Geophysical Research Abstracts
Vol. 12, EGU2010-8254, 2010
EGU General Assembly 2010

Simulation of the Caribbean Climate during the early and mid-Holocene with GCM

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Although a set of coupled ocean-atmosphere simulations using state-of-the-art climate models is available for the mid-Holocene since PMIP2 (Paleoclimate Modeling Intercomparison Project Phase II), little research has been directed towards climate variability in the early Holocene when the Laurentide ice sheet presented. The Holocene thermal maximum between 11,000 and 5,000 years ago is mostly recorded in the middle and high latitudes; however, the subtropical and tropical regions play a quite important role in modulating the global climate, and more debates exist concerning the consistence of simulation and proxy reconstructions in these regions.

Long-term Simulations with a coupled atmosphere-ocean-vegetation general circulation model (ECHAM5/JSBACH/MPI-OM) configured for the present, mid-Holocene (6 ka B.P.) and early Holocene (9 ka B.P. with/without Laurentide ice sheet) are performed in this study by specifying the appropriate change of forcing, i.e., orbital parameter, greenhouse gases and topography.

Prescribed changes in insolation due to orbital variations are considered to be the major external forcing, which leads to increased seasonality in the Caribbean as indicated by the surface temperature, with a cooling in the winter and a warming in the summer. The magnitude of the seasonality variation is approximately 1-2°C, comparably much smaller than that in the extratropics, whereas, it is consistent with coral-based 18O and Sr/Ca seasonality analysis. Compared to the mid-Holocene, the early Holocene seasonality increase is more dramatic due to more incoming radiation in summer and less in winter. The sea surface temperature (SST) is similar, showing the expansion of the Atlantic warm pool in summer during the Holocene. Weakening of the thermohaline circulation during the Holocene results in less northwards heat transport at 30°N and thus partly contributes to the warming in the summer. Comparison of the two simulations for the early Holocene shows that the topography change in high latitudes which is associated with change in glacial distribution and the corresponding albedo does not only influence the local climate but also have a cooling effect in the tropics.

The simulated hydrological cycle reflects the wetter conditions of the Holocene (especially for the early Holocene) in the south Caribbean, which have been proved by marine and lake sediment records. The annual precipitation anomaly during the Holocene can be more than 500mm/a, similar to that for Africa over the same period. This long-term change can be attributed to orbitally forced variations in solar insolation, which led to a more northwards shift of the mean latitude of the Atlantic Intertropical Convergence Zone (ITCZ). Meanwhile, the prevailing easterly trade wind gets weakened during the Holocene, which may reduce the water vapor transported from the tropical Atlantic to the western Pacific via the Caribbean. This provides another explanation of the wetter conditions in the Caribbean.

The teleconnection pattern, which refers to the interannual variability of the Caribbean climate, ENSO and the Atlantic, does not have much change during the Holocene compared to the present. The Caribbean rainfall is positively correlated to the tropical Atlantic SST, while it shows a La Niña-like pattern with the western Pacific, as deciphered in research related to the modern Caribbean climate. Nevertheless, some proxy studies demonstrate the ENSO only became as active as it is at present after the mid-Holocene. From this point of view, more proxy and simulation comparisons are required as well as comparisons between different GCM results.