Bushfire Resilience Inc. Webinar 4 2024. Presentation 3

Understanding our changing bushfire weather

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Malcolm

Welcome to the fourth webinar of our 2024 series. Understanding Our Changing Bushfire Weather.

I know from firsthand experience Understand your weather Know your risk. It's a fact.

Tonight we have three industry experts - Kevin Parkyn, Justin Leonard and Mika Peace.

Our objective is to provide information to help you and explain how you will be affected.

Malcolm
Now we'll hear from Mika with some information that I think will all be very new to us. Thanks Mika.

Mika
Good evening everyone. I'm going to talk about something a little bit different to Justin and Kevin. I'm going to talk about the processes and meteorological drivers of fire behaviour and what we know and what might change into the future.

Some of you may have seen some of the detail of the IPCC (Intergovernmental Panel on Climate Change) projections from last year in particular. We're looking at longer fire seasons extending from summer into spring and autumn as Justin mentioned. And an increase in the number of dangerous fire weather days for a lot of the world including Australia. The frequency of extreme fire weather days has increased in recent years and the fire season has become longer in the last 50 years or more in a lot of locations.

Overall we're expecting to see the intensity, frequency and duration of fire weather events increasing across Australia. We are really interested in some of the detail of that and what it might really look like.

What I'm going to talk about tonight is an overview or a summary of a paper that was published earlier this year by myself and Lachlan McCaw who's in Western Australia. What we were looking at was what are the processes driving fire behaviour that are outside of what's kept in the IPCC reports?

When you look at all of the references on all of the studies that are in there most of them use either FFDI (Forest Fire Danger Rating) or FWI (the Canadian Fire Weather Index), looking at climate projections into the future and taking either the midday or the 3:00 PM values, the hottest period in the day.

What we're really asking is does looking at the temperature, wind speed, relative humidity, and the dryness at 3 o'clock in the afternoon or at midday really capture some of the complex processes into the future? We're going to talk tonight about some of the things that might not be captured in those projections.

Some of the things we're worried about into the future are overnight fire activity and how much we might see more increasing fire activity overnight, and we're seeing that already around the world. Some of the other processes are heatwaves and droughts and how that changes fuel availability across the landscape. Some of the dynamical meteorological processes including deep boundary layers we'll talk about a little bit more. Low level jets the winds above the surface. And as Kevin already mentioned, pyrocumulonimbus clouds.

I'm going to show a couple of cases from the Badja Fire, the Yanchep Fire, and the Corryong Fire. And some people may have had personal experiences in the Corryong Fire. I'm going to finish up by talking about some of the implications for future fire regimes and the things we need to think about.

Many of you will already know that most fires aren't put out by water bombers. We know the normal diurnal cycle of fire activity and this is really Fire Behaviour 101 is that fires lie down overnight and will often self extinguish. And the overnight reduction in fire activity means fire crews can put in suppression and containment activities. That's especially the case for forest fires where you've got continuous fuels over large areas. As I mentioned we're already seeing in the satellite data an increase across the globe in overnight fire activity. That's pretty well documented.

A lot of that work's been done in the United States. One of the concerns is what's overnight fire behaviour going to look like in the future? Another thing is heatwaves and as we just heard from Kevin and from Justin the hot days are really the bad ones in terms of fire activity. And heatwaves aren't just the daytime hot temperatures. It's also the night time temperatures. And a lot of human physiological stress is from the night time temperatures and the fact that our bodies can't recover overnight and also fires will continue to burn day and night in a heatwave.

When we're talking about heatwaves the high pressure systems that drive heatwaves can be a few thousand kilometres across. So we're talking about big systems. They become near stationary for several days. Heat waves don't just affect small pockets or isolated areas. They can affect extensive areas for several days. And as we know during heatwaves the conditions tend to get hot earlier in the day and they continue to be hot into the evening. What that means is that you don't get an afternoon peak in your fire danger and your fire activity but your fires can stand up and run much earlier in the day and they've got a much longer window of hours that are favourable for fire spread. So you've got a much much longer number of hours where you can get fire spread in a heatwave and that continues into overnight fire activity.

In heatwaves we obviously do see a little bit of cooling in the overnight period but that's always a very shallow nocturnal layer. That shallow cool layer is really near the surface - in the bottom, a couple of hundred metres usually. Above that you've got a reservoir of hot dry air that often goes up to 4 or 5 kilometres deep. All that hot dry air is always above a heatwave. We've got this shallow layer near the surface. And as we'll see a fire plume in heavy fuels can actually tap into that hot dry air above the surface and mix it down to the surface and continue to drive overnight fire activity. As we've heard one of the big hazards particularly in South Eastern Australia, and it's really something that happens here rather than other places in the world, we often get frontal wind changes or sea breeze wind changes on the last day of a heatwave. Once you've actually got fire established in the landscape where it might have been burning for several days you then get the wind change which changes the open flank of the fire and can then increase your fire spread in a new direction.

Heatwaves of course change fuel availability, and fuel availability obviously determines how much fuel there is in the landscape to burn. Usually in fires we're talking about the dead fuel that's available to burn. But as we know during heatwaves and extreme conditions we also see the live

fuel burning as well. Heatwaves not only dry the dead fuels but they also stress the vegetation and they make the live fuel more flammable and available to burn. There was a lovely description from a lady who was in the Black Saturday fires and she said she knew it was going to be a bad day because the eucalyptus trees were silvering. As we know our eucalyptus trees have got a high oil content and when they're heat stressed they catch the sunlight and they start to reflect it like a mirror. She knew it was going to be a bad day that day because the eucalyptus trees were silvering.

On hot days and nights during heatwaves it means that the overnight fuel recovery, or the fuel moisture recovery doesn't happen. Usually the dry fuels increase in moisture levels in the overnight period when the humidity comes up and then dry out during the day. But because conditions are hot and dry during the day and night you don't get that overnight fuel moisture recovery so the fuels are dry and available to burn at night as well. Heatwaves and also drought (we'll talk about drought in a minute) also increase the size of the available combustible fuel in the landscape.

Normally when you're talking about the fuel that's available to burn in a bushfire you're talking about the fine fuel which is the top image that you can see here. And I like to think of it as the stuff that's around about the size of your little finger. But during heat waves and droughts the heavier fuels, so the stuff that's the size of your torso or bigger, starts to dry out and that becomes available for combustion and burning in a bushfire as well. And of course if you've got the heavier fuels burning they take longer to burn because they're heavier but it increases significantly the total energy release and that then interacts with the atmosphere.

This is a photo of drought stressed trees in Western Australia. It's worth pointing out that definitions of drought vary considerably. Different time periods, different kinds of drought - agricultural drought, and water drought. But drought effectively is a deficiency in rainfall. And what we get during drought and heatwaves is a greater availability of live and dead fuel and of course the same kinds of weather patterns and climate patterns that are favourable for droughts are also favourable for heatwaves. We tend to see droughts and heatwaves in the same seasons.

Drought impacts are dissimilar across vegetation types and particularly in terms of the time period that the drought will affect the vegetation. One of the big questions about drought is forest mortality particularly when big trees will die. It's really difficult from a research point of view to attribute tree mortality so trees dying to a drought because often there's a lag between when the impacts of the drought are greatest and when the trees die. That's a big uncertainty. They've done some work in Europe in particular looking in climate change is how the big old trees are likely to respond to novel climate conditions. And the reality is that we simply don't know because it's impossible to do experiments to see how the tree mortality is going to change in future.

Drought cycles are really important as well. They'll have a really big impact on fuel availability whether you have a dry year or two dry years followed by two wet years. Or whether you have five dry years followed by five wet years. The cycle of fuel growing - vegetation growing and then drying out, changes considerably and that alters the fuel availability in the landscape if you've got a 1 or 2 year wet dry cycle compared to a 5 or 10 year wet dry cycle. And it's really a little unclear in the climate projections how that might play out. What we also know is that the fire spread models developed in Australia are the ones in the rating system Kevin in particular talked about is that most of those were done from experimental fires that happened in the previous climate regime. We really don't know how those might translate into the really dry conditions. The kinds of conditions that we saw in Black Summer and the kinds of conditions that we might see into the future.

One of the things that we've been doing a fair bit of work on is not just looking at what's happening at the surface and the way the surface conditions are affecting fire behaviour but also what's

happening above the surface and how the atmosphere above the surface influences and interacts with the fire plume. You've all seen these kinds of photographs. This is one from Kangaroo Island in January in 2020. And what you can see is the fire plume in particular isn't just at the surface. It's extending through a real depth of the atmosphere and it's interacting with the atmosphere and the energy in the atmosphere through a really deep layer. We call this layer, the layer that's affected by diurnal heating or daytime heating, the planetary boundary layer. And what we get is this layer which can mix to four or five kilometres deep in a heatwave. And we see some of the deepest planetary boundary layers in Australia. Certainly much deeper than a lot of other places in the world. And this is the layer that the fire plume interacts with. As I said in the overnight period we get shallow surface inversion. So you get a cooler layer near the surface but that hot dry air is still above the surface.

These deep boundary layers are really favourable for ember transport and for spot fires day and night as well. So when you've got a really deep boundary layer with a nice plume like this well developed in it you've also got potential for firebrands being lofted up into the plume and then carried by the stronger winds aloft and deposited further downstream and then igniting new spot fires.

As we'll see again in a minute these really deep boundary layers can support deep organized plumes and also convection column development. And what we also see is these deep plumes they've got a really strong updraft associated with them. Some of these updrafts are similar speeds going up to what we see in a thunderstorm. You get really strong inflow at the surface to replace that air that's accelerating upwards. So you can get really strong environmental winds at the surface which won't be seen in our forecast models and won't be seen in the forecast that you'll see on the websites because the atmospheric models don't actually know that there's a fire there. The atmospheric models that we run are usually done without the knowledge about any fires that are in the landscape, so the really strong winds associated with the fire won't be predicted in those models.

Kevin also talked about pyrocumulonimbus clouds, an extreme form of pyroconvective clouds. You can see this little photograph down the bottom of a kind of cute little pyroconvective cloud little pyroCu cloud that's sitting on the top of a smoke plume. Which is a really a different beast to the larger photograph which is a pyrocumulonimbus cloud where you've got that really deep cloud extending for 10 or 15 kilometres up through the atmosphere.

These fire generated thunderstorms or pyroCb clouds can cause new ignitions downwind. Certainly they've been measured up to 80 kilometres downwind for new ignitions at the original fire front. You can get really gusty turbulent outflows and variable winds associated with these kinds of systems.

We've also seen fire generator vortices some with tornado strength winds both in the Australian fires in 2020 and then in the 2022 fire season in the United States. You can get vortices sea or fire wells which have got winds between 300 and 400 kilometres an hour. Really destructive winds that are generated by really strong updrafts that then shear at the surface producing these water seas. And of course these mean really hazardous conditions for firefighters.

This is a video that was taken in the Green Valley fire. What you can see here is a rotating convection column. This fire took a significant run in the afternoon period when the winds were stronger. And then as the winds dropped off in the late afternoon the whole column stood upright and started rotating. What we're looking at here is what we call fire and atmosphere interactions. They happen a lot where you've got complex topography and you can get wind regimes and updrafts which are really different to the background environment.

We've seen these in photographs. As I mentioned we don't get these kinds of systems or these phenomena resolved in our weather models but we have got them in some of the research models we use. We use coupled fire atmosphere models to actually resolve these processes in the modelling framework and try and understand the kinds of conditions they form in and the kinds of ingredients you start to see. We see really deep unstable boundary layers are favourable for these organised convection columns. And of course you've got the potential for rotation. These kinds of rotating convection columns are often associated with fire generated vortices and really hazardous conditions at the surface. We can also see elevated wind maxima or low level jets that can drive overnight fire spread especially during heatwaves and I'll show an example of those in a minute.

The first example I want to talk about was the Badja Forest Fire in New South Wales. It was ignited by a lightning strike in late December and it did an overnight run of 36 kilometres in six hours leading into New Year's Eve. It impacted the towns of Wandella, Cobargo and Quaama and the extreme fire behaviour associated with this fire resulted in two fatalities. There was a fire generated vortex. The wind strength is unconfirmed but it certainly looks like there were tornado strength winds that occurred in the Wandella valley. The satellite imagery in the overnight period recorded a fire generated thunderstorm and that was one of the first times that a fire generated thunderstorm or a pyrocumulonimbus cloud have been observed overnight. This image from RFS was taken at nearly midnight. You can see the really active fire behaviour in the overnight period. And at one of the automatic weather stations Catastrophic FFDI was recorded between 4 and 5 o'clock in the morning. So really extreme conditions in the overnight period and that was associated with winds above the surface that were mixing down to the surface. This fire was burning in really heavy fuels. RFS estimates were between 20 and 30 tonnes per hectare in terms of the fuel loads and they may have been higher.

The second case was the Yanchep Fire in Western Australia, just north of Perth in December 2019. Perth's about 50 kilometres to the south. There'd been drought in the lead up so the fuels were really dry but it's on the coastal plain north of Perth so relatively low fuel loads compared to what we saw in the previous fire. There was a heatwave. Perth had three days over 40 degrees. And the interesting thing about this fire was that the fire effectively zigzagged up the coast for three days. So what happened was they had easterly winds from the land in Perth. All the deserts are to the east of them. Really hot dry winds during the overnight period and in the morning and the late afternoon. And then the sea breeze came in from the southwest as it does in that corner of the world with a real kick and turned the direction and the fire spread. You can see the yellow arrow there.This is the Sentinel high resolution Copernicus imagery. You can see that the ignition point was where the yellow arrow's pointing. And the fire initially took a run up to the northwest. And then as the sea breeze came in it pushed inland. Then when the sea breeze died off it pushed it towards the coast and that continued for three days.

On the 13th of December there was an ember attack at about 4 o'clock in the morning and they had to evacuate or put out evacuation calls for the town of Two Rocks in the middle of the night. The dry winds from inland really limited the moisture recovery. So they had a lot of nocturnal fire spread. Made it really difficult to get any kind of containment in the overnight period. But because this was only 50 kilometres north of Perth they had a lot of resources on it. There were a lot of trucks, a lot of personnel and aircraft on this. As I mentioned not particularly heavy fuel loads compared to some of the fires that we've seen in the eastern states and also further southwest in Western Australia. So an unusually difficult fire to fight that ran for four days in relatively accessible landscape because there is quite a few roads around there and they had a lot of firefighting resources. But it was that changing wind direction with the sea breeze offshore flow that really made it difficult to fight.

And the last case is the Corryong Fire. Some of you may know this one. This started off as the Green Valley Fire in New South Wales. And what we're looking at here is a cross section of the winds using the coupled fire atmosphere model that we use ACCESS-Fire. So if you look at the plot in the bottom right corner the red outline is the fire perimeter. The black line is the position of the cross section that we're looking at in the main image. You can see that on the y axis there we're looking at the atmosphere from the surface up to a height of nine kilometres. And the shading is the topography and the red is the wind. So we're looking at a cross section of the wind speed at 10 minute time intervals all the way through the night period. And the yellow and pink bits are showing where the fire line is on the topography.

What you can see here is that there's incredibly strong winds up around 70 to 80 kilometres an hour around about 1,000 to 2,000 metres above the surface. What you can see is where the fire front is those winds are coming closer to the surface and then accelerating up in front of the fire in the fire plume. This is one of the few pieces of evidence we've got about how the winds above the surface can interact with a fire plume. What we can do with this model is run it with the fire on and off. For the image on on the left there the fire atmosphere coupling is off. The atmosphere doesn't know there's a fire there. And you can see there's much lighter winds. Winds less than 10 kilometres an hour near the surface in the overnight period because we've got that nocturnal inversion forming. And as usual we'd expect to see lighter winds near the surface overnight. In the one on the right with the fire coupling on the fire plume is interacting with the atmosphere above it you can see that the fire plume brings those 70 to 80 kilometre an hour winds down to the surface and that's what's driving the really fast fire behaviour and produce that really fast fire activity and really fast fire spread overnight. So it's those interactions between the fire plume and the winds above the surface not the winds at the surface that are driving the overnight fire behaviour.

What are we worried about in future? Longer multi day heatwaves supporting overnight fire behaviour and reducing the suppression effectiveness so making it harder to put fires out at night. Hotter temperatures overall and hotter and longer heatwaves producing drier fuels and then we'll see increased fuel availability both the live fuel and the dead fuel available to burn in the landscape. There's a lot of uncertainty in drought cycles in the future. Are we going to see one to two year cycles from wet to dry or are we going to see five to ten year cycles from wet to dry? And that produces a lot of uncertainty in vegetation regimes in the future and also how much fuel will be available. We are expecting in hotter temperatures to see more deep boundary layers and that will support organised fire plumes and an increased potential for spot fires. And with that there's a potential for really deep pyrocumulus cloud and also pyrocumulonimbus cloud and those fire generated vortices with fire modified extreme winds. And the plumes above high intensity fires can bring those winds that are above the surface the low level jets down to help accelerate the surface fire spread.

As we see in this MODIS image on the right we've got multiple fires burning in the landscape. All of these conditions tend to happen not just in isolated pockets but across large areas because that's the way the weather system works. So we can start to see multiple fire ignitions in the landscape and really long fire perimeters that have the potential to impact large areas.

So what are the implications? With overnight fire activity and multi day events you've got a lot of strategic and tactical challenges for the fire management agencies. We'll need more resources for overnight work and staggered resources for multi day versus single day events. Do you put all of your resources on the first day or do you need to manage your resources to extend over weeks or even months of firefighting? As we know you get a lot more fatigue in hot temperatures and a lot of heat stress. So it's people's physiological response and also if people are sleeping out in tents you're going to have reduced sleep quality on hot nights so the human recovery won't be as good.

There's also a lot of risks associated with nightime evacuations both in terms of getting messages to people and also a number of cases where people have tried to evacuate large animals particularly horses and cows overnight. And we will need more training to look at the conditions that are conducive for active fire behaviour overnight. Because a lot of our current models assume that the winds and the temperature will drop off overnight.

One of the other things is that we're starting to see extreme fires move into areas that are not historically fire prone. The fires in Hawaii are an example of that where they've seen fires in areas where they don't necessarily have fire fighting resources ready and they don't necessarily have a well organised volunteer cohort and because they haven't had fires in those kinds of areas in the past.

And that's also the case in Queensland in the 2018 and 2019 fires where we saw areas of rainforest fires. And of course they don't have the same organisation of the volunteer response that they do in some of the fire prone areas further south in Australia. And we will need to look at what the messaging is needed to minimise fire ignitions and also to alert communities to the changing fire environment.

So thank you and happy to take any questions.

Malcolm
Thanks Mika. That was both fascinating and a little frightening.