Atmos. Chem. Phys. Discuss., 7, S4225–S4228, 2007
www.atmos-chem-phys-discuss.net/7/S4225/2007/

Atmospheric Chemistry and Physics Discussions

ACPD

7, S4225–S4228, 2007

Interactive Comment

Interactive comment on "Small-scale mixing processes enhancing troposphere-to-stratosphere transport by pyro-cumulonimbus storms" *by* G. Luderer et al.

Anonymous Referee #1

Received and published: 21 August 2007

General comments

This article presents a compelling new simulation of pyro-Cumulonimbus convection that both well describes a previously unexplained observed phenomenon (cold U/warm center) and also provides insight into the role of gravity wave breaking in tropospheric-stratospheric exchange. This particular simulation shows strong evidence of gravity wave breaking (figure 9). The increase of aerosol mass in a given potential temperature range with time (figure 10) is a convincing way to show that transport is occurring via mixing. However, I wonder if much of the mixing is in fact due local turbulence (e.g., see "turbulence local to the cloud top" in Lane et al., 2003), as opposed to breakdown of the main stationary gravity wave caused by the overshoot. The mixing bullseye in figure 9h that is centered at x=-28 seems responsible for a greater increase in aerosol concentration than the bullseye at x=-17 and is not clearly associated with steep or overturning isentropes. This x=-28 bullseye also doesn't appear to be turbulence advected from the breakdown region, as it actually starts to form prior to the wave-breaking event. I would agree, however, that the breakdown of the main gravity wave (at x=-17) is probably very important for the highest potential temperature bins in figure 10b, as that mixing zone brings in the highest stratospheric temperatures. I would like the authors to address the issue of the different mixing zones, but otherwise strongly support publication of this informative and well-written article.

Specific comments

-page 10374, line 17:

How is the air mass "exposed"? Do you just mean to convey that the cold U region is due to air masses that have ascended past the level of neutral buoyancy? If so, "— cold U region is due to air masses that have —" would be clearer.

-page 10375, lines 20-22:

A cold front in the vicinity may have meant the pyroCb actually developed in an air mass with a lower tropopause and a different buoyancy profile than shown in the Edmonton sounding, which might have significant bearing on the TST. Was this considered? Did the ECMWF reanalysis show a sloping tropopause in the region?

-page 10386, lines 14-15:

You have calculated the equivalent potential temperature from the boundary layer to 8 km to be 320-322 K, which, when the fire heating is added, is not enough to reach tropopause temperatures. However, estimating from the sounding (figure 2), the equivalent potential temperature in the boundary layer looks to be at least 325 K. Did you include the boundary layer air mass (it was not clear from your wording if you only calculated from the top of the boundary layer, or from within the boundary layer)? If you are not considering the boundary layer air, why not? If, on the other hand, you are considering boundary layer air, the addition of a lifted parcel on figure 2 would help clarify the failure of parcel theory to explain the transport.

-page 10394, figure 1:

The structure in the visible channel that is mentioned in the text (page 10376, lines 21-22) is hard to discern. Could this figure be made larger to show higher resolution?

Technical corrections

-page 10372, lines 21-23:

This sentence is difficult to read. A suggested rewrite: “In its most extreme form, this fire-induced convection is called pyro-Cumulonimbus (pyroCb), a phenomenon shown by both observational and modeling studies to result in direct —”

-page 10380, line 29:

“In the case of water droplets —”

-page 10381, line 10:

overshooting top is centered at x=-15 km (minus sign omitted)

-page 10386, line 17:

“air masses” (space omitted)

-page 10394, figure 2:

“diagram”

-pages 10401-10402, figure 9:

“vertical”

Also, could this figure me made larger so that the potential temperature values could be read? Perhaps break into two four-panel figures.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 10371, 2007.

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