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The role of small scale processes in troposphere-stratosphere transport by pyro-convection

G. Luderer (1), J. Trentmann (2), K. Hungershoefer(3), M. Herzog (4), M. Fromm(5), R. Servranckx(6), M. O. Andreae (1)

(1) Dept. of Biogeochemistry, Max Planck Institute for Chemistry, Mainz, Germany, (2) Institute for Atmospheric Physics, University of Mainz, Germany, (3) Institute for Meteorology, University of Leipzig, Germany, (4) Geophysical Fluid Dynamics Laboratory (GFDL), NOAA, Princeton, USA, (5) Naval Research Laboratory, Washington DC, USA, (6) Meteorological Service of Canada, Montreal, Canada (Contact: gunnar@mpch-mainz.mpg.de)

Deep convection induced by large forest fires is an efficient mechanism for transport of aerosol particles and trace gases into the upper troposphere and lower stratosphere region. Several cases of stratospheric smoke injection by such pyro-cumulonimbus (pyroCb) convection have been documented. For these pyroCbs as well as other cases of severe convection without fire forcing, radiometric observations of cloud tops in the thermal IR reveal characteristic structures featuring a region of relatively high brightness temperatures (warm core) surrounded by a v-shaped region of low brightness temperatures.

The Chisholm fire presents a well studied case of stratospheric smoke injection by pyro-convection. We performed numerical simulations of the Chisholm pyroCb using the Active Tracer High resolution Atmospheric Model (ATHAM), a non-hydrostatic cloud resolving model with a two-moment cloud microphysics parameterization and a prognostic turbulence scheme. The model was able to reproduce the IR structure as observed by satellites. Our results show that the thermal structure of the cloud top is due to small scale mixing around the overshooting cloud top. Due to the gravity wave induced by the overshoot, gradients of smoke concentration and potential temperature are very large in this area. Turbulent kinetic energy advected from the pyroCb interior and generated at the cloud top results in efficient cross-isentrope mixing. This process is found to be of major significance for irreversible transport of smoke into the lower stratosphere.