How Deep Convective Storms Influence Global Climate: Cross-tropopause Transport of H_2O

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Deep convective storms play many important roles in weather processes but most of time they are regarded as the response of the atmospheric dynamic system to climate, i.e., they have not been regarded as a possible climate forcing. Observational findings by meteorological satellites now give clear evidence that this is not the case.

A phenomenon called above anvil cirrus plumes (AACP) discovered first in early 1990s show that there is chimney plume-like cirrus clouds often occur right above many severe thunderstorms whose anvils are already at the tropopause level. The AACP can be located 3-4 km above the anvil, indicating that they are stratospheric clouds. The stratosphere is usually considered as very dry (3-4 ppmv of H_2O) and hence it is unlikely to have adequate water vapor for such extensive cirrus cloud formation. Therefore, the water vapor must come from somewhere else, rather than pre-existing in the stratosphere.

Our cloud resolving model studies show that the water vapor for AACP comes from the thunderstorm. Strong convection in the storm causes intense internal gravity waves at the tropopause level. Under suitable atmospheric conditions, these gravity waves can break and cause materials such as water substance (water vapor, ice particles) to penetrate the tropopause and enter the stratosphere irreversibly. Once there, condensed phase water substance will likely evaporate completely and in effect moisturize the stratosphere.

Because of the surface climate change, e.g., global warming, global deep convective storm activities may also change in response which then causes the amount of water vapor transported into the stratosphere by this wave breaking mechanism to change. Changing water vapor in the stratosphere then, in turn, causes the change in the surface warming due to the changing amount of terrestrial IR intercepted by stratospheric water vapor. It is now well known that the stratospheric water vapor concentration has been fluctuating as much as 50% in the past 40 years.

In this paper, we will show the evidence of AACP by satellite and aircraft observations as well as numerical simulations of this phenomenon by cloud resolving models to illustrate the gravity wave breaking process.

Key words: cross-tropopause transport, stratospheric water vapor, thunderstorms, gravity wave breaking