RECENT NEW EVIDENCES OF DEEP CONVECTIVE VERTICAL TRANSPORT OF WATER VAPOR THROUGH THE TROPOPAUSE

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I. INTRODUCTION

A few years ago, by means of numerical modeling we identified a deep convective transport mechanism (storm top gravity wave breaking) of water vapor through the tropopause, injecting the tropospheric water substance into the lower stratosphere (Wang, 2003). The main observational evidence of this mechanism we presented previously was based on the lower resolution geostationary (GOES) and namely on the AVHRR instrument of polar orbiting satellite images of the storm anvil top cirrus plumes (Levizzani and Setvak, 1996).

II. PRESENTATION OF RESEARCH

Recent observations have provided more supporting evidences for this important cross-tropopause transport mechanism. There are now new higher resolution satellite images, mainly from the MODIS instrument (REF), that show more definitely the existence of these plumes, many of which would probably have remained unseen by lower resolution GOES images. Moreover, the main advantage of the higher resolution MODIS images (250 m) is that they can show very fine details of the plume structure, which remains unresolved even in the AVHRR 1 km imagery. Finally, availability of the MODIS instrument images enables more detailed multispectral study of plumes, providing detailed information on cloud top microphysics, as well as on their possible link to lower stratospheric moisture (Setvak et al, 2007). One example of MODIS storm top plume is shown in Fig. 1. Detailed multispectral MODIS data also enable the study of a possible contribution of plumes to appearance of the enhanced-V (cold-U/V) shape, documented back at 80's and early 90's (e.g. Adler and Mack, 1986; Heymsfield et al., 1991; McCann, 1983; Negri, 1982).

Furthermore, movies taken by a building top webcam in Federal Institute of Technology (ETH) at Zurich, Switzerland also demonstrate that the jumping cirrus phenomenon, first identified by T. Fujita (1982, 1989), may be quite common in active thunderstorm cells, quite contrary to previous belief that it is rare. In particular, a thunderstorm system occurred in 2003 in Bavaria, Germany, was recorded as a movie by a rooftop webcam. This movie showed that most of the individual storm cells that can be seen clearly exhibited the jumping cirrus phenomenon, suggesting that this phenomenon is probably quite common. We have used a cloud model to demonstrate that the jumping cirrus is exactly the gravity wave breaking phenomenon that transports water vapor through the tropopause (Wang, 2004).

Finally, the recent measurements of the heavy water to normal water ratio (HDO/H_2O) clearly indicate that the ratio is much highly than that would be if the transport of water from the troposphere to the stratosphere is via slow ascent (Kuang et al., 2003; Hanisco et al., 2007). HDO is more prone to condensation and hence is more readily to precipitate out from the atmosphere as compared to the lighter H_2O. The ratio of HDO/H2O would thus indicate how fast the condensation process occurs. The measurements show that the ratio is ~ 3×10^{-4} whereas the slow ascent scenario would result in a much smaller ratio. The only explanation at present that can be used to interpret this high ratio observation is that water substance is transported through the tropopause via rapid vertical motion, i.e., deep convection. The most likely transport mechanism is again the one proposed by Wang (2003).

We will present satellite images, a surface-based thunderstorm movie and the chemical measurement results to demonstrate that the deep convective transport of water substance (and possibly other trace chemicals) through the tropopause is a very common phenomenon and may be one of the most important pathways of vertical transport between the troposphere and stratosphere. These new evidences will be compared to cloud model simulation results as presented in Wang (2003, 2004, and 2007).

This transport mechanism is thus capable of transporting water vapor and other trace species which may include aerosol particles and greenhouse gases) through the tropopause. It is possible that these greenhouse gases may present substantial climatic impacts once they enter the stratosphere due to their interaction with solar radiation. Such a possibility needs to be carefully assessed.

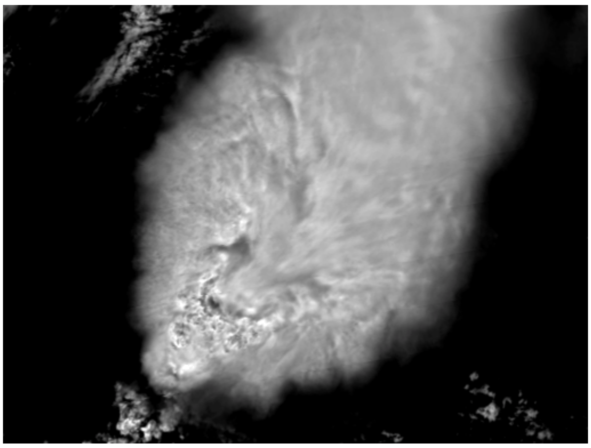

FIG. 1: Plume atop of convective storm as observed in 250 m resolution image of the Aqua/MODIS instrument. 12 May 2005, 19:45 UTC, Texas.

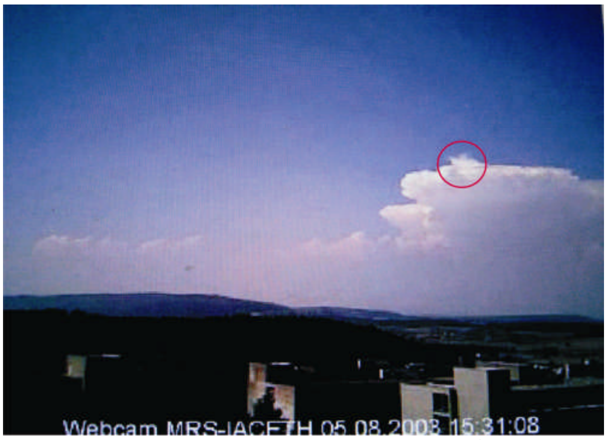

FIG. 2: Jumping cirrus (circled in red) seen at the top of a storm cell occurred on 5 Aug 2003 in Bavaria , Germany, as seen by a webcam mounted on top of Institute of Atmospheric and Climate Science Building, ETH, Zurich, Switzerland (courtesy of Dr. Willi Schmid).

III. RESULTS AND CONCLUSIONS

IV. AKNOWLEDGMENTS

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