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Dynamics of ascending smoke-charged anticyclones

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Anticyclonically-trapped plumes were discovered following the unprecedented 2020 Australian fires, which saw the rise of a 1,000-km diameter, 6-km deep bubble of tropospheric air enriched in combustion products from 19 to 35 km asl over 3 months. Since then, a number of previous occurrences has been reported, notably in the aftermath of the 2017 Canadian fires. Lifted by solar heating from black carbon aerosols, the long-lived anticyclonic plumes are characterized by a joint upward motion of plume material and anticyclonic potential vorticity (PV). These newly discovered objects raise fundamental questions from a dynamical standpoint. In particular, although the similar evolution of tracers and PV is a well-known property of quasi-adiabatic flows, it has no reason to hold in the presence of diabatic heating. Hence, there is seemingly a contradiction between the observed preservation of the low PV-aerosol-tracer relationship over time and fundamental properties of PV in this diabatically-forced flow.

In this presentation, we propose a conceptual model for the formation and evolution of smoked-charged anticyclones. The mechanisms at play will first be illustrated using idealized numerical simulations with the Weather Research and Forecast (WRF) model where we explore for the first time the flow response to a Lagrangian tracer locally heating the atmosphere. We will then analyze key features of the observed anticyclonic structures reproduced by the model, including the maintenance of the anticyclonic tracer bubble along its ascent, the formation of a tracer front at its top and of a tail at its lower bound, and a very low, almost-vanishing PV within the vortex. Finally, we will discuss some implications of our findings, in particular regarding the dynamical conditions favoring the formation and maintenance of such structures.