Paleoclimate Applications of a Regional Climate Model

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Progress in the analysis and interpretation of paleodata sets has led to increasingly refined hypotheses about the spatial and temporal aspects of past climates. The growing world-wide data base of geologic records of paleoclimate provides a foundation and motivation for applying a variety of atmospheric, oceanic, and coupled earth-system models at increasingly finer resolution. Because we cannot simulate past climates over thousands and millions of years using full-physics AGCMs, paleoclimate modeling must be aimed at simulating a general climatology for a particular period or snapshot in time and at sensitivity testing to assess hypothesized surface-atmosphere feedbacks. The specific questions being addressed are motivated by the geologic record of Milankovitch or orbital-scale (10^5 yr) climate changes which occur as a result of well-known changes in Earth-Sun geometry, and more abrupt or millennial scale changes that are superimposed on orbital-scale changes and that are associated in geologic time with events such as freshwater routing to the North Atlantic.

Over the past ten years we have used the NCAR RegCM in a variety of paleoclimate experiments. The focus of some experiments has been to produce general climatologies, to assess feedbacks, and to produce internally consistent, high-resolution climate fields with which to drive independent surface process models (e.g., lake, hydrology, glacier, upwelling, vegetation). Based on a number of published and unpublished experiments, our greatest success has been assessing at high resolution particular feedbacks (lakes, ice) between the surface and the atmosphere, and relative changes from one climate phase to another as in millennial scale changes. The success of these experiments is attributed to the scale of land-surface change, resolution of important details (e.g., the margin and height of the Laurentide ice sheet), and to robust circulation forcing exerted by large ice sheets. We have been less successful in simulating general orbital-scale climate change (e.g., Early and mid-Holocene).

Our variable success stems from the use of AGCMs to produce boundary conditions, and the strengths and weaknesses of the RegCM. We have derived boundary conditions for the RegCM from CCM0, CCM1, CCM3, and (primarily) GENESIS (V2). As is the case for any AGCM-RCM experiment, the quality of a paleosimulation depends heavily on the ability of the AGCM to simulate synoptic-scale circulations arising from large-scale boundary conditions such as atmospheric CO_2 levels, sea surface temperatures, and continental ice sheets. In some regions, such as around the large Laurentide Ice sheet that existed over North America during the last glacial cycle, the presence of the thermal and topographic forcing of the ice sheet and changes in SSTs and sea ice produce relatively uniform responses in most AGCMs (Paleomodel Intercomparison Project, PMIP). These forcings are also robust in the RegCM, resulting in simulations that generally agree with geologic data and provide insights into potentially important surface-atmosphere feedbacks. On the other hand, the

AGCM-RCM modeling hierarchy has not been as successful for simulations away from the ice sheet where the key forcing is derived by general atmospheric cooling or warming derived from changes in SSTs or seasonal change in solar inputs associated with precession and obliquity.

In this talk I will present an overview of various paleoclimate simulations that we have completed or are in the process of completing. The experiments range from various phases of our work in developing a 3-D ice sheet model for the Laurentide ice sheet to the LGM climate of South America.