Oxygen isotopes in tree rings are a good proxy for Amazon precipitation and El Niño-Southern Oscillation variability

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Edited by Robert E. Dickinson, University of Texas at Austin, Austin, TX, and approved September 10, 2012 (received for review April 26, 2012)

We present a unique proxy for the reconstruction of variation in precipitation over the Amazon: oxygen isotope ratios in annual rings in tropical cedar (*Cedrela odorata*). A century-long record from northern Bolivia shows that tree rings preserve the signal of oxygen isotopes in precipitation during the wet season, with weaker influences of temperature and vapor pressure. Tree ring $\delta^{18}O$ correlates strongly with $\delta^{18}O$ in precipitation from distant stations in the center and west of the basin, and with Andean ice core $\delta^{18}O$ showing that the signal is coherent over large areas. The signal correlates most strongly with basin-wide precipitation and Amazon river discharge. We attribute the strength of this (negative) correlation mainly to the cumulative rainout processes of oxygen isotopes (Rayleigh distillation) in air parcels during westward transport across the basin. We further find a clear signature of the El Niño-Southern Oscillation (ENSO) in the record, with strong ENSO influences over recent decades, but weaker influence from 1925 to 1975 indicating decadal scale variation in the controls on the hydrological cycle. The record exhibits a significant increase in $\delta^{18}O$ over the 20th century consistent with increases in Andean $\delta^{18}O$ ice core and lake records, which we tentatively attribute to increased water vapor transport into the basin. Taking these data together, our record reveals a fresh path to diagnose and improve our understanding of variation and trends of the hydrological cycle of the world's largest river catchment.

climate change | dendrochronology | plant physiology

Author contributions: R.J.W.B., G.H., T.L.P., J.-L.G., and M.G. designed research; R.J.W.B. and G.H. performed research; R.J.W.B., G.H., and M.G. analyzed data; and R.J.W.B. and M.G. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1205977109/-/DCSupplemental.

Results and Discussion

What Controls Oxygen Isotopes in *Cedrela* Tree Rings?

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Climatic Signals in Tree-Ring Oxygen Isotopes at Interannual to Decadal Time Scales.

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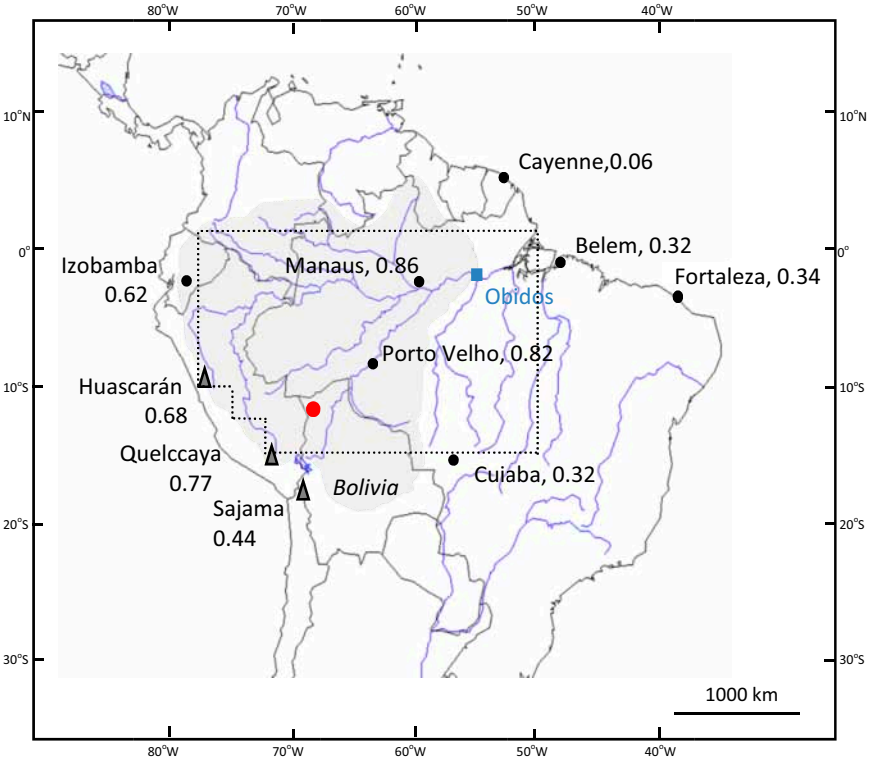
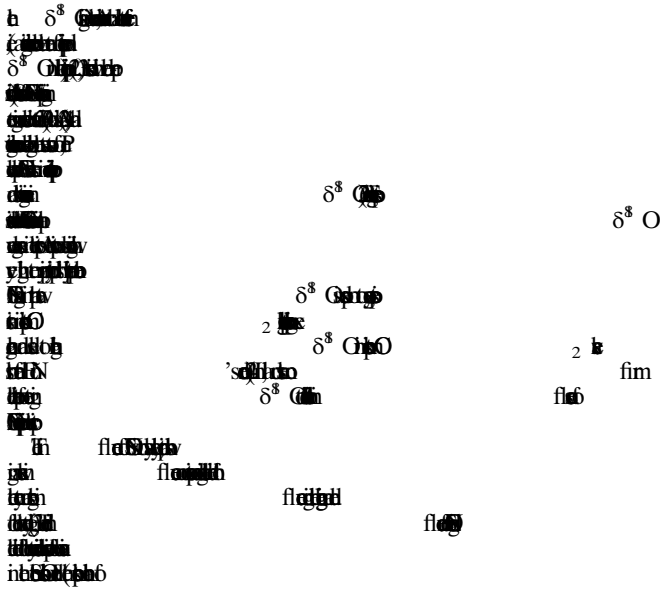


Fig. 1. Map of the Amazon indicating the study site (red dot), stations with records of $\delta^{18}O$ in meteoric precipitation (black dots), Andean glaciers with records of $\delta^{18}O$ (triangles), and the location of the Amazon River discharge records at Obidos (blue square). The shaded area shows the area of the catchment of the Amazon River that discharges at Obidos, an area encompassing 77% of the entire basin, or 4.68 million km^2 (5). The broken line indicates area from which climate data for the whole basin were extracted. Values next to the station names and glaciers indicate the correlation coefficients between $\delta^{18}O_{tr}$ and $\delta^{18}O$ measured in precipitation or ice cores at those sites. For details on data sources for $\delta^{18}O$ records, see *SI Appendix*.



Long-Term Trends in Tree-Ring Oxygen Isotopes.

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Outlook.

Cedrela

Conclusions

Cedrela

Methods

Complete discs were collected from the bases of approximately 60 logged trees of *C. odorata* from undisturbed tropical moist lowland forest from Purissima, northern Bolivia (11°24′S, 68°43′W) (Fig. 1) in October 2002. Tree rings were measured and successfully cross-dated (28). For this study, we selected eight large

trees (>60 cm in diameter) and isolated wood from each individual ring along a single radius using sharp knives and razor blades. Procedures for cellulose extraction and homogenization are described in the *SI Appendix*. The samples were weighed and packed into silver capsules, and pyrolized at 1.080 °C in an element analyzer (Carlo Erba) coupled to an isotope spectrometer (OPTIMA; Micromass). Values are expressed relative to V-SMOW and have an analytic precision of 0.3‰. In all analysis we used the arithmetic mean isotope ratios of the different trees ($\delta^{18}O_{tr}$). Details on the sources of climate, $\delta^{18}O_{prec}$ and $\delta^{18}O_{ice}$ records are provided in the *SI Appendix*.

ACKNOWLEDGMENTS. We thank Carmen Buerger and Peter van der Sleen for their help with cellulose extraction and isotope analysis; Stephen Arnold for running the back-trajectories; and Jeanette Pacajes for help with the export of samples. R.J.W.B. was supported by Dirección General de Asuntos del Personal Académico of the Universidad Nacional Autónoma de México, the Gordon and Betty Moore Foundation [Grant to Amazon Forest Inventory Network (RAINFOR)], and a Research Fellowship from the United Kingdom Natural Environment Research Council. M.G. was financially supported by Amazon Integrated Carbon Analysis (AMAZONICA) (Natural Environment Research Council).

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