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Observations of vorticity-driven lateral spread in a wildfire

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Abstract: A HPWREN camera system is installed on Santigo Peak in California. The Airport Fire, on two consecutive days burned past the cameras by means of vorticity-driven lateral spread (VLS). This provided the most complete sets of time-series observation of VLS on a landscape-scale. Some remarkable measurements are derived from the observations. The overall lateral rate-of-spread averaged at 1.9 km/hr. Around plume touch-down events that rose to 4 km/hr, but also peaked at 20 km/hr. Effective downwind spread of the overall fire envelope was 45 km/hr. A major spot-fire had a slope-affected headfire rate-of-spread of 15 km/hr (equivalent to c.2 km/hr on flat ground) and a burn rate of 150 ha/hr. The implications for fireground safety are extreme. An emphasis must be placed on predicting these events, as any burn-over entrapments may well be unsurvivable. For this reason, fire behaviour models need to be able to indicate the potential for such behaviour.

Keywords: *VLS, HPWREN, California, spot-fire, ember storm, eddy wind, extreme wildfire, blow-up fire event, fire camera, lateral spread*

1. INTRODUCTION

A HPWREN camera system is installed on Santigo Peak in California (117.57° 33.71°). The four wide-angle cameras each provide a frame per minute. HPWREN, based at University of California at San Diego forms part of a growing on-line fire camera network in the west of the USA.

The Airport Fire started on 9 September 2024 and burnt 23.500 ha. On two consecutive days it burned past the cameras by means of vorticity-driven lateral spread (VLS). This provided unprecedented sets of time-series observation of VLS on a landscape-scale. VLS involves fire entering a lee-slope eddy wind while fine fuels are dry. It has been modelled, recreated in laboratories and observed in the field with remote

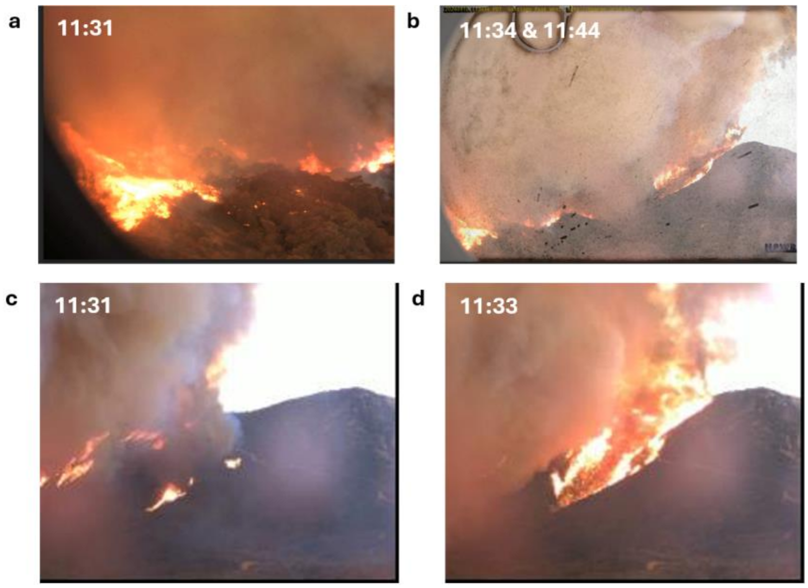

Figure 1. Details from HPWREN imagery as fire nears Modjeska Peak. (a) shows dense, short-range spotting close to the camera at 11:31. (b) is a highly filtered composite image showing fire approaching the camera from the west and forming new spot-fires outside the lee-slope eddy at 11:34 and embers (black) radiating out at 11:44 from a source point in the area affected by those new spot-fires. The fire is clearly making intense runs in two opposing directions. (c) and (d) show an intense spot-fire within the lee-slope eddy at 11:31 and 11:33, with significant spread in those two minutes.

sensing. Direct observations have been lacking. The HPWREN videos on these two days were clear and of high resolution.

On the 9th a VLS event downwind of the cameras moved past while spreading laterally. The formation of spotfires downwind was well recorded. On the 10th a new VLS event formed upwind and spread laterally past the camera while igniting the landscape near the cameras.

2. OBSERVATIONS

Some remarkable measurements are derived from the observations (Figure 1). The overall lateral rate-of-spread averaged at 1.9 km/hr. Around plume touch-down events that rose to 4 km/hr, but also peaked at 20 km/hr. Effective downwind spread of the overall fire envelope was 45 km/hr. A major spot-fire had a slope-affected headfire rate-of-spread of 15 km/hr (equivalent to c.2 km/hr on flat ground) and a burn rate of 150 ha/hr. These rates mean that the situation would be unsurvivable for any field crews nearby.

Ignition of the hillside near the cameras was well recorded. This allowed quantification of a VLS induced burn-over situation (Figure 2). It lasted 31 minutes, with a pulse of heavy smoke every 10 minutes, each lasting 8 minutes on average. There were 7 pulses of embers, each 3 minutes apart, lasting on average 2 minutes. The embers were an ember storm (a field of terrain following embers), with no ballistic embers recorded. While suggested, there was no unambiguous record of the fire jetting laterally along the ridgetop wind separation line.

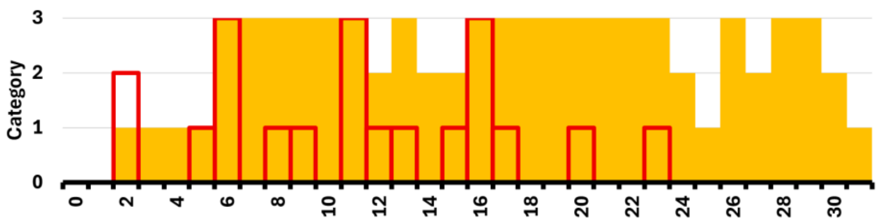

Figure 2. Summary of ember activity close to the camera, detailing an ember storm life-cycle, starting at 11:33. Smoke density in the images (yellow) is shown using three classes: 1 = some smoke visible; 2 = heavy smoke; 3 = opaque smoke obstructing view. Ember density (red outline) is overlaid on smoke density and is shown using three classes: 1 = few visible; 2 = some visible; 3 = many visible.

3. CONCLUSIONS

Terrain geometry can affect VLS behaviour. If the fire gets hot the plume can rise to nearly vertically. As the fires ease the overall plume-base may touchdown under the influence of complex local wind patterns, starting new spotfires. These may enhance the fire, leading to a new pulse.

These fires are too dangerous for planned research activities to be conducted. More such observational data are needed to better understand such complex fire behaviour. The most detailed observations will come when a fire comes into view of fixed, high-quality systems such as HPWREN or AlertCalifornia, which have sub-metre middle-ground resolution and repeat times of 1 minute or less. These are becoming widely used in Australia.

The implications for fireground safety are extreme. An emphasis must be placed on predicting these events, as any burn-over entrapments may well be unsurvivable, even with burn-over protection equipment. For this reason, fire behaviour models need to be able to indicate the potential for such behaviour.

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