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The overshoots that hydrate the stratosphere in the tropics

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The overshoots are the convective air parcels that rise beyond their level of neutral buoyancy. They are assumed to rarely reach the Tropical Tropopause Layer (TTL, between 14 and 18 km altitudes) and, even more infrequently, to cross the tropical tropopause at 17 km altitude. On 30 Novembre 2005, plumes of ice particles were observed up to 18 km altitude above Hector the Convector, a deep convective system that regularly develops in Northern Australia. We performed a Giga Large-Eddy Simulation (Giga-LES, 100 m cubic resolution, more than one billion grid points) of Hector, on which two tens of overshoots reached the TTL with a width of 5 km or more. From a previous study, the hydration led by such overshooting convection was estimated to contribute to almost 20 % of the global transport of water across the tropopause. The mechanisms of the overshoots that hydrate the stratosphere need thus to be better understood, and eventually parametrized in general circulation models.

All the identified overshoots are made of negatively-buoyant air parcels that collapse 1 min after reaching their overshooting maximal altitude. Some environmental air is then entrained into the top of the overshoots, where the turbulence promotes an efficient mixing between the cloudy air and the entrained, warmer air. This mixing gives a larger buoyancy to the subsequent mixed air, leaving it at about the overshooting maximal altitude. The top of the overshoots is then stretched by wind shear and gravity wave breaking, generating a cloudy plume downstream.

Two categories of overshoots are distinguished: the overshoots that hydrate the stratosphere and the ones without any effect on the stratosphere humidity. The former contrast from the latter as a part of their hydrometeors sublimate and form a vapor-enriched layer in the cloudy plume. They reach higher altitudes, where the potential temperature vertical gradient is larger and the air is subsaturated. The systematic characterization of the overshoots indicates that the main mechanism for the overshoot to hydrate the stratosphere is the entrainment at its top. Furthermore, the wider the overshoot is, the more water it injects. This makes the overshooting width and maximal altitude the key variables for a future parametrization of the overshoots.

Such a study provides a conceptual framework to analyze the measurements of convective hydration in the TTL observed during the StratoClim field campaign (July-August 2017).