3	0.87	0.74	0.85	0.72
BCC	0.86	0.73	0.85	0.72
MRI	0.86	0.73	0.85	0.72
FGOALS	0.8	0.31	0.81	0.42
IPSL	0.86	0.72	0.84	0.7
MIROC	0.73	0.51	0.68	0.46
GISS	0.82	0.66	0.8	0.63
LME A1	0.89	0.71	0.85	0.64
LME A2	0.89	0.71	0.84	0.65
LME A3	0.89	0.71	0.85	0.65
LME A4	0.88	0.70	0.84	0.64
LME A5	0.89	0.71	0.84	0.64

SI Table 3.
Calibration statistics between the Niño 3.4 from LMR coral-only reconstructions and HadISST reanalysis (Rayner et al. 2003).

HADISST	r(1950-2000)	CE(1950-2000)	r(1900-2000)	CE(1900-2000)
Prior				
CCSM4	0.82	0.66	0.77	0.42
CSIRO	0.75	0.55	0.69	0.41
MPI	0.80	0.63	0.75	0.48
20CR	0.78	0.61	0.76	0.56
HADCM3	0.82	0.65	0.75	0.51
BCC	0.82	0.66	0.79	0.54
MRI	0.81	0.65	0.76	0.46
FGOALS	0.74	0.07	0.70	0.01
IPSL	0.80	0.63	0.73	0.47
MIROC	0.66	0.40	0.52	0.16
GISS	0.78	0.59	0.70	0.38
LME A1	0.87	0.69	0.84	0.47
LME A2	0.87	0.71	0.84	0.52
LME A3	0.87	0.70	0.84	0.50
LME A4	0.87	0.69	0.84	0.49
LME A5	0.87	0.71	0.84	0.51

SI Table 4.
Calibration statistics between the Niño 3.4 from LMR coral-only reconstructions and SODA version 2.2.4 reanalysis (Giese et al. 2011).

SODA 2.2.4	r(1950-2000)	CE(1950-2000)	r(1900-2000)	CE(1900-2000)
Prior				
CCSM4	0.85	0.72	0.76	0.47
CSIRO	0.78	0.58	0.69	0.40
MPI	0.82	0.67	0.74	0.49
20CR	0.81	0.63	0.74	0.52
HADCM3	0.85	0.69	0.75	0.51
BCC	0.86	0.73	0.80	0.58
MRI	0.84	0.70	0.77	0.51
FGOALS	0.77	0.30	0.70	0.25
IPSL	0.83	0.66	0.72	0.46
MIROC	0.69	0.44	0.50	0.16
GISS	0.80	0.62	0.69	0.38
LME A1	0.89	0.77	0.83	0.57
LME A2	0.89	0.78	0.83	0.59
LME A3	0.89	0.77	0.83	0.58
LME A4	0.89	0.77	0.83	0.57
LME A5	0.90	0.78	0.84	0.59

SI Table 5.
Calibration statistics between the Niño 3.4 from LMR coral-only reconstructions and COBE SST2 reanalysis (Hirahara et al. 2014).

COBE-SST2	r(1950-2000)	CE(1950-2000)	r(1900-2000)	CE(1900-2000)
Prior				
CCSM4	0.84	0.70	0.83	0.61
CSIRO	0.76	0.56	0.75	0.53
MPI	0.82	0.65	0.80	0.61
20CR	0.80	0.63	0.81	0.65
HADCM3	0.83	0.67	0.80	0.63
BCC	0.84	0.70	0.84	0.67
MRI	0.83	0.68	0.82	0.62
FGOALS	0.75	0.18	0.76	0.26
IPSL	0.82	0.65	0.78	0.59
MIROC	0.68	0.42	0.57	0.28
GISS	0.78	0.60	0.75	0.52
LME A1	0.89	0.76	0.87	0.64
LME A2	0.89	0.77	0.87	0.67
LME A3	0.89	0.76	0.87	0.66
LME A4	0.89	0.76	0.87	0.65
LME A5	0.89	0.77	0.88	0.67

SI Table 6.
Calibration statistics between the Niño 3.4 from LMR coral-only reconstructions and Kaplan reanalysis (Kaplan et al. 1997).

Kaplan	r(1950-2000)	CE(1950-2000)	r(1900-2000)	CE(1900-2000)
Prior				
CCSM4	0.85	0.66	0.82	0.42
CSIRO	0.78	0.61	0.74	0.47
MPI	0.83	0.66	0.80	0.52
20CR	0.82	0.67	0.81	0.63
HADCM3	0.84	0.69	0.80	0.56
BCC	0.85	0.64	0.84	0.56
MRI	0.84	0.67	0.81	0.50
FGOALS	0.77	-0.16	0.76	-0.10
IPSL	0.83	0.67	0.78	0.52
MIROC	0.70	0.45	0.57	0.18
GISS	0.81	0.64	0.75	0.42
LME A1	0.89	0.60	0.88	0.41
LME A2	0.89	0.62	0.88	0.46
LME A3	0.89	0.61	0.88	0.45
LME A4	0.89	0.61	0.88	0.43
LME A5	0.89	0.62	0.88	0.46

SI Table 7.
Table of key characteristics of the reconstructions arranged by the model prior. We consider the values of the mean Niño 3.4 and SPCZ regional surface temperature over the 1809-1830 period using three groups of proxy fractions: no coral, all coral, and western Pacific coral $\delta^{18}O$. We additionally include the number of incidences of pantropical cooling, or years in which both the Niño3.4 and SPCZ region simultaneously have a cold anomaly of 1 standard deviation (0.5 standard deviations).

	CSIRO	CCSM4	BCC	FGOALS	GISS	Hadcm3	IPSL	MIROC	MPI	MRI	20CR	LME-A1	LME-A2	LME-A3	LME-A4	LME-A5
1809-1830 mean Nino 3.4 TAS (no coral)	-0.37	-0.61	-0.22	-0.63	-0.08	-0.44	-0.24	-0.19	-0.24	-0.03	-0.13	-0.17	-0.22	-0.31	-0.21	-0.25
1809-1830 mean Nino 3.4 TAS (all coral)	-0.19	-0.09	0.07	-0.45	-0.41	-0.11	-0.55	-0.55	-0.42	0.05	0.01	0.31	0.37	0.33	0.36	0.36
1809-1830 mean Nino 3.4 TAS (W.Pacific $\delta^{18}O$)	0.29	0.44	0.24	-0.74	-0.12	-0.10	-0.44	-0.58	-0.11	0.17	0.27	1.79	1.75	1.70	1.75	1.72
1809-1830 mean SPCZ TAS (no coral)	-0.12	-0.07	-0.01	-0.30	-0.16	-0.12	-0.19	-0.10	-0.22	-0.11	-0.14	-0.12	-0.11	-0.06	-0.11	-0.12
1809-1830 mean SPCZ TAS (all coral)	-0.33	-0.45	-0.21	-0.49	-0.39	-0.42	-0.37	-0.49	-0.15	-0.29	-0.48	-0.37	-0.38	-0.36	-0.36	-0.38
1809-1830 mean SPCZ TAS (W.Pacific $\delta^{18}O$)	-0.46	-0.56	-0.22	-0.52	-0.43	-0.51	-0.40	-0.52	-0.47	-0.28	-0.71	-0.67	-0.67	-0.64	-0.63	-0.63
Pantropical cooling occurrences 1σ (0.5σ)	26 (60)	18 (35)	16 (66)	14 (89)	35 (89)	23 (60)	38 (103)	79 (187)	28 (64)	14 (62)	0 (5)	4 (21)	2 (13)	2 (18)	0 (20)	4 (18)

Supplementary Information References

Abram, Nerilie J., Michael K. Gagan, Julia E. Cole, Wahyoe S. Hantoro, and Manfred Mudelsee. "Recent intensification of tropical climate variability in the Indian Ocean." *Nature Geoscience* 1, no. 12 (2008): 849-853.

Alibert, Chantal, and Leslie Kinsley. "A 170-year Sr/Ca and Ba/Ca coral record from the western Pacific warm pool: 2. A window into variability of the New Ireland Coastal Undercurrent." *Journal of Geophysical Research: Oceans* 113, no. C6 (2008).

Asami, Ryuji, Tsutomu Yamada, Yasufumi Iryu, Terrence M. Quinn, Christopher P. Meyer, and Gustav Paulay. "Interannual and decadal variability of the western Pacific sea surface condition for the years 1787–2000: Reconstruction based on stable isotope record from a Guam coral." *Journal of Geophysical Research: Oceans* 110, no. C5 (2005).

Bagnato, Stefan, Braddock K. Linsley, Stephen S. Howe, Gerard M. Wellington, and Jim Salinger. "Coral oxygen isotope records of interdecadal climate variations in the South Pacific Convergence Zone region." *Geochemistry, Geophysics, Geosystems* 6, no. 6 (2005).

Bagnato, Stefan, Braddock K. Linsley, Stephen S. Howe, Gerard M. Wellington, and Jim Salinger. "Evaluating the use of the massive coral Diploastrea heliopora for paleoclimate reconstruction." *Paleoceanography* 19, no. 1 (2004).

Boiseau, Muriel, Michael Ghil, and Anne Juillet-Leclerc. "Climatic trends and interdecadal variability from south-central Pacific coral records." *Geophysical Research Letters* 26, no. 18 (1999): 2881-2884.

Carilli, Jessica E., Helen V. McGregor, Jessica J. Gaudry, Simon D. Donner, Michael K. Gagan, Samantha Stevenson, Henri Wong, and David Fink. "Equatorial Pacific coral geochemical records show recent weakening of the Walker Circulation." *Paleoceanography* 29, no. 11 (2014): 1031-1045.

Charles, Christopher D., Kim Cobb, Michael D. Moore, and Richard G. Fairbanks. "Monsoon–tropical ocean interaction in a network of coral records spanning the 20th century." *Marine Geology* 201, no. 1-3 (2003): 207-222.

Charles, C. D., D. E. Hunter, and Richard G. Fairbanks. "Interaction between the ENSO and the Asian monsoon in a coral record of tropical climate." *Science* 277, no. 5328 (1997): 925-928.

Charles, Christopher D., Kim Cobb, Michael D. Moore, and Richard G. Fairbanks. "Monsoon–tropical ocean interaction in a network of coral records spanning the 20th century." *Marine Geology* 201, no. 1-3 (2003): 207-222.

Cobb, Kim M., Niko Westphal, Hussein R. Sayani, Jordan T. Watson, Emanuele Di Lorenzo, Hai Cheng, R. L. Edwards, and Christopher D. Charles. "Highly variable El Niño–Southern Oscillation throughout the Holocene." *Science* 339, no. 6115 (2013): 67-70.

Cole, Julia E., Robert B. Dunbar, Timothy R. McClanahan, and Nyawira A. Muthiga. "Tropical Pacific forcing of decadal SST variability in the western Indian Ocean over the past two centuries." *Science* 287, no. 5453 (2000): 617-619.

Cole, Julia E., and Richard G. Fairbanks. "The Southern Oscillation recorded in the δ18O of corals from Tarawa Atoll." *Paleoceanography* 5, no. 5 (1990): 669-683.

Damassa, Thomas D., Julia E. Cole, Heidi R. Barnett, Toby R. Ault, and Timothy R. McClanahan. "Enhanced multidecadal climate variability in the seventeenth century from coral isotope records in the western Indian Ocean." *Paleoceanography* 21, no. 2 (2006).

DeLong, Kristine L., Terrence M. Quinn, Frederick W. Taylor, Ke Lin, and Chuan-Chou Shen. "Sea surface temperature variability in the southwest tropical Pacific since AD 1649." *Nature Climate Change* 2, no. 11 (2012): 799-804.

DeLong, Kristine L., Jennifer A. Flannery, Richard Z. Poore, Terrence M. Quinn, Christopher R. Maupin, Ke Lin, and Chuan-Chou Shen. "A reconstruction of sea surface temperature variability in the southeastern Gulf of Mexico from 1734 to 2008 CE using cross-dated Sr/Ca records from the coral Siderastrea siderea." *Paleoceanography* 29, no. 5 (2014): 403-422.

Druffel, Ellen RM, and Sheila Griffin. "Variability of surface ocean radiocarbon and stable isotopes in the southwestern Pacific." *Journal of Geophysical Research: Oceans* 104, no. C10 (1999): 23607-23613.

Dunbar, R. B., G. M. Wellington, M. W. Colgan, and P. W. Glynn. "Eastern Pacific climate variability since 1600 AD: stable isotopes in Galápagos corals." *Paleoceanography* 9 (1994): 291-315.
Linsley, Braddock K., Robert B. Dunbar, Gerard M. Wellington, and David A. Mucciarone. "A coral-based reconstruction of Intertropical Convergence Zone variability over Central America since 1707." *Journal of Geophysical Research: Oceans* 99, no. C5 (1994): 9977-9994.

Felis, Thomas, Jürgen Pätzold, Yossi Loya, Maoz Fine, Ahmed H. Nawar, and Gerold Wefer. "A coral oxygen isotope record from the northern Red Sea documenting NAO, ENSO, and North Pacific teleconnections on Middle East climate variability since the year 1750." *Paleoceanography* 15, no. 6 (2000): 679-694.

Felis, Thomas, Atsushi Suzuki, Henning Kuhnert, Mihai Dima, Gerrit Lohmann, and Hodaka Kawahata. "Subtropical coral reveals abrupt early-twentieth-century freshening in the western North Pacific Ocean." *Geology* 37, no. 6 (2009): 527-530.

Felis, Thomas, Atsushi Suzuki, Henning Kuhnert, Norel Rimbu, and Hodaka Kawahata. "Pacific Decadal Oscillation documented in a coral record of North Pacific winter temperature since 1873." *Geophysical Research Letters* 37, no. 14 (2010).

Giese, Benjamin S., and Sulagna Ray. "El Niño variability in simple ocean data assimilation (SODA), 1871–2008." *Journal of Geophysical Research: Oceans* 116, no. C2 (2011).

Goodkin, Nathalie F., Konrad A. Hughen, Scott C. Doney, and William B. Curry. "Increased multidecadal variability of the North Atlantic Oscillation since 1781." *Nature Geoscience* 1, no. 12 (2008): 844-848.

Gorman, Meaghan K., Terrence M. Quinn, Frederick W. Taylor, Judson W. Partin, Guy Cabioch, James A. Austin Jr, Bernard Pelletier, Valérie Ballu, Christophe Maes, and Steffen Saustrup. "A coral-based reconstruction of sea surface salinity at Sabine Bank, Vanuatu from 1842 to 2007 CE." *Paleoceanography* 27, no. 3 (2012).

Grove, C., Jens Zinke, F. Peeters, Wonsun Park, T. Scheufen, S. Kasper, B. Randriamanantsoa, Malcolm Mcculloch, and G. Brummer. "Madagascar corals reveal a multidecadal signature of rainfall and river runoff since 1708." *Climate of the Past* 9, no. 2 (2013): 641-656.

Guilderson, Thomas P., and Daniel P. Schrag. "Reliability of coral isotope records from the western Pacific warm pool: A comparison using age-optimized records." *Paleoceanography* 14, no. 4 (1999): 457-464.

Heiss, Georg A., Wolf-Christian Dullo, Michael M. Joachimski, John JG Reijmer, and Helmut Schuhmacher. "Increased seasonality in the Gulf of Aqaba, Red Sea, recorded in the oxygen isotope record of aPorites lutea coral." *Senckenbergiana maritima* 30, no. 1-2 (1999): 17-26.

Heiss, Georg A., Wolf-Christian Dullo, Michael M. Joachimski, John JG Reijmer, and Helmut Schuhmacher. "Increased seasonality in the Gulf of Aqaba, Red Sea, recorded in the oxygen isotope record of aPorites lutea coral." *Senckenbergiana maritima* 30, no. 1-2 (1999): 17-26.

Hennekam, Rick, Jens Zinke, Erik van Sebille, Malou ten Have, Geert-Jan A. Brummer, and Gert-Jan Reichart. "Cocos (Keeling) corals reveal 200 years of multidecadal modulation of southeast Indian Ocean hydrology by Indonesian throughflow." *Paleoceanography and Paleoclimatology* 33, no. 1 (2018): 48-60.

Hetzinger, Steffen, Miriam Pfeiffer, Wolf-Christian Dullo, Dieter Garbe-Schönberg, and Jochen Halfar. "Rapid 20th century warming in the Caribbean and impact of remote forcing on climate in the northern tropical Atlantic as recorded in a Guadeloupe coral." *Palaeogeography, Palaeoclimatology, Palaeoecology* 296, no. 1-2 (2010): 111-124.

Hetzinger, Steffen, Miriam Pfeiffer, Wolf-Christian Dullo, Noel Keenlyside, Mojib Latif, and Jens Zinke. "Caribbean coral tracks Atlantic Multidecadal Oscillation and past hurricane activity." *Geology* 36, no. 1 (2008): 11-14.

Hirahara, S., Ishii, M., and Y. Fukuda, 2014: Centennial-scale sea surface temperature analysis and its uncertainty. *J of Climate*, **27**, 57-75. http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-12-00837.1 .

Huang, Boyin, Peter W. Thorne, Viva F. Banzon, Tim Boyer, Gennady Chepurin, Jay H. Lawrimore, Matthew J. Menne, Thomas M. Smith, Russell S. Vose, and Huai-Min Zhang. "Extended reconstructed sea surface temperature, version 5 (ERSSTv5): upgrades, validations, and intercomparisons." *Journal of Climate* 30, no. 20 (2017): 8179-8205.

Jimenez, Gloria, Julia E. Cole, Diane M. Thompson, and Alexander W. Tudhope. "Northern Galápagos corals reveal twentieth century warming in the eastern tropical Pacific." *Geophysical Research Letters* 45, no. 4 (2018): 1981-1988.

Kaplan, A., Y. Kushnir, M. A. Cane, and M. B. Blumenthal, 1997: Reduced space optimal analysis for historical data sets: 136 years of Atlantic sea surface temperatures. *J. Geophys. Res.*, **102** (C13), 27 835–27 860.

Kilbourne, K. H., Terrence M. Quinn, R. Webb, T. Guilderson, J. Nyberg, and A. Winter. "Paleoclimate proxy perspective on Caribbean climate since the year 1751: Evidence of cooler temperatures and multidecadal variability." *Paleoceanography* 23, no. 3 (2008).

Kilbourne, K. H., T. M. Quinn, F. W. Taylor, and T. Delcroix. "Y. Gouriou Y, 2004: El Nino–Southern Oscillation-related salinity variations recorded in the skeletal geochemistry of a Porites coral from Espiritu Santo, Vanuatu." *Paleoceanography* 19.

Kuhnert, Henning, Traute Crüger, and Jürgen Pätzold. "NAO signature in a Bermuda coral Sr/Ca record." *Geochemistry, Geophysics, Geosystems* 6, no. 4 (2005).

Kuhnert, H., J. Pätzold, B. Hatcher, K-H. Wyrwoll, Anton Eisenhauer, L. B. Collins, Z. R. Zhu, and G. Wefer. "A 200-year coral stable oxygen isotope record from a high-latitude reef off Western Australia." *Coral Reefs* 18, no. 1 (1999): 1-12.

Kuhnert, H., J. Pätzold, K-H. Wyrwoll, and G. Wefer. "Monitoring climate variability over the past 116 years in coral oxygen isotopes from Ningaloo Reef, Western Australia." *International Journal of Earth Sciences* 88, no. 4 (2000): 725-732.

Linsley, Braddock K., Alexey Kaplan, Yves Gouriou, Jim Salinger, Peter B. Demenocal, Gerard M. Wellington, and Stephen S. Howe. "Tracking the extent of the South Pacific Convergence Zone since the early 1600s." *Geochemistry, Geophysics, Geosystems* 7, no. 5 (2006).

Linsley, B. K. "L. Ren, RB Dunbar, and SS Howe, 2000a: El Nino Southern Oscillation (ENSO) and decadal-scale climate variability at 108N in the eastern Pacific from 1893 to 1994: A coral-based reconstruction from Clipperton Atoll." *Paleoceanography* 15: 322-335.

McGregor, Helen V., and Michael K. Gagan. "Western Pacific coral δ18O records of anomalous Holocene variability in the El Niño–Southern Oscillation." *Geophysical Research Letters* 31, no. 11 (2004).

Moses, Christopher S., Peter K. Swart, and Richard E. Dodge. "Calibration of stable oxygen isotopes in Siderastrea radians (Cnidaria: Scleractinia): Implications for slow-growing corals." *Geochemistry, Geophysics, Geosystems* 7, no. 9 (2006).

Murty, Sujata Annavarapu, Nathalie Fairbank Goodkin, A. A. Wiguna, and Arnold L. Gordon. "Variability in Coral-Reconstructed Sea Surface Salinity Between the Northern and Southern Lombok Strait Linked to East Asian Winter Monsoon Mean State Reversals." *Paleoceanography and Paleoclimatology* 33, no. 10 (2018): 1116-1133.

Murty, Sujata Annavarapu, Nathalie F. Goodkin, H. Halide, D. Natawidjaja, B. Suwargadi, I. Suprihanto, D. Prayudi, Adam Douglas Switzer, and A. L. Gordon. "Climatic influences on southern Makassar Strait salinity over the past century." *Geophysical Research Letters* 44, no. 23 (2017): 11-967.

Nakamura, Nobuko, Hajime Kayanne, Hiroko Iijima, Timothy R. McClanahan, Swadhin K. Behera, and Toshio Yamagata. "Mode shift in the Indian Ocean climate under global warming stress." *Geophysical Research Letters* 36, no. 23 (2009).

Nurhati, Intan S., Kim M. Cobb, and Emanuele Di Lorenzo. "Decadal-scale SST and salinity variations in the central tropical Pacific: Signatures of natural and anthropogenic climate change." *Journal of Climate* 24, no. 13 (2011): 3294-3308.

Osborne, Michael C., Robert B. Dunbar, David A. Mucciarone, Ellen Druffel, and Joan-Albert Sanchez-Cabeza. "A 215-yr coral δ 18 O time series from Palau records dynamics of the West Pacific Warm Pool following the end of the Little Ice Age." *Coral Reefs* 33, no. 3 (2014): 719-731.

Pfeiffer, Miriam, Oliver Timm, Wolf-Christian Dullo, and Steffen Podlech. "Oceanic forcing of interannual and multidecadal climate variability in the southwestern Indian Ocean: Evidence from a 160 year coral isotopic record (La Réunion, 55 E, 21 S)." *Paleoceanography* 19, no. 4 (2004).

Quinn, Terrence M., Thomas J. Crowley, and Frederick W. Taylor. "New stable isotope results from a 173-year coral from Espiritu Santo, Vanuatu." *Geophysical Research Letters* 23, no. 23 (1996): 3413-3416.

Quinn, T. M., T. J. Crowley, F. W. Taylor, C. Henin, P. Joannot, and Y. Join. "A multicentury stable isotope record from a New Caledonia coral: Interannual and decadal SST variability in the southwest Pacific since 1657." *Paleoceanography* 13, no. 4 (1998): 412-426.

Quinn, Terrence M., Frederick W. Taylor, and Thomas J. Crowley. "Coral-based climate variability in the Western Pacific Warm Pool since 1867." *Journal of Geophysical Research: Oceans* 111, no. C11 (2006).

Rayner, N. A.; Parker, D. E.; Horton, E. B.; Folland, C. K.; Alexander, L. V.; Rowell, D. P.; Kent, E. C.; Kaplan, A. (2003) Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century J. Geophys. Res.Vol. 108, No. D14, 4407 10.1029/2002JD002670

Rosenheim, Brad E., Peter K. Swart, Simon R. Thorrold, Anton Eisenhauer, and Philippe Willenz. "Salinity change in the subtropical Atlantic: Secular increase and teleconnections to the North Atlantic Oscillation." *Geophysical Research Letters* 32, no. 2 (2005).

Saha, Narottam, Alberto Rodriguez-Ramirez, Ai Duc Nguyen, Tara R. Clark, Jian-xin Zhao, and Gregory E. Webb. "Seasonal to decadal scale influence of environmental drivers on Ba/Ca and Y/Ca in coral aragonite from the southern Great Barrier Reef." *Science of the Total Environment* 639 (2018): 1099-1109.

Sanchez, S. C., C. D. Charles, J. D. Carriquiry, and J. A. Villaescusa. "Two centuries of coherent decadal climate variability across the Pacific North American region." *Geophysical Research Letters* 43, no. 17 (2016): 9208-9216.

Sun, Yali, Min Sun, Gangjian Wei, Typhoon Lee, Baofu Nie, and Zhiwei Yu. "Strontium contents of a Porites coral from Xisha Island, South China Sea: A proxy for sea-surface temperature of the 20th century." *Paleoceanography* 19, no. 2 (2004).

Swart, Peter Koenraad, Genevieve Healy, Lisa Greer, Michael Lutz, Amel Saied, Daniel Anderegg, Richard E. Dodge, and David Rudnick. "The use of proxy chemical records in coral skeletons to ascertain past environmental conditions in Florida Bay." *Estuaries* 22, no. 2 (1999): 384-397.

Swart, Peter Koenraad, Richard E. Dodge, and Harold J. Hudson. "A 240-year stable oxygen and carbon isotopic record in a coral from South Florida: Implications for the prediction of precipitation in southern Florida." *Palaios* (1996): 362-375.

Swart, Peter K., Genevieve F. Healy, Richard E. Dodge, Philip Kramer, J. Harold Hudson, Robert B. Halley, and Michael B. Robblee. "The stable oxygen and carbon isotopic record from a coral growing in Florida Bay: a 160 year record of climatic and anthropogenic influence." *Palaeogeography, Palaeoclimatology, Palaeoecology* 123, no. 1-4 (1996): 219-237.

Swart, Peter K., Kathy S. White, David Enfield, Richard E. Dodge, and Peter Milne. "Stable oxygen isotopic composition of corals from the Gulf of Guinea as indicators of periods of extreme precipitation conditions in the sub-Sahara." *Journal of Geophysical Research: Oceans* 103, no. C12 (1998): 27885-27891.

Tangri, N., R. B. Dunbar, B. K. Linsley, and D. M. Mucciarone. "ENSO's Shrinking Twentieth-Century Footprint Revealed in a Half-Millennium Coral Core From the South Pacific Convergence Zone." *Paleoceanography and Paleoclimatology* 33, no. 11 (2018): 1136-1150.

Thompson, Diane M., Julia E. Cole, Glen T. Shen, Alexander W. Tudhope, and Gerald A. Meehl. "Early twentieth-century warming linked to tropical Pacific wind strength." *Nature Geoscience* 8, no. 2 (2015): 117-121.

Tudhope, Alexander W., Colin P. Chilcott, Malcolm T. McCulloch, Edward R. Cook, John Chappell, Robert M. Ellam, David W. Lea, Janice M. Lough, and Graham B. Shimmield. "Variability in the El Niño-Southern Oscillation through a glacial-interglacial cycle." *Science* 291, no. 5508 (2001): 1511-1517.

Tudhope, A. W., G. B. Shimmield, C. P. Chilcott, M. Jebb, A. E. Fallick, and A. N. Dalgleish. "Recent changes in climate in the far western equatorial Pacific and their relationship to the Southern Oscillation; oxygen isotope records from massive corals, Papua New Guinea." *Earth and Planetary Science Letters* 136, no. 3-4 (1995): 575-590.

Urban, F. E., J. E. Cole, and J. T. Overpeck. "Modification of tropical Pacific variability by its mean state inferred from a 155-year coral record." *Nature* 407 (2000): 989-993.

Wu, Henry C., Braddock K. Linsley, Emilie P. Dassié, Benedetto Schiraldi, and Peter B. deMenocal. "Oceanographic variability in the South Pacific Convergence Zone region over the last 210 years from multi-site coral Sr/Ca records." *Geochemistry, Geophysics, Geosystems* 14, no. 5 (2013): 1435-1453.

Wu, Henry C., Mélanie Moreau, Braddock K. Linsley, Daniel P. Schrag, and Thierry Corrège. "Investigation of sea surface temperature changes from replicated coral Sr/Ca variations in the eastern equatorial Pacific (Clipperton Atoll) since 1874." *Palaeogeography, Palaeoclimatology, Palaeoecology* 412 (2014): 208-222.

Xu, Yuan-Yuan, Sean Pearson, and K. Halimeda Kilbourne. "Assessing coral Sr/Ca–SST calibration techniques using the species Diploria strigosa." *Palaeogeography, palaeoclimatology, palaeoecology* 440 (2015): 353-362.

Zinke, Jens, W-Chr Dullo, G. A. Heiss, and Anton Eisenhauer. "ENSO and Indian Ocean subtropical dipole variability is recorded in a coral record off southwest Madagascar for the period 1659 to 1995." *Earth and Planetary Science Letters* 228, no. 1-2 (2004): 177-194.

Zinke, Jens, A. Hoell, J. M. Lough, M. Feng, A. J. Kuret, Heather Clarke, Vincenzo Ricca, Kai Rankenburg, and M. T. McCulloch. "Coral record of southeast Indian Ocean marine heatwaves with intensified Western Pacific temperature gradient." *Nature Communications* 6, no. 1 (2015): 1-9.

Zinke, Jens, Adam Rountrey, M. Feng, S-P. Xie, Delphine Dissard, Kai Rankenburg, J. M. Lough, and M. T. McCulloch. "Corals record long-term Leeuwin current variability including Ningaloo Niño/Niña since 1795." *Nature Communications* 5, no. 1 (2014): 1-9.

Zinke, Jens, Miriam Pfeiffer, O. Timm, W-C. Dullo, D. Kroon, and B. A. Thomassin. "Mayotte coral reveals hydrological changes in the western Indian Ocean between 1881 and 1994." *Geophysical Research Letters* 35, no. 23 (2008).

Zinke, Jens, Benjamin R. Loveday, C. J. C. Reason, W-C. Dullo, and D. Kroon. "Madagascar corals track sea surface temperature variability in the Agulhas Current core region over the past 334 years." *Scientific reports* 4 (2014): 4393.

Zinke, Jens, A. Hoell, J. M. Lough, M. Feng, A. J. Kuret, Heather Clarke, Vincenzo Ricca, Kai Rankenburg, and M. T. McCulloch. "Coral record of southeast Indian Ocean marine heatwaves with intensified Western Pacific temperature gradient." *Nature Communications* 6, no. 1 (2015): 1-9.