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Modeling of biomass smoke injection into the lower stratosphere by a large forest fire (Part I): reference simulation

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Abstract. Wildland fires in boreal regions have the potential to initiate deep convection, so-called pyro-convection, due to their release of sensible heat. Under favorable atmospheric conditions, large fires can result in pyro-convection that transports the emissions into the upper troposphere and the lower stratosphere. Here, we present three-dimensional model simulations of the injection of fire emissions into the lower stratosphere by pyro-convection. These model simulations are constrained and evaluated with observations obtained from the Chisholm fire in Alberta, Canada, in 2001. The active tracer high resolution atmospheric model (ATHAM) is initialized with observations obtained by radiosonde. Information on the fire forcing is obtained from ground-based observations of the mass and moisture of the burned fuel. Based on radar observations, the pyro-convection reached an altitude of about 13 km, well above the tropopause, which was located at about 11.2 km. The model simulation yields a similarly strong convection with an overshoot of the convection above the tropopause. The main outflow from the pyro-convection occurs at about 10.6 km, but a significant fraction (about 8%) of the emitted mass of the smoke aerosol is transported above the tropopause. In contrast to regular convection, the region with maximum updraft velocity in the pyro-convection is located close to the surface above the fire. This results in high updraft velocities >10 m s^{-1} at cloud base. The temperature anomaly in the plume decreases rapidly with height from values above 50 K at the fire to about 5 K at about 3000 m above the fire. While the sensible heat released from the fire is responsible for the initiation of convection in the model, the release of latent heat from condensation and freezing dominates the overall energy budget. Emissions of water vapor from the fire do not significantly contribute to the energy budget of the convection.

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