Geophysical Research Abstracts
Vol. 17, EGU2015-12349-1, 2015
EGU General Assembly 2015

Giga-LES of Hector the Convector keeping the tallest updrafts undiluted

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The trend of stratospheric water vapour during the past decades is not correctly reproduced by current GCMs. This may be due to lack of representation of rapid water transfers from troposphere to stratosphere. Our modeling study focused on a particular case of tropical very deep convection which takes an active part in this transport. We aimed at understanding its dynamics and the stratosphere moistening processes. We selected a Hector thunderstorm observed on 30 November 2005 over Tiwi Islands, Australia, during the SCOUT-O_3 field campaign. Plumes of ice particles reaching 19 km altitude were measured by lidar aboard the Geophysica stratospheric aircraft. We performed a Giga Large-Eddy Simulation of Hector (100 m horizontal resolution, more than 1 billion grid points) using cutting-edge computing resources, as well as a series of simulations with coarser and coarser horizontal resolutions, from 200 m to 1600 m. A strong morning sea breeze deviated boundary layer westerlies and led to intense convergence of humid air over Tiwi Islands. Deep convection triggered around 12:15 pm and quickly reached 14 km altitude. The associated cold pools organised and generated upward motions at the surface. The most intense upward transport started 1 hour later and lasted around 2 hours. As a result, a couple of updrafts overshot the tropopause carrying ice crystals in the stratosphere. Part of the ice particles precipitated then whereas the remainder sublimated in the lower stratosphere. The consequent vapour pockets were transported and diluted within the stratosphere by easterlies. While moistening appeared to be robust with respect to the grid spacing used, grid spacing on the order of 100 m may be necessary for a reliable estimate of hydration (Dauhut et al. ASL 2014, doi: 10.1002/asl2.534). A comprehensive analysis of individual updrafts and their properties once sorted by their height has been carried out. The couple of updrafts that reach the stratosphere presents a higher buoyancy, stronger vertical velocities and larger hydrometeor contents compared to the ordinary deep convective updrafts. At the cloud base, the stronger horizontal convergence due to the cold pools generated by the previous deep convective updrafts strengthens the vertical velocity while no differences in the size of the cloud base have been found. At 10 km altitude, the overshooting updrafts show a much larger core size suggesting that the reduced lateral mixing promotes the tropopause overshoot. Similar results are obtained whatever the resolution. The preconditioning through cold pools generation and troposphere moistening is found to be determinant for the transition from the deep to the very deep convection.
This study was supported by the StratoClim project.