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The Australian bushfires of 2019/20 caused a massive injection of combustion products into the stratosphere that led to a persistent planetary-scale perturbation of all stratospheric climate-relevant variables. This extreme event enabled study of a striking atmospheric phenomenon, the smoke-charged vortex (SCV) – a persistent synoptic-scale anticyclone, which acts to confine the carbon-rich aerosol clouds during their solar-driven rise. This way, highly-concentrated absorbing aerosols are lofted above 30 km, which prolongs their stratospheric residence time and radiative effects. Here, we use lidar observations at Lauder, New Zealand together with high-resolution radiosonde data and ozone soundings as well as satellite observations (CALIPSO, MLS, TROPOMI) and ERA5 reanalysis to characterize the optical, chemical and thermodynamical properties of a matured 7-km-tall SCV during its transfer over the South Island at 27 km altitude. The gaseous composition of the SCV was characterized by strongly enhanced water vapour and depleted ozone concentrations, leading to a synoptic-scale ozone hole with the total column reduced by up to 20%. The lidar measurements reveal a characteristic bottom-side elongation of the smoke bubble – a tail of aerosols extending over hundreds of kilometers and rotating together with the main body.

Using long-term ground-based lidar and satellite measurement records, we show that monthly-mean stratospheric aerosol optical depth in early 2020 was highest since the major eruption of Mt. Pinatubo in 1991. With that, the removal of smoke aerosol from the stratosphere took longer than one year.