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THE BUSHFIRE CONVECTIVE PLUME EXPERIMENT: MOBILE RADAR OBSERVATIONS OF PYRO-CONVECTION FROM THE MT BOLTON FIRE, 2016

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ABSTRACT

Immediately above fires are the extremely localised columns of buoyant air known as convective plumes. The intensity and evolution of convective plumes is critical in the understanding of lofting and spotting of firebrands, where plume structure begins to play an important role in how the firebrands are spatially distributed. Weather radar has been demonstrated as a highly effective tool in analysing plume structure and evolution, but there is very little research using mobile radar in the field despite its proven effectiveness in deconstructing the meteorology of severe convection in thunderstorms. In January 2016, observations were taken at two bushfires using a portable dual-polarisation X-band Doppler radar in Victoria. One of these fires at Mt Bolton showed significant plume-driven fire behaviour, with a convective plume extending up to 7 km above the surface captured on the mobile radar. Here we present the initial findings of this observational dataset of convective plume dynamics, with unprecedented detail in resolution including the development of a deep convective cloud above the fire. We also show that a unique differential reflectivity signature within the dual-polarisation data could bear potential links to the identification of ember and firebrand transport within the plume. This is explored for the Mt Bolton fire where several spot fires were documented over 5 km from the fireground.

EXTENDED ABSTRACT

The study of convective bushfire plumes is critical to improve accuracy of bushfire-spread models and has direct impacts on operational bushfire management. Weather radar has been demonstrated as a highly effective tool in observing pyro-convective plume structure and evolution, and is used by fire behaviour analysts. However, very little research has combined the analysis of radar data above fires with simultaneous measurement of the key thermodynamic aspects in the atmosphere that govern the development of convective plumes above fires. The Bushfire Convective Plume Experiment aims to identify key indicators of intense pyro-convections by means of direct observation using mobile weather radar and aerological soundings (weather balloons), along with other supporting instrumentation in the field at going bushfires. With the support of the Country Fire Authority, the first major observations were obtained following a deployment to the Mt Bolton bushfire in Victoria in early 2016.

While pyro-convective fires may only develop for a portion of bushfires in Australia, these fire-atmosphere coupled events are some of the most difficult fires to manage from an operational perspective. Research to date of pyro-convection in Australia has focused predominantly on numerical modelling, reflecting in part the challenges of direct observation. As promising results are arrived at, verification with direct measurements is becoming an increasingly pressing need (Cunningham and Reeder, 2009; Simpson et al., 2013; Thurston et al, 2013). For example, both nationally and internationally, debate continues in the field of fire-atmosphere interaction on the role of heat as compared to moisture in pyro-convective plumes (Potter, 2005; Achtemeier, 2006; Luderer et al., 2006; 2009; Parmar et al., 2006; Kiefer et al., 2012; Tory and Thurston, 2015).

The general structure of pyro-convective plumes is well established, and is built around the framework of the idealised model of a main updraft and downdraft, supported by various flow features and structures including vortices (Potter 2012ab). However, the spatial and temporal scales on which these features exist present a problem for investigation especially in the fire environment, requiring multiple lines of investigation that range in scale from metres with vortices to that of kilometres in overall plume growth. The recent review of pyro-cumulus and pyro-cumulonimbus (pyroCb) interaction with bushfire highlights operational problems associated with pyro-convection specifically for an Australian context. The review emphasized knowledge gaps pertaining to the role of the pyroCb in closing the feedback loop between fire and atmosphere in how pyro-convection influences surface fire behaviour as implied by Rothermel (1991) and Banta et al. (1992). Equally as important, they raised the question as to the relative importance of atmospheric environmental factors (such as stability) as compared to fire-induced factors (such as released heat and moisture) in triggering pyro-convection.

To begin to address the fundamental dearth of quantitative data on pyro-convection in an Australian context, the Bushfire Convective Plume Experiment undertook initial work during the 2014-2015 bushfire season in order to pilot, test equipment and establish procedures for direct measurement of pyro-convection. The framework of the experiment is a trailer equipped with portable dual-polarised X-Band Doppler radar (UQ-XPOL), ab atmospheric sounding system, Portable Automatic Weather Stations and timelapse cameras. This equipment is used for rapid deployments to the vicinity of going firegrounds to employ as much of it as is safely possible to observe the complex meteorology of pyro-convection. The

development of this novel methodology involved extensive risk treatment and mitigation strategies to allow the research to take place in an ongoing bushfire environment with minimisation of impact on fire management operations. From January to March 2016, the fieldwork domain for collecting the first direct observations of pyro-convective plumes above bushfires was extended over all of south-east Australia with a focus on western Victoria where fuels were driest.

The deployment to the Mt Bolton bushfire on 23 February represented the first significant observations of pyro-convection using the UQ-XPOL radar. The fire burnt through a mixture of remnant bushland as well as pine and native plantations on a day of severe fire danger. It exhibited significant spotting behaviour, both short- and long-range before and after a significant wind change. A pyro-convective column observed by UQ-XPOL extended up to an approximate height of 6,000 metres, including deep cloud development associated with the fire. In addition to a large amount of dual-polarisation data collected pertinent to the microphysics of the column, the observations on the scale of the structure of the plume included several key results that relate directly to the fire behaviour and significant spotting on the day. These observations include tilting of the plume and interaction with upper level winds, as well as large fire-induced horizontal vortices. Previously, both tilting and vortices have been highlighted in the literature as important to the dynamics of long-range spotting but the lack of quantitative data on the atmospheric side of the process has limited the conclusions that can be made on their role (Berlad and Lee, 1968; Kerr et al., 1971). The observations are coupled with aerial photography of fire behaviour and spotting on the day, as well field mapping following the incident to provide a comprehensive picture of the plume dynamics on the day.

The success of the 2015–2016 field campaign for the Bushfire Convective Plume Experiment provides several standalone findings pertinent to convective plume dynamics and critically provides the proof of concept for the ability of a rapid deployment of mobile radar as a highly effective tool for deconstructing the behavior of convective plumes. With this proof of concept obtained, plans are in place for an extensive field campaign through the 2016–2017 bushfire season in south-east Australia.

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