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Organic Vapor Condensation in Pyro-cumulonimbus Outflow Explains Large Stratospheric Smoke Mass Injection and Thickly Coated Black Carbon

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Airborne measurements of upper troposphere and lower stratosphere biomass burning smoke show a large size mode at 350nm radius. Furthermore, very thickly coated black carbon (300-400nm radius) is observed in 2 month aged Pyro-cumulonimbus (PyroCb) smoke in the lower stratosphere. Finally, the stratospheric aerosol mass injections from the 2017 British Columbia (BC17) PyroCbs are much larger than fuel loading predicts. We propose a secondary organic aerosol (SOA) production mechanism where volatile organic compounds (VOCs) emitted by fires condense in the cold convective PyroCb updrafts to explain the aforementioned data. Observations supporting this mechanism present in FIREX-AQ, ATOM and CARIBEC airborne data are synthesized. The condensation, evaporation and coagulation mechanisms are implemented into LANL's large eddy cloud resolving model called HIGRAD. Our simulations provide insights into the vertical distribution of SOA in the BC17 PyroCb and the role of warm and ice clouds in lofting it into the lower stratosphere. We show that SOA formation can increase aerosols by a factor of 2-3 and latent heat from warm and ice clouds adds 5 km to the injection height of BC17 fire smoke. The fate, transport and impacts of smoke from BC17 and 2020 Australian fires are examined using climate model (CESM) simulations.