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The modest role of pyrogenous moisture in pyrocumulus development

Jeffrey Kepert (1), Will Thurston (2), and Kevin Tory (1)

(1) Bureau of Meteorology, Science to Services, Australia (jeff.kepert@bom.gov.au), (2) UK Met Office

Pyro-convective clouds have the potential to increase surface rates of wildfire spread, enhance ember transport, generate lightning and tornadic storms, and alter the Earth's radiative balance through the stratospheric injection of combustion products. It is well known that sufficient moisture is required for a buoyant plume above a wildfire to generate pyro-convective cloud, and indeed this happens with some degree of regularity. However, the moisture source has been questioned recently, with conflicting arguments regarding the relative significance of pyrogenous moisture and entrained environmental moisture. Here we attempt to quantify the relative importance of these two sources in pyrocumulus development. We expand upon previous case-study-based modelling approaches by performing large-eddy simulations of buoyant wildfire plumes of different intensities and over the environmental moisture—pyrogenous moisture parameter space, using circular surface heat and moisture fluxes to represent idealised fires.

Intense fires in sufficiently moist atmospheres can produce pyro-convective cloud in the absence of any pyrogenous moisture, and the cloud is deeper for the more-intense fires and moister atmospheres. The addition of pyrogenous moisture only has a small effect on the development of pyro-convective cloud. Further analysis reveals that this is due to substantial entrainment of environmental air into the sub-cloud buoyant plume. We show that entrainment dilutes the pyrogenous moisture in the plume to such an extent that it contributes to only a small fraction of the overall plume moisture at the cloud base, suggesting that relative to environmental moisture, pyrogenous moisture plays only a modest role in pyrocumulus development. This is a reassuring result for forecasting pyro-convective cloud and its impacts, since the atmospheric moisture is comparatively easy to measure and predict, compared with the poorly observed fire moisture.