IS FIRE MOISTURE IMPORTANCE FOR PYROCUMULUS DEVELOPMENT?

bushfire&natural HAZARDSCRC

K. J. Tory[1,2], W. Thurston[1,2], J. D. Kepert[1,2]

[1] High Impact Weather, Research and Development, Bureau of Meteorology, [2] Bushfire & Natural Hazards CRC, Melbourne, Victoria

PYROCUMULONIMBUS CLOUDS HAVE BEEN LINKED TO HIGHLY DANGEROUS FIRE BEHAVIOUR. ONE OF THE MANY CHALLENGES OF FORECASTING PYROCUMULONIMBUS IS KNOWING HOW MUCH FIRE HEAT AND MOISTURE SHOULD BE INCLUDED IN ESTIMATES OF PLUME INSTABILITY. THIS STUDY SUGGESTS FIRE MOISTURE CAN BE IGNORED.

MODELLING METHODOLOGY

- The UK Met Office Large-Eddy Model (LEM) is used to perform high-resolution, time-varying, three-dimensional simulations of bushfire plumes, represented by a surface heat source (250 m diameter, 30 $kW\ m^{-2}$ intensity), in a 4 km deep well mixed boundary layer (black line in Fig. 1).
- **Experiment 1:** The sensitivity of PyroCu formation is tested using a range of atmospheric moisture profiles depicted in Fig. 1 (blue lines). The boundary-layer moisture varies between 2 and 4 $g\ kg^{-1}$ for each simulation.
- **Experiment 2:** A second set of simulations adds "fire moisture" (evaporation of fuel moisture, and moisture from combustion),to the 4 $g\ kg^{-1}$ boundary-layer moisture experiment, by including surface latent heat fluxes (L_E) of 2.1 (dry) and 11.4 (moist) $kW\ m^{-2}$.

EXPERIMENT 1: PLUME SENSITIVITY TO BOUNDARY LAYER MOISTURE

Figure 2 shows the moistest environment plume (centre) is about1 km deeper than the driest environment plume (left, cf. red arrows), the cloud base is about 1.5 km lower (cf. yellow arrows) and there is considerably more cloud present. The lower cloud base latent heat release provides increased buoyancy that deepens the plume.

EXPERIMENT 2: PLUME SENSITIVITY TO FIRE MOISTURE

The moist fire heat source is applied to the moist boundary layer (right panels of Fig. 2). Comparisons between the centre and right panels show the additional fire moisture has a barely discernible influence on cloud-base height, but a small difference in plume height.

WHY ISN'T FIRE MOISTURE IMPORTANT?

Fire plumes entrain large amounts of environmental air as they ascend, which greatly dilutes the plume gases, including the fire moisture. Figure 3 shows the fire moisture dilution for the moist fire simulation(right panels of Fig. 2). The lightening shades of blue with height demonstrate the fire moisture dilution. When the plume reaches the condensation level (4.5 km) there is barely any fire moisture evident to contribute to cloud development. The dilution rate may be sensitive to fire size and intensity.

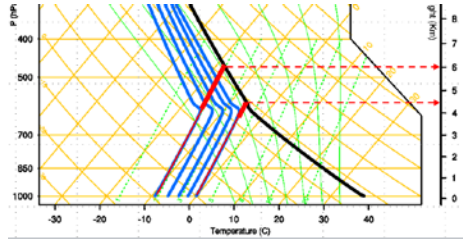

Figure 1: Thermodynamic profiles for the boundary-layer moisture experiments (blue lines). The red lines show the estimated cloud-base height, using the objective method described in the box below.

Lareau and Clements (2016) PyroCu cloud-base forecast technique:

- A technique for predicting the cloud-base height of pyrocumulus clouds uses a standard thermodynamic diagram as depicted in Fig. 1. The boundary-layer moisture trace (blue line) is extended upwards at constant mixing ratio. The cloud base is the height it intersects the temperature trace (black line).
- Moisture from the fire is assumed to be negligible.
- This method predicts accurately the simulated cloud bases for the 2 and 4 $g\ kg^{-1}$ atmospheric moisture experiments (Fig. 2).

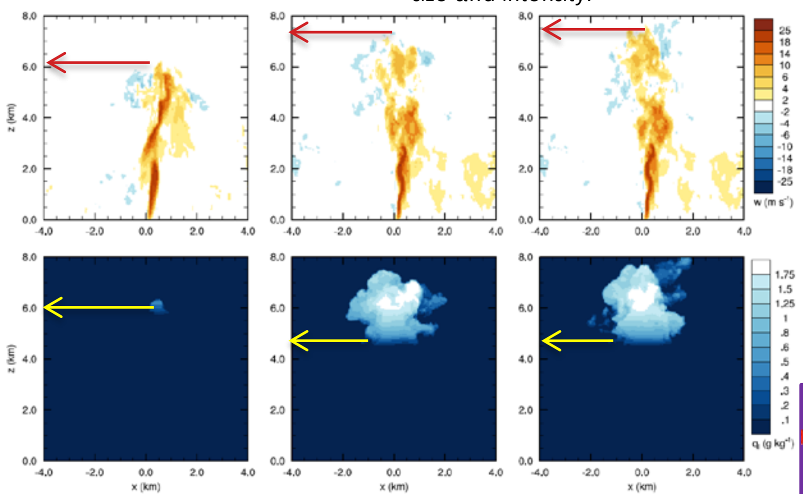

Figure 2: Vertical velocity (upper) and cloud water (lower) for the 2 (left) and 4 (centre) $g\ kg^{-1}$ boundary layer moisture simulations. The moist boundary layer (4 $g\ kg^{-1}$) simulation is repeated with a moist fire (11.4 $kW\ m^{-2}$, right). The arrows indicate cloud base (yellow) and plume top (red) height.

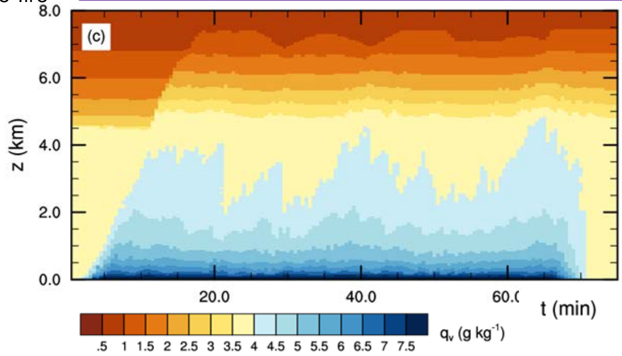

Figure 3: Time-height plot of environmental moisture (yellow-red shades) and fire moisture (blue shades).

Conclusions:

- For a given temperature profile, PyroCu development is very sensitive to environmental moisture. Moister environments produce deeper plumes and lower condensation heights.
- Fire moisture had minimal influence on PyroCu development (even for the very moist fire case presented here) due to substantial entrainment as the plume ascended to the 4.5 km condensation level.
- The Lareau and Clements PyroCu cloud-base forecast technique, which ignores fire moisture, accurately predicted the cloud bases for each simulation presented.

Reference:

Lareau, N. P. and C. B. Clements, 2016: Environmental controls on pyrocumulus and pyrocumulonimbus initiation and development. *Atmos. Chem. Phys.*, **16**, 4005—4022. doi:10.5194/acp-16-4005-2016.

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