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Exploring three-dimensional coupled fire–atmosphere interactions downwind of wind-driven surface fires and their influence on backfires using the HIGRAD-FIRETEC model

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Abstract. The obstruction of ambient winds and the possible existence of indrafts downwind of a wildfire are aspects of coupled fire–atmosphere interaction influencing the effectiveness of a backfiring operation. The fire-influenced winds behind a headfire as well as their influences on backfire spread are explored using the three-dimensional HIGRAD-FIRETEC model. Fires are simulated under weak to strong wind speeds and in shrubland and grassland fuel types. The importance of three-dimensionality in the simulation of such phenomena is demonstrated. Results suggest that when fire–atmosphere interaction is constrained to two-dimensions, the limitations of air moving through the head fire could lead to overestimation of downwind indrafts and effectiveness of backfiring. Three-dimensional simulations in surface fuels suggest that backfires benefit from the obstruction of ambient winds and potentially the existence of an indraft flow in only a limited range of environmental conditions. Simulations show that flows are most favourable when the wildfire is driven downslope by a weak wind and the backfire is ignited at bottom of the slope. Model simulations are compared with backfiring experiments conducted in a dense shrubland. Although this exercise encountered significant difficulties linked to the ambient winds data and their incorporation into the simulation, predictions and observations are in reasonable agreement.

Additional keywords: backfire, indraft, suppression fire.

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Introduction

Wildfires often include significant buoyant updrafts resulting from the heat released as a part of the combustion process. As air is drawn upward, these updrafts in turn create a pressure deficit below them, which draws air in from its surroundings. In situations near the ground where the mean wind is not sufficient to feed the draw below the updraft, lateral indrafts can occur. In the context of a wildfire, the strength of these indrafts and their vertical profiles depend on the intensity of the fire, the strength of the resulting buoyant plume, the ambient wind speed and the nature of the vegetation drag.

The significance of the indrafts and the interaction between the indrafts and the ambient winds with respect to fire spread enable fire managers to consider managing fire spread by managing the ventilation of the fire. One way to manage the fire through management of its ventilation is to create situations where one fire's indraft or its obstruction of flow affects another fire in an advantageous way. A good example of this tactic is the use of backfires, where a second fire (the backfire) is ignited downwind of the fire that is to be managed (the head fire). In this text, we will use the terms backfiring and backfire to designate the operation and the fire used to perform this operation respectively (Chandler *et al*. 1983). Backfires are sometimes called counter-fires.

Ideally, the backfire is established in a position where the heading fire is obstructing the ambient winds that would otherwise reach the backfire. Firefighters sometimes report that the head fire also induces an indraft wind but the conditions for these indrafts are not well understood (Benoît de Coignac 1986). The existence of the indraft flow is also part of a theory

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