Idealised numerical modelling of bushfire plumes

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Introduction

The lofting of firebrands from bushfires into a background flow leads to spotting downwind of the fire front. Firebrands can travel a considerable distance under suitable conditions, so lofting and spotting make a significant contribution to the spread of fires. A thorough knowledge of the potential for lofting from a fire is therefore desirable in order to accurately predict the fire's rate of spread and coverage.

The interaction between the atmospheric boundary layer, topography and fire convective column can lead to strong and deep updrafts with great potential for firebrand lofting. Here we present some preliminary, very high resolution, idealised simulations which explore the behaviour of thermal plumes under different background atmospheric conditions.

Methodology

We use the UK Met Office Large Eddy Model (LEM) to perform a number of two-dimensional, idealised simulations over a 20 km wide by 20 km high domain with a grid spacing of 50 m. The model is initialised with the horizontally homogeneous wind and potential temperature profiles shown in Fig. 1 (A,B), upon which the circular potential temperature perturbation in Fig. 1 (C) is superimposed.

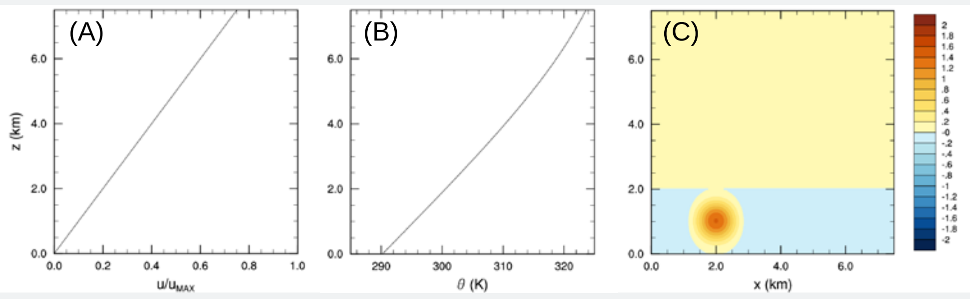

Fig. 1. Initial conditions for the LEM simulation. (A) velocity profile, (B) potential temperature profile and (C) potential temperature perturbation.

This method of initialising with an instantaneous warm bubble differs from continuous heat source at the surface provided by a fire, however it provides preliminary insight into thermal plume behaviour. Six simulations are presented in total, with u_{MAX} values of 2, 4, 8, 12, 16 and 20 m s^{-1}, to assess the impact of wind shear on the rising plume.

Results

Snapshots of the rising plume at 10, 20 and 30 minutes are shown in Fig. 2 for the u_{MAX} = 2 m s^{-1} wind regime and in Fig. 3 for the u_{MAX} = 16 m s^{-1} wind regime. Under the weak wind-shear regime, the plume remains almost axially symmetric as it rises, forming a pair of counter-rotating eddies that enhance the central updraft after 20 minutes of simulation time. Under the stronger wind-shear regime, the plume rise begins more asymmetrically and by 20 minutes the plume is fully bent over. After 30 minutes, the plume in weak wind shear still has a coherent, symmetric structure, whereas the plume in strong wind shear has become far more diffuse, with a reduced updraft speed.

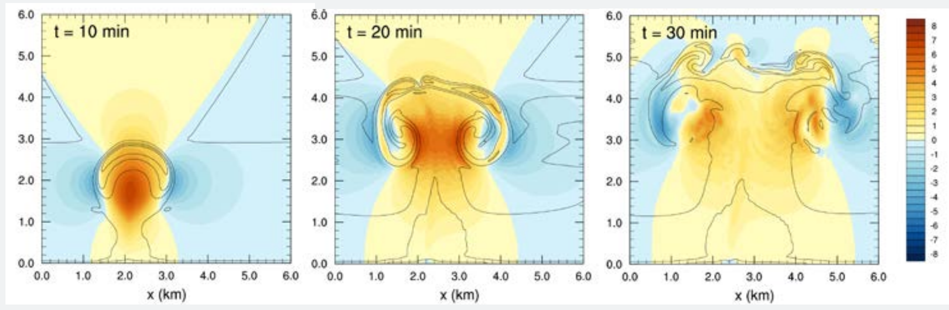

Fig. 2. Potential temperature perturbation, contours every 0.4 K, overlaid on vertical velocity (m s^{-1}), solid colour. Model output shown after 10, 20 and 30 minutes of simulation time for the u_{MAX} = 2 m s^{-1} case.

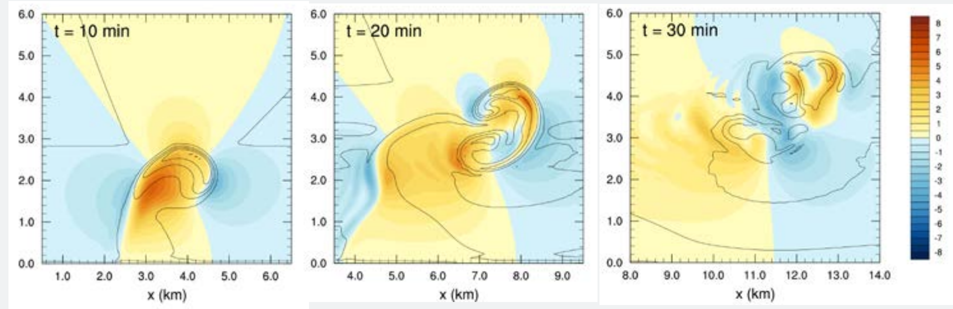

Fig. 3. Potential temperature perturbation, contours every 0.4 K, overlaid on vertical velocity (m s^{-1}), solid colour. Model output shown after 10, 20 and 30 minutes of simulation time for the u_{MAX} = 16 m s^{-1} case. Note the time-varying distance values along the x-axis.

Timeseries plots of the maximum updraft velocity and the horizontal location of the maximum updraft for all six simulations are given in Fig. 4. The peak updraft speed varies between 5.4 and 8.1 m s^{-1} from the strongest to the weakest wind-shear simulations.

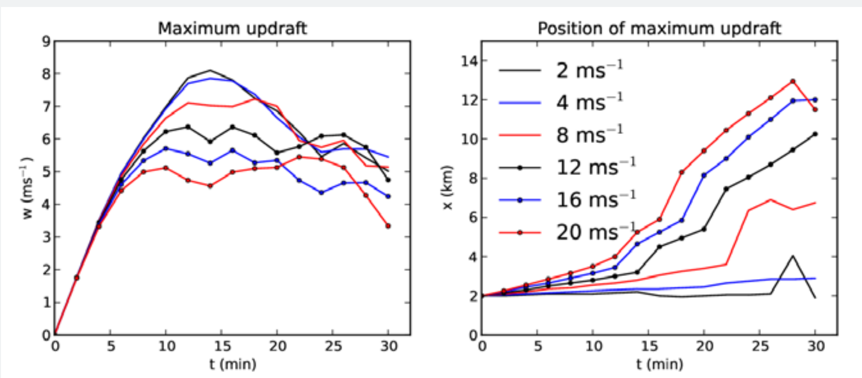

Fig. 4. Timeseries of the maximum updraft (m s^{-1}) and the location downwind of the maximum updraft (km) for the thermal plume under the six different wind regimes.

Summary

We have used the UK Met Office LEM to perform very high resolution, idealised simulations of thermal plume rise under varying wind regimes. Plumes in weak wind shear were more symmetric in structure than the highly tilted over, asymmetric plumes in strong shear. The asymmetry reduces the maximum updraft, and thus firebrand lofting potential. The weakly-sheared plumes have maximum updrafts up to 50% larger than the plumes in stronger shear.

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