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The development of a pyrocumulonimbus prediction tool

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In favourable atmospheric conditions, large hot fires can produce pyrocumulonimbus (pyroCb) cloud in the form of deep convective columns resembling conventional thunderstorms, which may be accompanied by strong inflow, dangerous downbursts and lightning strikes. These in turn may enhance fire spread rates and fire intensity, cause sudden changes in fire spread direction, and the lightning may ignite additional fires. Dangerous pyroCb conditions are not well understood and are very difficult to forecast.

Here, a conceptual study of the thermodynamics of fire plumes is presented to better understand the influence of a range of factors on plume condensation. Recognising that plume gases are undilute at the fire source and approach 100% dilution at the plume top (neutral buoyancy), we consider how the plume condensation height changes for this full range of dilution and for a given set of factors that include: environmental temperature and humidity, fire temperature, and fire moisture to heat ratios. The condensation heights are calculated and plotted as saturation point (SP) curves on thermodynamic diagrams for a broad range of each factor. The distribution of SP curves on thermodynamic diagrams provides useful insight into pyroCb behaviour.

A method is proposed for identifying on an atmospheric sounding the minimum plume height and plume buoyancy at which free moist convection can develop. A pyroCb forecast tool is being developed that uses this free convection plume height and buoyancy, in combination with a simple analytical plume model, to estimate the net buoyancy flux and fire power required for pyroCb formation from a single atmospheric sounding. Applied to numerical weather prediction models, it is anticipated that spatial and temporal forecast maps of threshold “fire power” will be generated and made available to operational forecasters as a tool to identify pyroCb threat.