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A numerical process study on the rapid transport of stratospheric air down to the surface over western North America and the Tibetan Plateau

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Upper-level fronts are often associated with the rapid transport of stratospheric air along tilted isentropes to the middle or lower troposphere, there leading to significantly enhanced ozone concentrations. Only occasionally these plumes of originally stratospheric air can be observed at the surface, because (i) stable boundary layers prevent an efficient vertical transport down to the surface, and (ii) if boundary layer turbulence is strong enough to enable this transport, the originally stratospheric air mass is strongly diluted by mixing such that only a weak stratospheric signal can be recorded at the surface.

Most documented examples of stratospheric air reaching the surface are from mountaineous regions. This study investigates two such events, using a passive stratospheric air mass tracer in a mesoscale model to address the processes that enable the transport down to the surface. The events occurred in early May 2006 in the Rocky Mountains and in mid June 2006 on the Tibetan Plateau. In both cases, a tropopause fold associated with an upper-level front enables stratospheric air to enter the troposphere. In our model simulation of the North American case, the strong frontal zone reaches down to 700 hPa and leads to a fairly direct vertical transport of the stratospheric tracer along the tilted isentropes to the surface. In the Tibetan Plateau case, however, no near-surface front exists and a reservoir of high stratospheric tracer concentrations forms at 300-400 hPa, without further isentropic descent. Entrainment at the top of the very deep boundary layer (reaching to 300 hPa over the Tibetan Plateau) and turbulence within the boundary layer fosters downward transport of stratospheric air to the surface.

Interestingly, despite the strongly differing dynamical processes, stratospheric tracer concentrations at the surface reach peak values of 10-20% in both cases, indicating the potential of deep stratosphere-to-troposphere transport events to significantly influence surface ozone concentrations in these regions.