

## **Ocean-atmosphere trajectories of extended drought in Southwestern North America**

**Luke A Parsons<sup>1</sup>, Sloan Coats<sup>2</sup>,**

<sup>1</sup>Department of Atmospheric Sciences, University of Washington, Seattle, WA.

<sup>2</sup>Woods Hole Oceanographic Institution, Woods Hole, MA

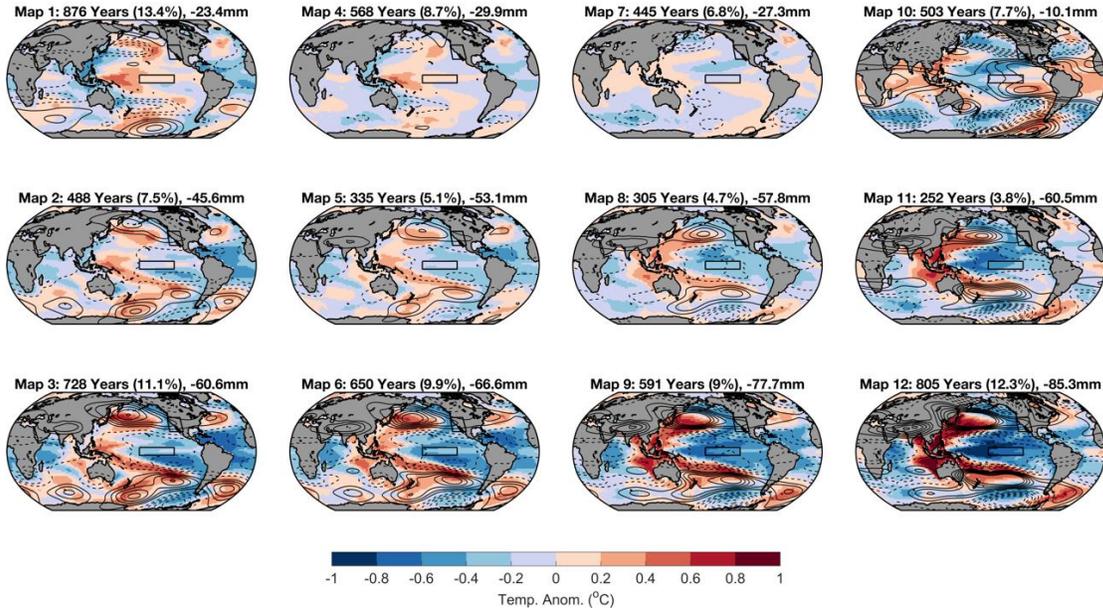
### **Contents of this file**

Figures S1 to S6

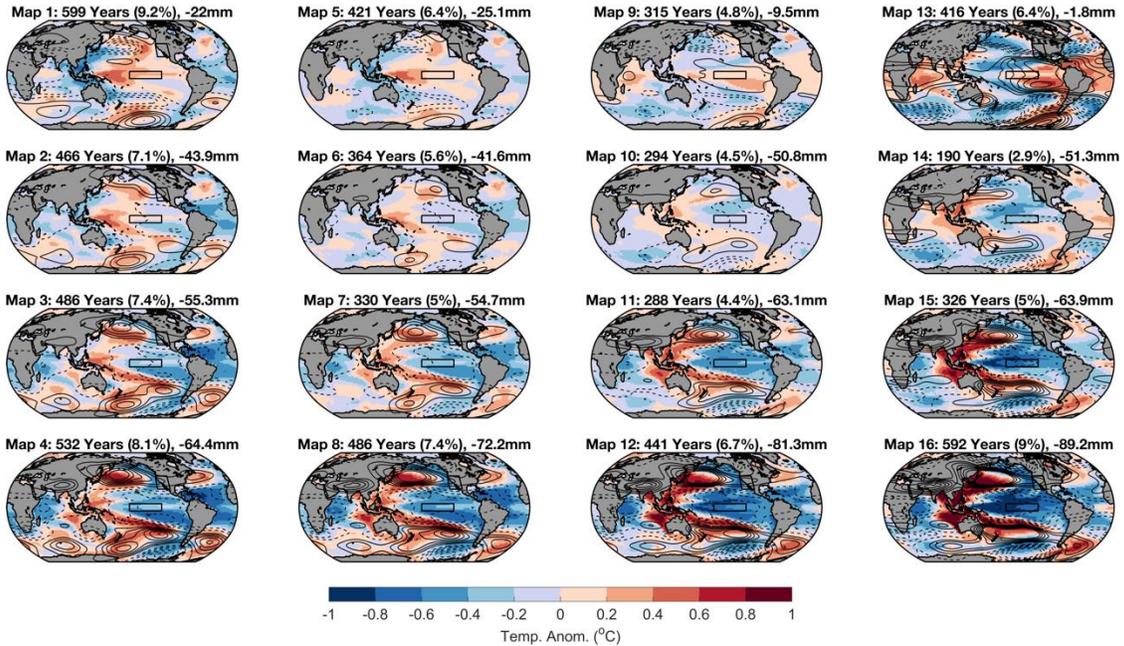
### **Introduction**

Supplementary figures showing various orientations of self-organizing maps output conducted on annual mean surface temperature anomaly patterns during SWNA droughts in the NCAR CESM Last Millennium Ensemble (Figure S1); the relationship between the tropical Pacific and precipitation in Southwestern North America in the CESM LME as well as the instrumental record (Figure S2); time series of SWNA precipitation and tropical Pacific surface temperature indices and maps showing surface temperature and geopotential height anomalies associated with the lifecycle of one example drought in the CESM LME that contains an El Niño event mid-drought (Figure S3); time series of SWNA precipitation and various tropical Pacific surface temperature indices (Figure S4); field correlations showing the relationships between various tropical Pacific surface temperature indices and 250mb geopotential height and surface temperature (Figure S5); and maps showing mean sea-surface temperature and 250mb geopotential height anomalies and histograms showing Niño3.4 index distributions during the lifecycle of drought in 42 historical runs and the 1800-year pre-industrial Control run of the CESM1 Large Ensemble.

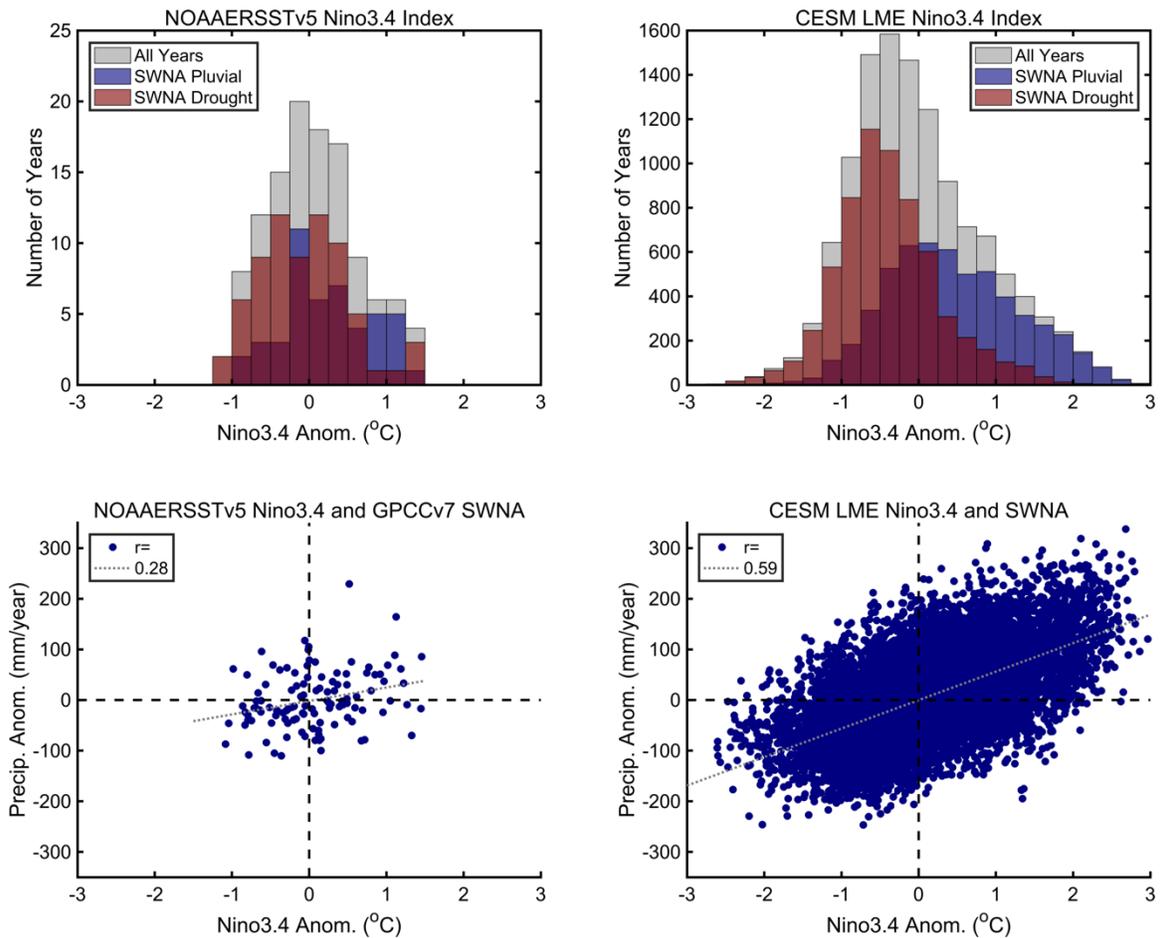
CESM LME SOM: All 6,546 Years During SWNA Drought



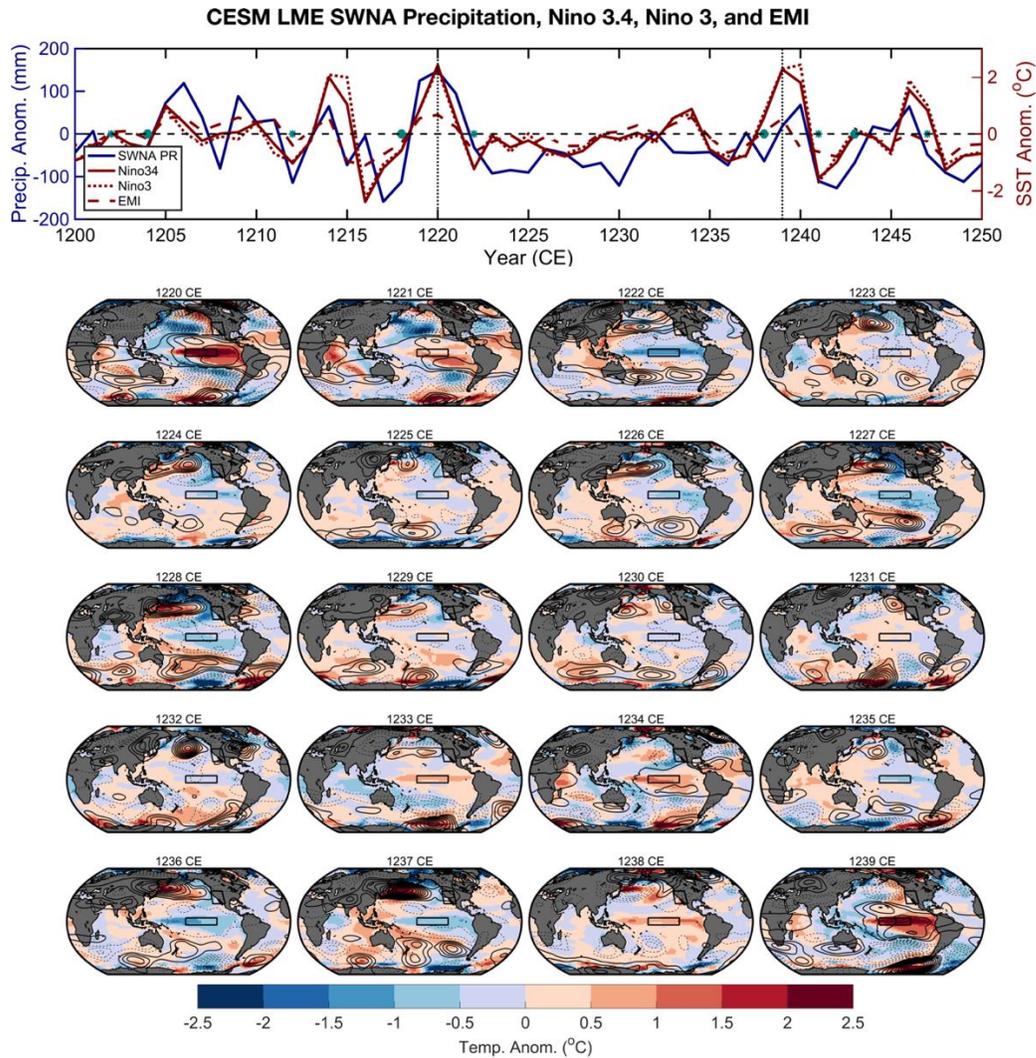
CESM LME SOM: All 6,546 Years During SWNA Drought



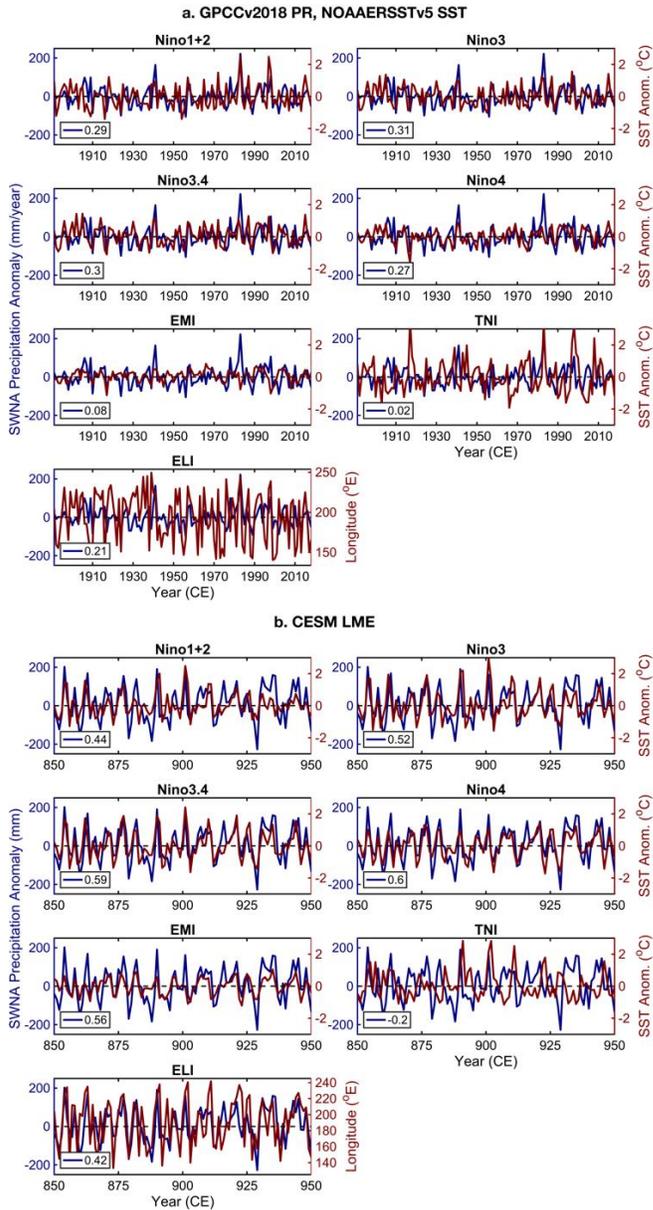
**Figure S1.** Self-organizing maps (SOM) output conducted on annual mean surface temperature anomaly patterns during the 6,546 years coinciding with SWNA droughts in the CESM LME using various user-selected SOM grid structures. Percent of drought years is show in parentheses, and mean annual precipitation anomaly for these years is shown above each map. Positive (negative) 250mb geopotential height anomalies associated with each SOM map shown in solid (dashed) contour lines. Geopotential height contour interval is 4mb.



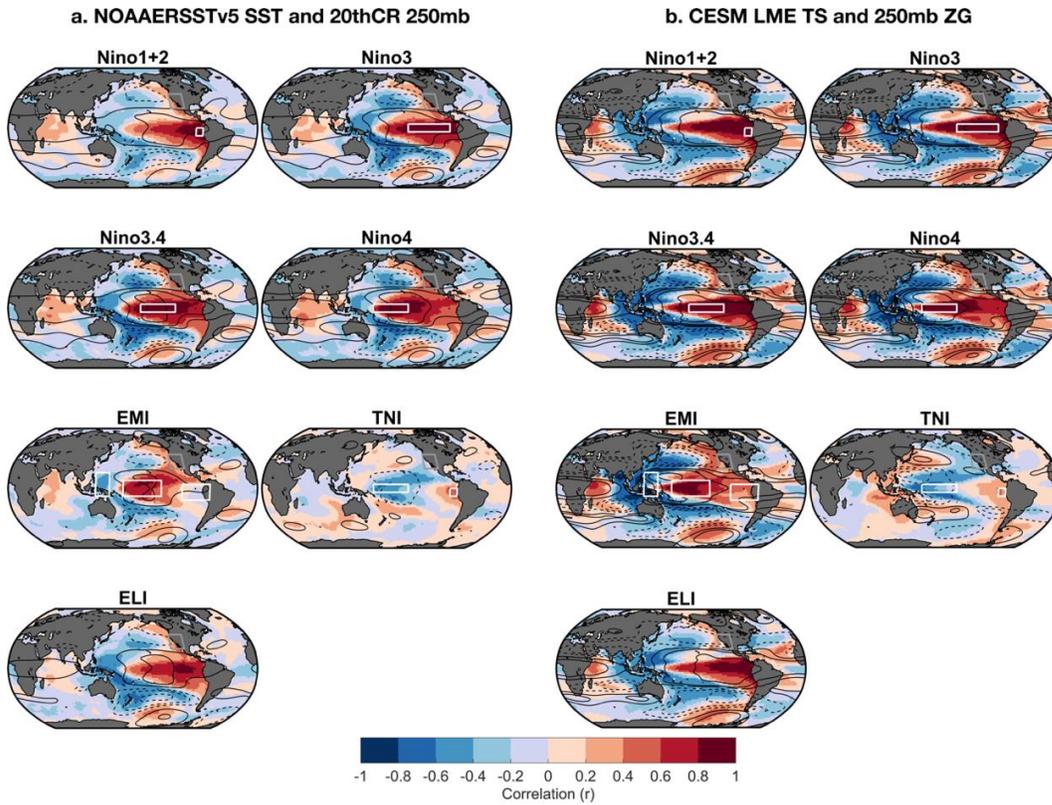
**Figure S2.** Histograms (top) of Niño3.4 index and scatter plots (bottom) showing the relationship between Niño3.4 index and annual mean SWNA precipitation anomalies in observation-based data (left) and the CESM LME (right). Histogram bars show the Niño3.4 index during all years (grey), SWNA pluvial years (blue), and SWNA drought years (red). Data from all 12,000 CESM LME years (right) and 1891-2018 CE in the GPCCv2018 and NOAA ERSSTv5 data (left). Grey lines in scatter plots show the least squares linear fit to the data, and boxes in upper left corners of scatter plots show Pearson’s correlation coefficient (‘r value’) between Niño3.4 index and SWNA precipitation (bottom).



**Figure S3.** Time series (top) of SWNA precipitation (blue line), Niño3.4 (solid red line), Niño3 (dotted red line), and El Niño Modoki indices (dashed red line) and maps (bottom) showing surface temperature and 250mb geopotential height anomalies associated with the years before, during, and after a drought spanning the simulation years 1222-1239 CE in run 3 of the CESM LME. In the time series plot, anomalies are relative to the 850-1850 CE mean (horizontal dashed black line). The time period shown in the maps, from two years before the droughts starts to the first wet year after the drought ends, is marked with dashed vertical lines in the time series. Teal stars on zero line mark the drought start year, and teal circles mark the last year of the drought in the time series. Black boxes in maps (bottom) outline the Niño3.4 region and SWNA region used to make the time series. Solid (dashed) black contour lines in maps mark positive (negative) geopotential height anomalies, with a contour interval of 10mb.

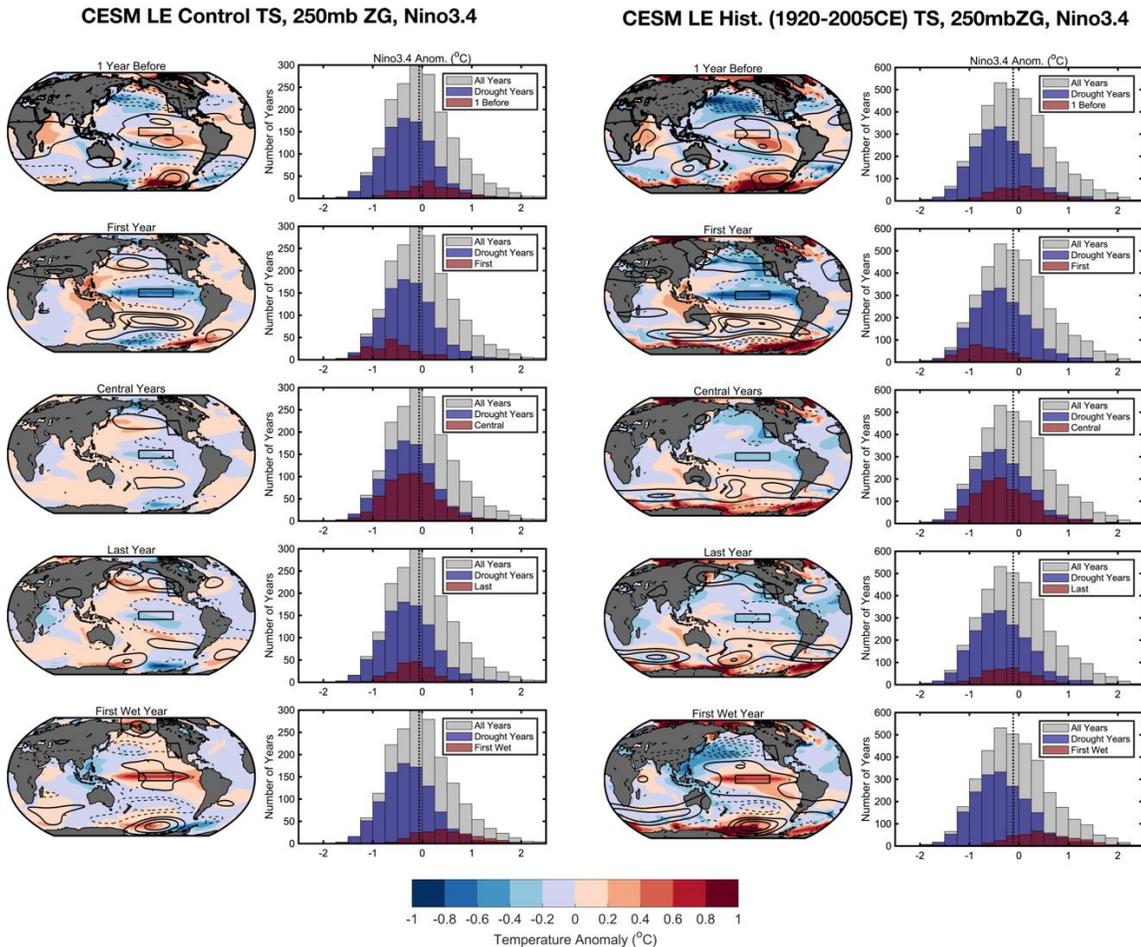


**Figure S4.** Time series of SWNA precipitation anomalies (blue line) and various tropical Pacific surface temperature indices from the GPCCv2018 and ERSSTv5 data (top) and for the first 100 years of run 2 of the CESM LME (bottom). Anomalies are relative to the 1891-2018CE mean in the instrumental data and the 850-1849 CE mean (horizontal dashed line) in the CESM, and the Pearson's correlation coefficient between the time series (calculated over the full instrumental and model time periods) is shown in the box in the lower left corner of each plot. Geographic regions used to create indices are shown in the maps in Figure S5.



**Figure S5.** Field correlations among various tropical Pacific surface temperature indices and surface temperature and 250mb geopotential height in the NOAA ERSSTv5 and twentieth century reanalysis data (left) and the CESM LME (right). The correlations are calculated over the 1891-2018CE time period for the instrumental data and over all 12,000 years in the CESM LME simulations. Geographic regions used to create indices are outlined in the maps in white. The EMI index is described in the Methods section of the main text (Ashok et al., 2007). The TNI is calculated by taking the difference between the normalized Niño1+2 and Niño4 indices (Trenberth and Stepaniak, 2001). ELI is calculated by tracking the eastward extent of the ascending branch of Walker circulation in the tropical Pacific (Williams and Patricola, 2018).

Correlations among the indices and SWNA precipitation (outlined in grey box on maps) are shown in Figure S4.



**Figure S6.** Maps showing mean sea-surface temperature and 250mb geopotential height anomalies and histograms showing Niño3.4 index distributions during the year preceding drought initiation, the first year of drought, the central years of drought, the last year of drought, and the first wet year after drought. Composites are from the 1800-year pre-industrial Control run (left) and the 42 historical (1920-2005CE) runs (right) of the CESM1 Large Ensemble. Black boxes in maps outline the Niño3.4 region and SWNA regions. Solid (dashed) black contour lines in maps mark positive (negative) geopotential height anomalies, with a contour interval of 5mb. Grey histogram bars show the distribution of the Niño3.4 index for all years, blue histogram bars show distribution of the Niño3.4 index in the years during SWNA drought, and red bars show distribution of the Niño3.4 index during specified years associated with various stages of the SWNA drought life cycle.