Separating dynamical and thermodynamical impacts of climate change on clouds and precipitation for daytime convective development over land

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Abstract

This presentation will discuss results from high-resolution simulations applying piggybacking methodology to separate dynamical and thermodynamical impacts of climate change on convection developing during daytime over summertime continents. Dynamical impacts include an increase of convective updraft strength due to an increase of CAPE in a warmer climate. Thermodynamic impacts concern an increase of cloudiness and surface precipitation resulting from the increase of water vapor that the warmer atmosphere can hold and convection can work with. The main idea behind the piggybacking method is to use two sets of thermodynamic variables in a single cloud field simulation. The first set is coupled to the dynamics and drives the simulation (set D, as in Driving), and the second set piggybacks the simulated flow and does not affect it (set P, as in Piggybacking). Because the two sets are driven by the same flow, the methodology allows assessing the impact of initial thermodynamic profiles with high accuracy. The impact on the dynamics is assessed by performing a second simulation with thermodynamic sets swapped so the D set becomes the P set, and vice versa. This presentation will discuss application of the piggybacking method to the case of a global climate-model predicted change of the temperature and moisture profiles (the sounding) in the Amazon region. The CoNTRol sounding (CNTR hereafter) initiates the model with a profile that was observed at sunrise during the Large-Scale Biosphere–Atmosphere (LBA) field project in Rondonia (Brazil). This sounding was previously used in studies of convective development over summertime continents. The CLimate CHange sounding (CLCH hereafter) comes from adding climate change signal over the Amazon at the end of the 21st century as shown in Fig. 1 to the CNTR sounding. The CLCH initial sounding features increased CAPE (from ~1300 to ~2500 J kg^{-1}) and CIN (from ~20 to ~40 J kg^{-1}).

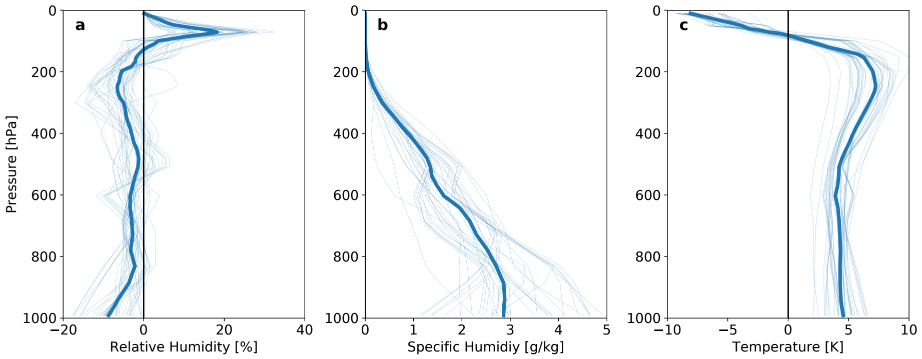

Figure 1. Differences in the relative humidity, specific humidity, and temperature between ends of the 21st and 20th-century climate over the Amazon as simulated by CMIP5 RCP8.5 global climate model ensemble. Thin lines represent individual model results. The thick line is the median used in LES simulations.

Figure 2 shows the impact of CNTR and CLCH soundings on the simulated convective development. Because of the differences in the low-level humidity, clouds in the CLCH environment develop later and have higher cloud bases regardless which set drives the simulation. Because of higher CAPE, deep convection is stronger in CLCH and transports more water into the upper atmosphere. The latter leads to deeper and more extensive anvils at the end of simulations. Reduced initial upper tropospheric humidity (cf. Fig. 1) results in reduced anvil coverage in CLCH at hour 12, again regardless which set drives the simulation. Other details of the simulations (e.g., surface rain accumulations), as well as results of sensitivity simulations with additional sounding modifications, will be discussed at the meeting.

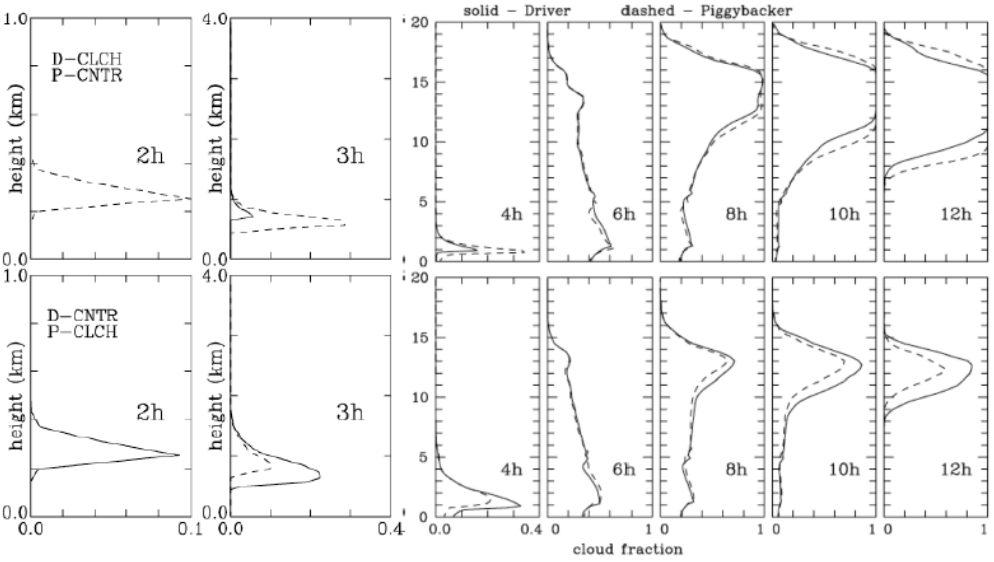

Figure 2. Evolution of cloud fraction profiles in piggybacking simulations applying CNTR and CLCH initial soundings. Driver/piggybacker results are shown with solid/dashed line. CNTR drives and CLCH piggybacks in lower panels (D-CNTR/P-CLCH); the reverse is in the upper panels, D-CLCH/P-CLTR.