Understanding the South American Monsoon through isotopic proxies and model simulations

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Background

The South American Monsoon is a result of interactions between land-ocean-atmosphere dynamics. The majority of the annual rainfall occurs during the monsoon season in the austral summer (NDJFM). This resource is vital for agriculture, hydroelectric power, and drinking water.

This research explores drivers of spatiotemporal variability of the South American Monsoon over the Last Millennium (850 – 1850 CE). The signal coherency of a network of stable isotopic proxies is analyzed (Table 1, Figure 2), as well as model simulations of the monsoon forced by isolated external forcing data sets (Figure 1). This represents a divergence from the traditional approach, which has focused on the interpretation of individual proxy records. We also expand on the proxy coherency analysis of Campos et al. (2019) by including a new record (#10, Table 1) and comparing proxy variability to model representation of the monsoon response to external forcings.

Motivating Questions

• What is the spatiotemporal pattern of δ18O variability across the monsoon domain during the Last Millennium (850 – 1850 CE)?
• How does the variability of the South American Monsoon System (SAMs) respond to external forcings?
• What are the mechanisms through which the SAMs responds to external forcings and changes in internal variability?

Methods

A Monte Carlo resampling of age tie uncertainty was used to establish a 1,000 member ensemble of the proxy age models. For every proxy, an isotopic time series was interpolated to annual resolution for each age model in the ensemble. (Figure 3). Using the smoothed time series, a data matrix was constructed from one member taken from each proxy record ensemble. Using empirical orthogonal function (EOF) analysis, each matrix was decomposed into the leading modes of explained variance. The resulting bootstrapped loadings show the spatiotemporal variance of the isotopic signal within the bounds of the time uncertainty inherent to each record. This method follows from Anchukaitis & Tierney (2013) and Campos et al. (2019). These modes are compared with the two sets of EOF maps derived from the CESM-LME simulations (Figure 4). The first is a set of pseudoproxy time series with added white noise whose locations were selected based on proxy locations. The second is an EOF analysis of data from the full monsoon domain (Figure 4).

Table 1. Proxy records. The location of the records are illustrated in Figure 1.

<table>
<thead>
<tr>
<th>Record</th>
<th>ID</th>
<th>Lat (°S)</th>
<th>Lon (°W)</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>PAL03 + PAL04</td>
<td>1</td>
<td>5.92</td>
<td>77.35</td>
<td>Apaestegui et al., Clim. Past, 2014</td>
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<td>HUA1 + HUA2</td>
<td>2</td>
<td>11.27</td>
<td>75.79</td>
<td>Kanner et al., Quat. Sci. Rev., 2013</td>
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<tr>
<td>PAR01 + PAR03</td>
<td>3</td>
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<td>Wang et al., Nature, 2017</td>
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<td>SBE3 + SMT5</td>
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<td>13.81</td>
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<td>Novello et al., Geophys. Res. Lett., 2018</td>
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<tr>
<td>TMG</td>
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<td>16.00</td>
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<td>Wortham et al., Earth Planet. Sci. Lett., 2017</td>
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<tr>
<td>CRT1</td>
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<td>Vuille et al., Clim. Past, 2012</td>
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<tr>
<td>JAR1 + JAR4</td>
<td>8</td>
<td>21.08</td>
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<td>Novello et al., Geophys. Res. Lett., 2018</td>
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<td>ALH6 + CUR4</td>
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<td>15.20</td>
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<td>Novello et al., Glob. Planet. Change, 2016</td>
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<td>18.12</td>
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<td>Apaestegui et al., Earth Planet. Sci. Lett., 2018</td>
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<td>QUEC</td>
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<td>13.93</td>
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<td>Thompson et al., Nature Geosci., 2010</td>
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<td>PUM12</td>
<td>12</td>
<td>10.07</td>
<td>76.06</td>
<td>Bird et al., Proc. Natl. Acad. Sci., 2011</td>
</tr>
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</table>

References


Acknowledgments

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Figures

1. CESM-LME members (from Otto-Bliesner et al., 2016)
2. shaded shows percentage of annual precipitation falling during the mature phase of the South American summer monsoon (EOF), based on CHAP data (1979 – 2004). Filled circles indicate proxy record network for this study. Colors indicate type: black for speleothem, white for ice cores, blue for lake sediment. Record Sites: 1) Palacota Cave; 2) Huagapo Cave; 3) Paralco Cave; 4) Diva Cave; 5) São Bernardo and São Mathias Cave; 6) Tamboril Cave; 7) Cristal Cave; 8) Jaragua Cave; 9) Pau d’Alvito Cave and Curupira Cave; 10) Uimaiglanta Cave and Chiffronkashuha Cave; 11) Quilicaya Ice Cap; 12) Pumacocha Lake. Exact location and source indicated in Table 1. (Figure adapted from Vuille et al., 2012)
3. Isotopic time series of δ18O derived from a speleothem record in Cristal Cave for (a) annually interpolated data and (b) Monte Carlo resampled data smoothed with an eleven year running average. Upper and lower bounds are shown in blue, the mean is shown as a black line.
4. Leading covariance maps and principal components of EOF analysis using one ensemble member from CESM-LME data generated using full forcing input. The EOFs represent the leading modes of the SAMs (in descending order of explained variance): the Intertropical Convergence Zone (ITCZ), the central monsoon footprint, and the South Atlantic Convergence Zone (SACZ).

Future Work

• Complete the MC-EOF analysis of the proxy network.
• Perform EOF analysis of pseudoproxy records with added white noise.
• Compare EOF analysis of proxy network, pseudoproxy matrix, and full domain analysis.
• Repeat proxy-model comparison with isotope enabled simulation data.

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