Environmental control of tropical cyclone genesis in paleoclimate simulations

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Global climate models have become important tools in assessing how the environmental conditions that favor tropical cyclone genesis may change over the next century. As a complement to these efforts, we have investigated how the same models respond when forced with very different conditions: paleoclimate simulations including hot periods in the early Cenozoic, the Last Glacial Maximum, and the middle Holocene (when summer solar radiation differed substantially owing to the precession of Earth's orbit). The responses to these very different forcings offer a valuable perspective into how genesis environments respond to climate more generally.

We examined the simulations of the paleoclimate intercomparison modeling project (PMIP2) to investigate how the dynamic and thermodynamic factors known to be important for tropical cyclogenesis change in response to cold climates (last glacial maximum; LGM) and solar radiation changes during the middle Holocene (6000 years ago; 6ka). We find that despite the universally colder conditions at the LGM, the potential intensity calculated from model generated soundings of this period is globally similar to today, and was actually higher in the colder state across much of the western and central Pacific. The colder climate also reduces relevant entropy deficits, which has been related to the gestation period of nascent systems. Combined metrics of large-scale environmental factors predict a higher genesis potential in many locations during the LGM than today.

Over the Holocene epoch, carbon dioxide levels were broadly stable while the distribution of solar radiation varied with Earth's orbit. We find that despite the increase in Northern Hemisphere storm season solar radiation at 6ka, there is a decline in the favorability of thermodynamic variables important for genesis during summer (e.g., potential intensity and measures of tropospheric entropy deficits), with a shift in the seasonal cycle towards an October peak. These changes appear principally related to the differential heating of the ocean surface and free troposphere, but the geographic distribution of changes is not uniform, and model variability is high in the central Pacific. We also examine the effects of major volcanic eruptions on tropical cyclone environments using output from the Last Millennium paleoclimate simulations. There is a broad stability in many of the factors across the 6000 years preceding the industrial era. Finally we compare these analyses to results from statistical downscaling techniques and the models own track density.