Can RCMs Properly Represent the Diurnal Cycle of Precipitation in the Tropics? Evaluating the Northeast Brazil Case

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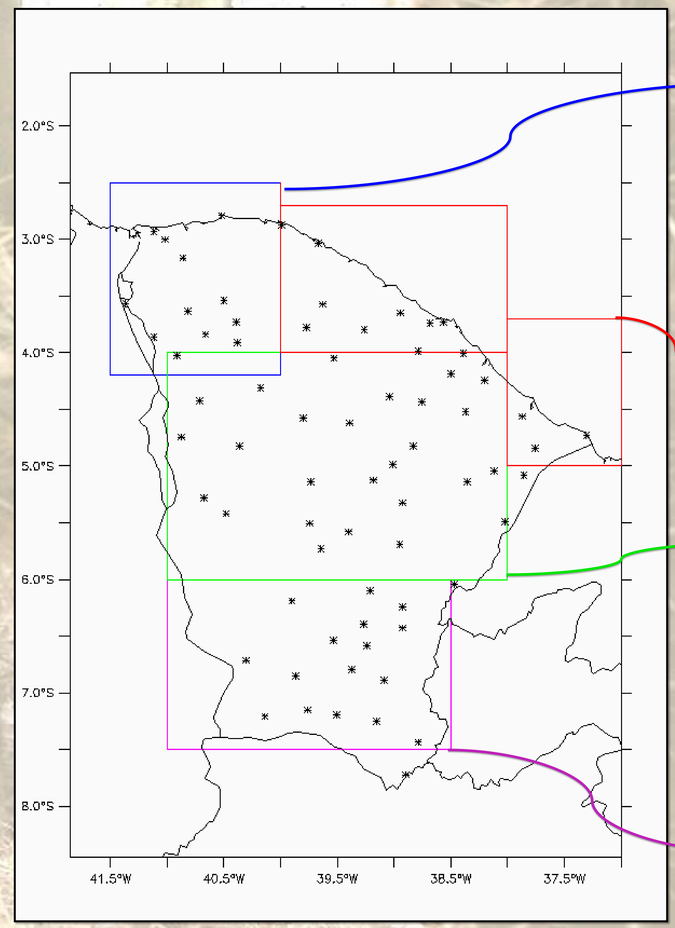
A number of physical processes act in modulating the occurrence of deep convection and precipitation over land and over ocean in tropical regions. Although it is quite obvious that the differential heating is responsible for establishing direct thermal circulations, large-scale advection and the internal evolution and dynamics of cloud systems (which depend on the microphysics) are also important to the diurnal distribution of precipitation in a given region.

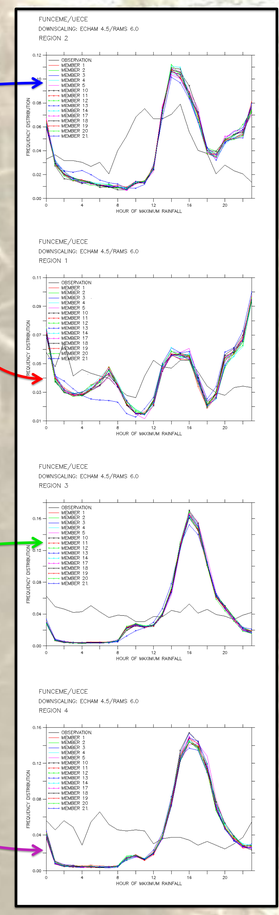
In this work, we analyze the capability of a regional climate model (Regional Atmospheric Modeling System, version 6.0, forced by ECHAM 4.5 AMIP runs) in simulating the diurnal cycle of precipitation over Northeast Brazil. The model results come from a 46-year, 15-member, climatological simulate,n performed as part of the upgrade of an operational dynamical downscaling forecast system at the Ceará State Foundation for Meteorology and Water Resources (FUNCEME). Model grid has 100 x 100 points in the horizontal, for a grid spacing of 30 km in both directions, covering Northeast Brazil and a portion of the intertropical Atlantic ocean.

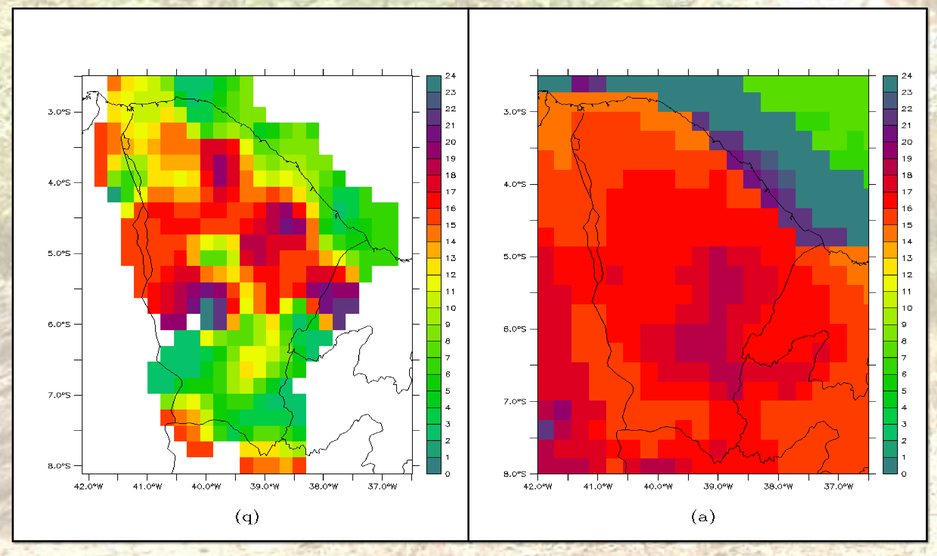
In order to conduct the verification of model results, data from FUNCEME's network of surface stations were used. As the stations produce hourly precipitation data, one determined the time of maximum precipitation over the state of Ceará, in Northeast Brazil. As expected, most of the coastal stations exhibit maximum precipitation rates in local morning hours, whereas afternoon precipitation dominated inland. Mountaneous regions to the northwest and to the south of Ceará state have opposite behaviors, the first with the predominance of afternoon rainfall; the later, with precipitation occurring mostly during late night and early morning hours. In contrast with this complex behavior, modeled precipitation shows a mostly binary signal, with afternoon precipitation dominating over the entire continent and night to morning rainfall being restricted to the ocean areas within the model domain.

Those discrepancies suggest that the RCM has serious limitations in representing the generation of instability and the interaction between convection and larger-scale advection, even with an adequate representation of the diurnal cycle of surface heating and cooling and the simulation of local wind patterns associated with the sea breeze and topography-forced circulations . With a resolution on the order of tens of kilometers, precipitation is mostly simulated via convective parameterizations. Hence, it is possible that the local removal of instability with rainfall being produced in a given model column does not correspond to the real evolving cloud system which are transported by the larger scale flow at the same time as they pass through growing, mature and dissipating stages.

Ceará state was divided into four regions, containing each a number of meteorological stations. The average diurnal cycle of the precipitation was computed for each of them and compared with the model results for the same boxes. Good agreement was achieved only for the coastal regions in the state.







There was virtually no difference among the results from the different members of the simulation regarding the representation of the diurnal cycle. They tend to generate nightime convection over ocean and daytime convection over the continent. Especially for the south of Ceará, the observed patterns of the diurnal cycle of precipitation were not well represented by the numerical model.

Hour of maximum precipitation: observed, from meteorological stations (left) and simulated, from one of the RAMS-ECHAM ensemble members (right)

Regions in Ceará state and their respective mean precipitation cycles (observed and modeled, including the various ensemble members): Northern coast and Ibiapaba (blue), metropolitan region of Fortaleza and eastern coast (red), sertão (green) and Cariri (south, magenta). The locations of the meteorological stations are also indicated.

The first author gratefully acknowledges the support by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)