**Overview**

Decadal variability of Pacific sea surface temperatures (SSTs) plays an important role in terrestrial climate anomalies as well as global temperature trends. Unfortunately, the character of this variability is poorly constrained by instrumental data, which is particularly sparse in the South Pacific. Few in-situ SST proxies extend the instrumental records in higher latitudes though new Pacific geoduck records from the North Pacific have recently filled an important data gap. The New Zealand geoduck shows similar promise, with previous shell collections from fisheries research readily available and a pilot chronology proving both crossdating viability and broad spatial SST correlations. The proposed research will develop several New Zealand geoduck chronologies, largely from existing shell collections, searching out the prime location for annual climate reconstruction from both the growth increments and δ18O. With an established knowledge of proxy potential, we will collect fossil shell samples from the sea floor to extend the geoduck climate archive into previous centuries. We will crossdate the collected shell, producing an extended calendar-year-dated chronology as well as radiocarbon dated chronologies which will provide climate snapshots through the late Holocene. This new reconstruction will be combined with other high resolution marine proxies to better characterize past Pacific decadal variability, providing insights into the range and spectral character of past variability. With the addition of terrestrial proxies as well as climate models, we will also explore teleconnection patterns

Proxy records and climate models provide important and complementary perspectives on past climate, and the synthesis of these two sources of information—in the form of paleoclimate data assimilation—is a valuable approach for exploring key questions of Holocene climate variability. Paleoclimate data assimilation provides a framework for distilling physically-consistent climate signals from a vast collection of proxy records. In this method, proxies provide time series information while model covariances relate proxy anomalies at specific locations to the broader climate system, taking advantage of the strengths of both sources of information. Paleoclimate data assimilation has been used to explore climate over the past two thousand years in the Last Millennium Reanalysis (LMR) project, and the proposed research will expand this methodology to the past 10,000 years using novel techniques and a diverse and extensive network of long-timescale proxy records. By producing a multi-variable Holocene Reconstruction of past climate, important questions about Holocene climate variability can be explored, particularly temperature trends on a variety of timescales as well as important changes in regional aridity. This research will also produce a curated database of Holocene proxy records in a standardized paleoclimate data format, making the proxy data well suited for future analysis. Both the multi-variable reconstruction of the past 10,000 years and the standardized proxy database will be made available to the broader climate community as a multi-use resource.

**Intellectual Merit**

Despite its relative recency and the density of observations, fundamental aspects of Holocene climate evolution and dynamics remain uncertain or unknown. The proposed research will use paleoclimate data assimilation to combine proxy observations with the physical relationships from climate models to investigate:

* Holocene temperature trends: Because of disagreement between proxy reconstructions and climate model simulations, the global-mean temperature trend since the early Holocene remains uncertain. This is the “Holocene Temperature Conundrum”: did global-mean temperature primarily increase or decrease over the Holocene? This disagreement represents a fundamental uncertainty for proxy and modeling studies, which will be explored holistically using paleoclimate data assimilation.
* Changes in regional aridity: During the mid-Holocene, two semiarid environments, western North America and northern Africa, underwent fundamental shifts in their hydrology, in opposite directions. The climate dynamics underlying the aridification of northern Africa and the humidification of western North America remain unknown, yet are of incredible relevance to future climate, for which understanding the causes, likelihood, and timing of such changes is of incredible societal relevance.

**Broader Impacts**

Paleoclimate data assimilation benefits from the use of a broad network of well-described proxy records, so part of the proposed research will involve assembling and curating a large database of proxy data and metadata. This network of records, formatted into a standard paleoclimate data format and ready for further use, will be freely released and will constitute a wonderful database for the broader community. Additionally, the Holocene Reconstruction, which will consist of a multi-variable reconstruction of climate over the past 10,000 years, will be a valuable resource for further Holocene exploration. The reconstruction, as well as the code to create it, will be made freely available. The research will train a graduate student to conduct data assimilation research and proxy record curation, and the PIs will hold two workshops at Northern Arizona University to train young scientists in data assimilation methodologies and analysis. Because paleoclimate data assimilation is a valuable framework for the synthesis of proxy data and model results, training early career scientists in these methods is crucial for future progress in understanding paleoclimate.