Macrophysical Climate Models and Holocene Hunter-Gatherer Subsistence Shifts in Central Texas, USA

AGU -2013
PP51A-1910

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SUMMARY

STABLE CARBON ISOTOPES IN COLLAGEN AND APATITE FROM 69 MIDDLE TO LATE HOLOCENE HUNTER-GATHERER SKELETONS FOUND ON NINE ARCHAEOLOGICAL SITES IN CENTRAL TEXAS, USA SHOW MULTI-CENTURY FLUCTUATIONS BETWEEN THE CONSUMPTION OF C_3 AND C_4/CAM PLANTS AND ANIMALS. ONE EXPLANATION FOR THESE SHIFTS IS THAT PEOPLE ARE RESPONDING TO CLIMATE INDUCED CHANGES IN RESOURCE AVAILABILITY. TO ASSESS SHIFTS IN RESOURCE AVAILABILITY, WE DEVELOP SEVERAL MACROPHYSICAL CLIMATE MODELS FOR THE REGION, FOCUSED ON FALL-SPRING RAINFALL THAT SHOULD TRACK C_3 RESOURCE PRODUCTION. COMPARISONS BETWEEN ISOTOPIC VALUES AND MODELED C_3 RESOURCE PRODUCTION SHOW GOOD RELATIONSHIPS EARLY, BUT THE COUPLING DETERIORATES LATE. OTHER NON-CLIMATE FACTORS REQUIRE INVESTIGATION FOR THIS LATE DIVERGENCE.

ACKNOWLEDGMENTS

Thanks to Richard Young for help with the graphics. Sample processing was done at CAR-UTSA Paleo-Research lab. Thanks to Dr. Steve Tomka and CAR-UTSA for research support. Jamie Brown, Melanie Caron and Ben Moan of the CPSIL at Northern Arizona University, Flagstaff, conducted the isotopic analysis. Dr. Marina Suarez allowed access to the UTSA Geology lab. Thanks also to Dr. Robert Hard, Dr. Jennifer Rice, and Kirsten Verostick for a variety of things. Additional information on the lab can be found by scanning the QR code to the left or by emailing the authors.

1.) Patterning in $\delta^{13}C_{collagen}$ and $^{13}C_{apatite}$ Isotopes from Holocene Burials in Central Texas.

The map to the right shows the archaeological sites from which we have acquired carbon isotope data ($\delta^{13}C$) from 69 human burials. The sites are from hunter-gather groups, and span a period from about 6900 to 500 BP. Figures 1 and 2 (right) show standardized carbon isotopic results though time for bone collagen (Fig. 1) and carbonate in bone apatite (Fig. 2). Carbon isotopes in collagen differentially track protein consumption while carbon from bone carbonate tracks whole diet.

Both data sets have similar patterns (see Fig. 3). Initially groups are dependent on C_4/CAM plants and animals. C_3 resource use then increases until about 4000 BP, and then $\delta^{13}C$ values fall suggesting increased C_4/CAM use until 2900 BP. A variable, but increasing pattern of C_3 use is then present through 1000 BP, followed by a strong shift to C_4/CAM. Given Holocene climate changes, one explanation for these dietary shifts lies in shifting availability of C_4/CAM resource relative to C_3 plants and animals.

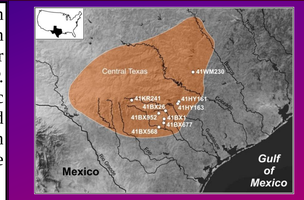


FIG. 1

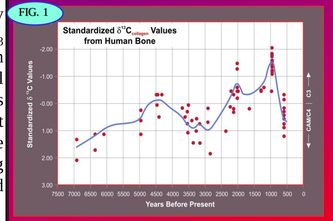


FIG. 2

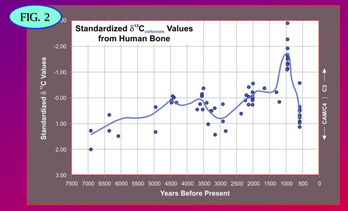
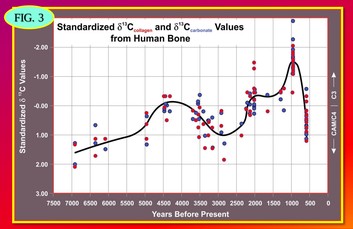
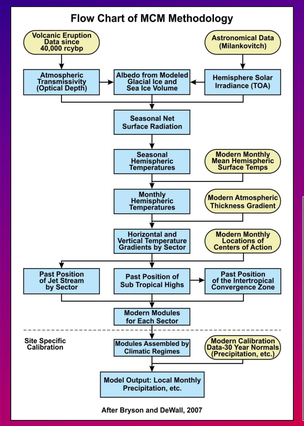


FIG. 3



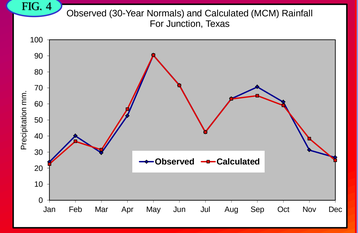
2.) Macrophysical Climate Models- Background and Development.

To assess the possible links between past diets, resource availability, and climate change, we turned to Macrophysical Climate Models (MCM) to provide a first approximation of climate at a fine-grained scale. As outlined in the flow chart to the right, MCMs rely on measured solar radiation as it varies with Milankovitch cycles and data on volcanic eruptions as initial starting points to model mean hemispheric seasonal temps. Using modern data, surface temperature gradients, and the seasonal position of "centers of action" such as the location of sub tropical highs and the jet stream, MCMs rely on non-linear regression techniques to develop location specific models. These models are fine tuned by calibration with 30-year normals for near-by weather stations. They provide 100-year resolution. References for the development and use of MCMs can be found by scanning the QR code above, or from emailing the authors.



For the current study, we chose four locations, shown on the map below, that had appropriate climate data and bracketed the archaeological site locations that contained the sampled human remains. For each location, comparisons between the modeled climate variables and the observed variables were made. Figure 4 presents one such example, a comparison of observed and calculated monthly rainfall at Junction, Texas. When the fit between the observed and modeled variables is sufficiently close (R^2 >.95), the modern data are used, in combination with information in the flow chart, to model past climate variables.

FIG. 4



3.) Holocene Macroclimate Models for Central Texas.

FIG. 5

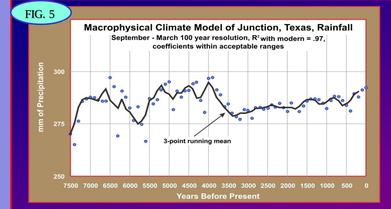


FIG. 6

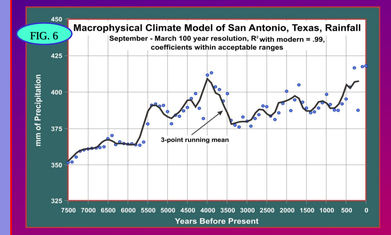


FIG. 9

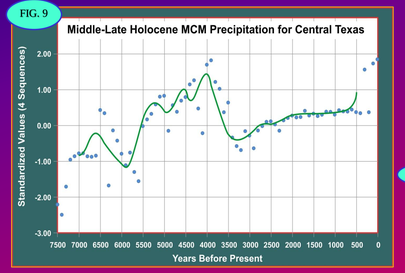


FIG. 7

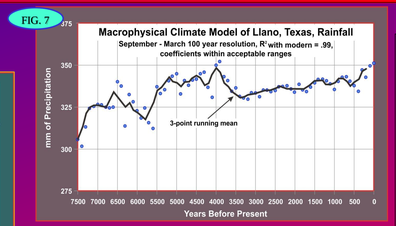
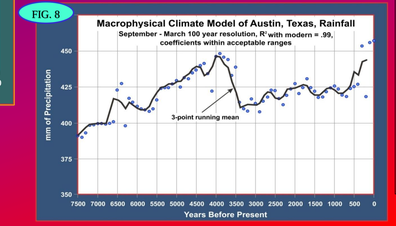


FIG. 8

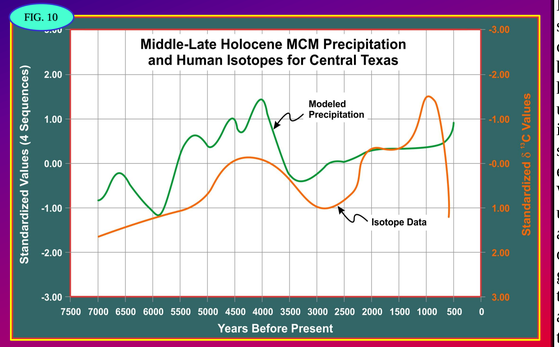


Figures 5, 6, 7, and 8 present MCMs for the four modern locations. We focus on the fall, winter, early spring rainfall as this is likely to correlate with C_3 production. The projected rainfall at 100-year resolution over the last 7500 years for the four locations is then standardized to create a more regional pattern shown in the Figure 9 (center). To the degree that the MCM rainfall is an accurate model of the actual rainfall, the smoothed line can be used as an estimate of C_3 resource availability in the region.

4.) Results and Assessment.

Figure 10 compares the curve for the modeled rainfall with the standardized isotope results presented previously (Fig. 3). Visually, there is a general relationship between the two, at least until roughly 1200 BP. Prior to that date, increases and decreases in modeled fall-spring rainfall broadly correlate with increases and decreases in C_3 plant and animal intake. These data suggest that the pattern of subsistence change may reflect changes in underlying resource structure. After 1200 BP, any obvious coupling breaks down. This suggests that other factors, likely residing in the social rather than the climate/ecological spheres, are involved.

FIG. 10



Like most models, MCMs attempt to simplify complex systems, isolating components as well as relationships between components, that appear to have explanatory power. Models are useful to the degree that they increase our understanding of the systems modeled, and highlight elements for further investigation. We have used MCMs not to understand climate, but as an approximation of shifts in the types of resources available for hunter-gatherers in Central Texas. While the base climate model needs to be assessed against independent data, the exercise has highlighted periods where climate-ecological data may, and may not, prove sufficient.