

A. Project Summary: High-Resolution Reconstruction of the South American Monsoon History from Isotopic Proxies and Forward Modeling

The South American summer monsoon (SASM) is of great socio-economic relevance to (sub)tropical South America, yet our understanding of its sensitivity to past and future changes in radiative forcing (volcanic, solar, greenhouse gases) is still in its infancy. Proxies incorporating stable water isotopes ($\delta^{18}\text{O}$ and δD) are ideally suited to document past monsoon variations because isotopic fractionation is affected by changes in atmospheric monsoon transport along the air mass trajectory from source to sink.

Here we propose a high-resolution, precisely dated and quantitative reconstruction of the SASM using a forward modeling approach based on the stable isotope record ($\delta^{18}\text{O}_{\text{ice}}$) from the Quelccaya ice cap, Peru. We have chosen this particular site because of a) its long, high-resolution and precisely dated ice core record and b) its history of on-site monitoring and calibration programs, providing us with a unique opportunity for developing a process-based climate-proxy forward model relying on hitherto unexploited high-quality climatological, glaciological and geochemical data.

We will validate our model with a suite of 20th century reanalysis and satellite products, before forcing it with an ensemble of GISS ModelE isotope-enabled millennium simulations. These model runs are based on several different radiative forcing combinations using different estimates of past solar and volcanic forcing. Our modeling approach will yield synthetic ice core records since 850 CE, which, when compared with the proxy-based Quelccaya record, provide an important test bed for the ability of various model-forcing combinations to reproduce the observed isotopic monsoon fingerprint over the past millennium. The forward model will also allow deriving a dynamic relationship between $\delta^{18}\text{O}_{\text{ice}}$ on Quelccaya and large scale SASM indices upstream. Applying this relationship, validated for the 20th century, to the entire ice core record, will result in reconstructed SASM indices for the past millennium. Our monsoon reconstruction will be further constrained by additional high resolution-proxies that are available or are slated to come online over the next couple of years.

The **intellectual merit** of our proposal is manifold. We will provide the first quantitative, high-resolution SASM history, which will allow insight into its sensitivity to radiative forcings and complement high-resolution reconstructions from mid- and high latitudes in S. America. The different model-forcing combinations will test the model's ability to reproduce the observed SASM fingerprint and document which forcing combinations yield regional fingerprints consistent with our reconstructed monsoon history. Our project will deliver the first tropical ice core forward model, accounting for post-depositional snow removal and alteration of the isotopic profile. We anticipate that this model could provide a major breakthrough in the interpretation of such archives and have applicability toward other tropical and extratropical coring sites. Our proposal will also provide a better quantitative, mechanistic understanding of how tropical ice core archives are formed, which is a key requirement for their climatic interpretation. Our project will therefore contribute to a reduction in uncertainties that still plague many isotope-based interpretations of tropical paleoclimate.

Given the growing concerns over future changes in monsoon intensity under enhanced greenhouse gas forcing, a better understanding of natural monsoon variability and its sensitivity to external forcing is absolutely essential. Hence the **broader impacts** include the proposal's focus on a problem of high socio-economic relevance. We will give high priority to the swift dissemination of our results. Aside from the traditional avenues of publications and scientific presentation, we will reach lay people and decision-makers through outlets such as the UAlbany and Quelccaya blogs and through PI Vuille's frequent visits to the region as Senior ECPA Fellow. The broader impacts also include educational aspects such as training of a graduate student and a Postdoctoral Research Associate, and integration of methods and results developed in this project into undergraduate and graduate classrooms.