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How deep land convective overshooting can penetrate the stratosphere?

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The amount of water vapour and ozone depleting substances in the stratosphere depends on how tropospheric air is transported into the stratosphere. Following Newell and Gould-Stewart (1981) it is generally assumed that Troposphere-Stratosphere exchange occurs where the tropopause is the coldest, the "Stratospheric Fountain" over the Maritime continent. However, if convective transport is observed to reach the TTL around 14km over oceans, there is no indication that it could cross the tropopause around 17.5km at 370K. A further mechanism is required attributed to slow radiative heating. However and although thought to be infrequent, it has been shown that overshoots over land could penetrate deeper the stratosphere. Indeed and in contrast to oceanic convection, land systems are displaying a strong diurnal cycle resulting in fast afternoon uplifts. Here we investigate the impact of convection on the TTL temperature over Brazil from 4 daily radiosondes during the HIBISCUS campaign in February 2004. In the presence of deep convection, the TTL is found to be cooler between 16 and 19 km (maximum 8K at 17 km). About half of this is shown to be due to a systematic diurnal variation displaying an average cooling of 3-4 K at 17-18 km in the afternoon between 11:00 and 17:00 LT, during the development phase of convection. Since this cooling occurs above the tropopause, during daytime and within a time scale of 6h, it cannot be attributed to radiation or large-scale waves, suggesting insertion of cold air parcels by overshooting followed by mixing with the warmer environment. During most intense convective days, the overshoot is shown to penetrate the stratosphere up to 440K potential temperature levels.