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FINAL PROJECT REPORT
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COUPLED FIRE-ATMOSPHERE MODELLING

Final project report

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Bureau of Meteorology

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Cover: Waroona fire. Source: Neil Bennett, Bureau of Meteorology.

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ACKNOWLEDGMENTS

We would like to acknowledge all our end-user representatives and their agencies. We are grateful for the helpful feedback from our end-users on the practical implications of what we do, and for guidance on the direction of the project. We would also like to thank those who have provided fire behaviour and other data and participated in valuable and enjoyable discussions with us as the case studies have unfolded.

We are especially grateful to those sponsors who have supported our work with coupled fire atmosphere models since our first experiments in 2010; through to the inception of this project in 2016; then to the current extension work on fires during 'Black Summer'; and to our current discussions on plans for operational application. It has been a long pathway which started with a very small team that has expanded in response to the value of this work in contributing to our future needs for fire prediction.

The authors are grateful to staff at the Bushfire and Natural Hazards CRC for their ongoing support of the project, from conceptualization through to utilization. Thank you to everyone at the Bushfire and Natural Hazards CRC for the behind-the-scenes work administering our project, running events and promoting research, facilitating end-user engagement and supporting communication activities. We are also extremely grateful to the BNHCRC for their ongoing support and flexibility in supporting outreach and operational activities.

We thank our colleagues at the Bureau and the UK Met Office for their advice on using the ACCESS and UM model. Many colleagues have helped us understand modelling developments, as well as encouraged us with the importance of our work.

EXECUTIVE SUMMARY

This project aims to improve understanding of fire and atmosphere interactions and feedback processes through running the coupled fire-atmosphere model ACCESS-Fire.

Project deliverables include: preparation of meteorological and simulation case studies of significant fire events as publications; installation and testing of the ACCESS-Fire coupled model on the National Computing Infrastructure (NCI); and preparation of training material to support operational implementation of research findings.

The project started in March 2016, and progress over the past four years has delivered across several activities:

- ACCESS-Fire has been installed on NCI and substantial progress has been made in testing and developing the model.
- A meteorological case study of the Waroona fire has been published ***Meteorological drivers of extreme fire behaviour during the Waroona bushfire, Western Australia***. The case study generated outreach activities across numerous agencies and jurisdictions.
- ACCESS-Fire has been successfully run on two fires; the Waroona fire in WA and the Sir Ivan fire in NSW. The simulations produced reasonably accurate predictions of fire spread, successfully captured cloud development consistent with pyrocumulonimbus and resolved complex atmosphere-fire interactions during downslope wind events that led to mass spotting events.
- The discussion paper ` ***Lessons Learned from Coupled Fire-Atmosphere Research and Implications for Operational Fire Prediction and Meteorological Products Provided by the Bureau of Meteorology to Australian Fire Agencies***. has been published.
- The manuscript `***Simulations of the Waroona fire with the coupled atmosphere-fire model ACCESS-Fire***' has been submitted to an international fire science journal
- The manuscript `***Simulations of the Sir Ivan Dougherty fire with the coupled atmosphere-fire model ACCESS-Fire***' has been submitted to an international meteorology science journal.
- The project team has participated strongly in outreach activities, including public seminars and media engagement through extended radio interviews and collaboration on print and online news articles.
- The project team has presented at numerous conferences and webinars with themes ranging across fire science, meteorology and computational modelling. Conference and panel presentations have been invited on topics including fire science, High Performance Computing, STEM careers and Women in Leadership.
- Operational support was requested by fire agencies and the Bureau during high-impact events during several fire seasons, the most extended

of which was the 2019-20 fire season. Specialist meteorological support was provided in CFS and SES in SA, RFS in NSW and QFES in QLD during the protracted fire campaigns.

- Specialist training presentations and webinars have been invited from end-users and the CRC on numerous occasions and provided to audiences across multiple jurisdictions.

The project has demonstrably achieved the objective of building and sharing national capability in fire research and has provided fire and meteorology expertise during high impact events in support of end-users inside their operational centers. That outcome is not a specific project deliverable and is to some degree intangible, so not as easily measured as outcomes such as publications. However, it successfully realises the CRC objective of building collaborations and trusted partnerships and strengthening national capability. The operational support capability is recognised and valued across fire and land management agencies and in the Bureau.

To complete the project we will finalise publication of the draft papers to ensure that our key findings are documented in the scientific literature; this will expand the international body of knowledge from coupled modelling studies.

We are pleased to bring the project to completion and are gratified that along the way we have shared a valuable legacy of knowledge on fire and atmosphere interactions. We have also delivered an important capability in ACCESS-Fire that can provide ongoing benefit to the field of meteorology and fire prediction and to the Australian community into the future.

In the coming months we will continue our conversations with partners and end-users to establish plans for future use and development of ACCESS-Fire as the BNHCRC transitions to the new Disaster Resilience Research Institute. ACCESS-Fire is an important research tool and has the potential to be a critical operational tool. It will assist in informing fire management decisions as we face increasingly hazardous scenarios in a changing climate.

END-USER PROJECT IMPACT STATEMENT

John Bally, *Fire Prediction Business Manager, AFAC, VIC*

This project has developed a sophisticated fire simulation system, built on one of the world's best numerical weather prediction models. These systems are normally developed and run by teams of dozens of expert meteorologists and software engineers. The progress achieved by this project is remarkable, given the relatively modest resources available. The case studies and engagement activities have added to the understanding of fire behaviour through operational fire agencies and will contribute to the quality of operational bushfire predictions. These case studies will no doubt be incorporated into FBAN training programs, and also used to inform the development of operational tools to diagnose the risks from downslope winds, pyro-cumulus and other dangerous fire conditions. The system will be available for use by other researchers. It is sufficiently developed to inform planning for eventual direct operational use, when computing resources become available.

Most approaches to diagnosing and predicting bushfires assume that the weather (and other factors) drive the fire, and ignore the influence the fire has on the atmosphere. This work tackles that much more difficult problem. It has taken much longer than anticipated for the project to successfully configure and run the ACCESS-Fire coupled model, due to the complexity of the task and the dependency on the base modelling system which has undergone major change during the life of the project, outside of the project's control. The model has now been run and has produced results for two important case studies.

Both case studies have shown significant modification of the weather (mostly the wind fields) driven by the heat generated by the fires. More realistic forecast wind fields generated by coupled models are a benefit in themselves, a result consistent with the benefits found in the Colorado coupled fire-weather experiment (CO-FPS).

The ACCESS-Fire runs for the Waroona fire reproduced downslope winds and fire induced turbulence, both drivers of large-scale ember transport and spotting. This is consistent with the Large Eddy Model work undertaken in the BNHCRC "Severe Weather" project which found that turbulence is a major driver of ember transport. The coupled runs were also able to develop fire induced convection consistent with in-situ observations of pyro-cumulonimbus. These results underscore the role this work can play in validating the (BoM) parameterised ember transport model and PFT work.

ACCESS-Fire runs also reproduced 3-D effects of the fire on the atmosphere which included coupling to upper winds, transient vortices and pulsing. These effects were important in the 2019-20 fires where it was common practice for FBANs to rely on experience-based estimates of which (stronger) upper wind levels to use for fire simulations. This project has shed some light on the mechanisms involved. It would be great to see the insights gained applied to developing more parameterised and other heuristic "models" which can be applied to current and emerging operational 2D (or 2.5D) simulation approaches. This application has become much more relevant with the recent national endorsement of the development of a new national bushfire simulation capability based on the CSIRO Spark system. The architecture of Spark is well suited to the incorporation of some relatively simple fire-atmosphere interactions that have been explored through this project.

The modeling framework used in this project is very computationally expensive, and spatial resolutions used are still about an order of magnitude coarser than those used in 2D models. Apart from waiting for computers to get faster, it is interesting to see some effort being put into running the fire components at a (much) higher resolution. This approach could bring forward direct use of coupled models in operations.

The coupled model runs have all used constant fuel layers. It is pleasing to see consideration being given to using the AFDRS fuel layers, as these should add more detail and accuracy to the simulations, but also to deepen the links between this and other related bodies of work.

PRODUCT USER TESTIMONIALS

Lachie McCaw, *Science and Conservation Division, Department of Biodiversity, Conservation and Attractions, WA*

The Coupled Fire-atmosphere Modelling Project has led to significant advances in our understanding of these complex phenomena and the ability to model and predict their occurrence. Importantly, the project has provided the framework for an operational capability linked to the ACCESS family of models that underpin much of the weather and climate information that BoM provides to fire managers. The project team have demonstrated persistence and a strong resolve to deliver a working prototype that has been verified using case studies of complex bushfires. They deserve credit for this achievement. This project demonstrates the benefits that arise from genuine engagement between researchers and end-users through national research coordination by the BNHCRC.

Laurence McCoy, *Fire Predictive Services, Rural Fire Service, NSW*

Thank you for the opportunity to participate as an end-user on this extremely important project. For me, the importance of this project was highlighted during the 2019-20 fire season where more coupled fire atmosphere interactions or PyroCb events were recorded than any season since records began. Recent 2019-20 bush fire inquiry findings suggest a changing climate could result in an increasing frequency of extreme fire atmosphere coupled fire events.

In this context, a model that can provide more accurate predictions of coupled fire-atmosphere interaction events could become very important to underpin operational decisions.

This project has demonstrated the capability to model historical coupled fire atmosphere events with the results of the case studies encouraging.

I note the roadmap for operational implementation has been developed. I look forward to the results of future trials and the project to implement the model into operations.

Although not a specific research objective, members of the High Impact Weather Project Team played an important role during the NSW 2019-20 Bush Fires at the RFS State Operations Centre. Briefings provided by Meteorologists assisted to increase weather situational awareness, highlight risks and monitor for the development and occurrence of coupled fire atmosphere interactions. This information was used to inform "PyroCb" safety warnings released to Incident Management Teams and fire fighters, improving safety for fire fighters and the community. We'd like to take this opportunity to thank those team members for this assistance.

INTRODUCTION

Large bushfires release substantial amounts of heat energy into the surrounding atmosphere. This energy release modifies the structure of the surrounding wind, temperature and moisture profiles. The changes induced by the fire can manifest as accelerations or reversals of the prevailing winds, pyrocumulus clouds and, in extreme cases, pyro-cumulonimbus clouds. The dynamic feedback loops produced by the fire-atmosphere coupling process can have a dramatic influence on how a fire evolves. Fire-atmosphere feedbacks can also be strongly enhanced by local topographic influences.

In current operational fire simulation models, simple near-surface meteorological values are provided as inputs to an algorithm for fire spread that is used to predict how a fire perimeter will evolve across a two-dimensional landscape. This approach does not incorporate any three-dimensional interactions between the fire and atmosphere and may provide a limited depiction of how a fire may evolve, particularly in a dynamic environment in complex terrain. This project explores fire and atmosphere interactions through use of a coupled model.

The project uses ACCESS, the Australian implementation of the UK Met Office Unified Model. ACCESS is the operational and research numerical weather and climate prediction model. The ACCESS model has provided Australia's operational numerical weather prediction capability for the past decade. It has been used to examine weather conditions associated with several high impact fire events and has provided detailed insights into the meteorological processes that occurred in the fire environment. ACCESS-Fire couples ACCESS to a fire-spread model. The use of ACCESS-fire to run case studies has extended the modelling expertise in the Bureau's research team and presents an exciting opportunity for future development and operational use of a coupled modelling capability in Australia.

ACCESS-Fire has been installed and run on the Australian National Computing Infrastructure (NCI) for research application and the capability has future potential for operational use, given appropriate development and testing. Two case studies have been run for this project, the Waroona and the Sir Ivan Dougherty ('Sir Ivan'fire).

The Waroona (southwest Western Australia) fire occurred in January 2016. Over a two-day period, it burnt more than 69,000 hectares. There were four periods of extreme fire behaviour; two separate pyro-convective thunderstorm events and two evening ember storms occurred. The Sir Ivan fire in central, eastern New South Wales occurred in February 2017. IT occurred on a day of 'Catastrophic' Fire Danger, burnt out a total of 55000 hectares of forest and farmland, and produced a pyrocumulonimbus cloud near the time of a change in wind direction.

Detailed examination of the case studies and comparison against available meteorological and fire behaviour data has provided compelling evidence for the importance of assessing and anticipating the likelihood of fire-atmosphere interactions when making predictions of fire evolution. The close links of the project team with operational and training groups in meteorology, fire behaviour and fire management have supported sharing of relevant research findings in operational settings in advance of formal publication of results.

BACKGROUND

The project examines case studies and uses high resolution coupled modelling to better understand and predict fire-atmosphere feedback processes. Fire-atmosphere feedback is important because it often reflects a transition from steady-state fire spread to rapidly fluctuating, dynamic and more intense fire activity, which is inherently more difficult to predict.

Blow-up fires, extreme fire behaviour and dynamic fire behaviour are all terms that may be used to describe fire activity that is erratic and potentially dangerous to fire fighters and destructive to communities. Coupled modelling assists in identifying and understanding the triggers and ingredients that lead to such fire activity. This knowledge can enable risk mitigation activities to be undertaken, both at bushfires and fuel reduction burns.

Coupled fire-atmosphere models have been used in Australia by several researchers and are being used increasingly internationally in both research and operational spheres. The most progressive operational implementation is in the USA state of Colorado, where the WRF-Fire model is a component of a new capability for fire prediction. WRF-Fire also includes capability to predict particulate trajectories in fire plumes, a feature that is not currently in ACCESS-Fire but could be included.

This project uses the ACCESS-Fire model, which links directly to the Bureau of Meteorology's operational and research computing capability. ACCESS-Fire provides an important opportunity for future development of Australia's fire-atmosphere modelling capability, as well as the potential to provide a fire prediction tool to international partners through the overarching UK Met Office Unified Model framework.

Australia has one of the most fire-prone landscapes in the world and as with many other regions, we are experiencing increased impacts of fire in a changing climate. Therefore, the potential benefits of developing capability in the coupled fire-atmosphere modelling space are considerable.

RESEARCH APPROACH

The research approach has been a combination of model development and running the ACCESS-Fire model on case studies of fires where extreme fire behaviour occurred.

CASE STUDIES

In both meteorology and bushfire management, a case study approach to examine events retrospectively is a well-established practice that can provide insights that were not possible in real time. These insights can translate into lessons learned which may be applied during future events. Case studies also provide a suitable platform for testing and evaluation of potential future prediction capability and they are a tractable approach to defining the scope of a project.

Our research methodology has been to perform detailed analyses of high-impact fires. We do this through examination of meteorological data and fire behaviour information that was available in real time and from post-event reconstructions and reports, as well as running ACCESS-Fire and examining the output.

The ultimate objective is to understand how the energy released by the fire modified the surrounding atmosphere and infer how this process subsequently influenced the fire behaviour.

The two case studies are the Waroona and Sir Ivan fires. The Waroona fire was requested for consideration as a case study by end-users in Western Australia, who were also co-authors of the Waroona case study. The Sir Ivan fire was requested as a case study by end-users in NSW Rural Fire Service.

ACCESS-FIRE

ACCESS is the Australian Community Climate and Earth-System Simulator. It is the Numerical Weather Prediction model used for climate and weather research and operations in Australia. The ACCESS model framework is the Australian version of the UK Met Office Unified Model (UM).

Coupling a fire model to the ACCESS model was a project originally conceived in a collaboration between the University of Melbourne and Monash University. The objective of that project was to simulate the Kilmore East fire on Black Saturday (Toivanen et al 2018). Section 2 of their paper describes the UM model and Section 3 has a detailed description of the fire code. A copy of the ACCESS-Fire code was provided to the Bureau in 2016.

The fire model runs in the 'nested suite' of the ACCESS model. The fire component of the code is located in the source tree for the land surface model (Joint U.K. Land Environment System – JULES). ACCESS-Fire currently includes fuel options for grass and forest for CSIRO and McArthur and Rothermel and it is conceptually possible to include the code for any compatible fuel model.

ACCESS-FIRE DEVELOPMENT

Substantial developments have been made to the original ACCESS-Fire framework. Progress with ACCESS-Fire was slower than anticipated for an extended period due to several unforeseen IT and model configuration challenges. The technical setbacks have been resolved and ACCESS-Fire high-resolution nested suites are now running on the Gadi supercomputer on NCI. Other development work has enhanced the model's functionality, capability and stability.

Two major stability changes were made:

- We encountered major problems with model stability in our initial simulations due to numerical stability being sensitive to the boundary layer settings; frequent model 'crashes' occurred, particularly around the time of pyroCb development. Available guidelines were followed, in combination with trial and error to make several adjustments to the UM science settings. We found that in order to achieve a numerically stable atmosphere when an intense fire is coupled, non-standard settings were required on the finer resolutions (Nest 3). The following two boundary layer settings were found to be critical: the convective boundary layer stability function needs to be set to `standard LEM'; and the `transition Ri for sharpest function' increased from 0.1 to 0.3
- A significant change was made in the temperature input to the fire code. In the CSIRO forest formula (used in our simulations) the temperature and relative humidity are meant to be measured in the fire-unaffected environment. The coupled model often produces local temperatures of several hundred degrees, therefore using fire-adjacent values to calculate fire-spread introduced a large error. The environment temperature is now taken from the minimum temperature for the sub-domain (a 7 x 7 km box for Nest 3), with the relative humidity taken from the maximum value in the same sub-domain.

A summary of other modifications follows:

- The original code was tailored to run for a single event. Effort has been invested in modifying the code to run on multiple events.
- The Kilmore East simulations were made in the now-retired UMUI ACCESS model interface. Numerous changes were made to implement the upgraded UM nesting suite and Rose-Cylc interface.
- The hard-coded switch to turn on/off the calls to the fire-specific subroutines has been replaced by a switch for specific parameters (such as the resolution of the nested domain)
- A user-defined polygon option has been introduced to enable start of fire simulation at any time (e.g. from a known fire perimeter after 36 hours), this is in addition to circle and line options for initial fire shape. The polygon option means that future experiments can be made using known perimeters from line scans or similar information.
- Automatic model restarts and time consistency has been implemented.

- A test has been included to check if a grid point is land or water (sea or lake), so as to prevent the simulated fire from burning across water.
- The orography used in the fire model can now be interpolated from the Shuttle Radar Topography Mission 1 arcsecond (30 m) data, as well as the 3 arcsecond data.
- In 2019 the code was ported from the 'Raijin' supercomputer to the new 'Gadi' supercomputer, which was officially commissioned in late 2019.
- Current runs implement the fire grid at 1:1 on the inner atmospheric nest. A zoom function has been developed that allows the fire grid to be run at variable resolution (i.e. 1:2, 1:10) within the inner atmospheric mesh.

The investment in developing ACCESS-Fire means that the modelling framework can be easily re-configured to relocate and run for a 'new' event anywhere in Australia and brings the model closer to being available to other research groups.

Members of the project team visited the UK Met Office (in 2017 and 2018) and held discussions with UK researchers involved in development of the overarching UM (Unified Model). UK Met Office colleagues are very interested in the project and have offered to assist in reviewing aspects of the model configuration and code.

ACCESS-FIRE SIMULATIONS AND MODEL CONFIGURATION

ACCESS-Fire simulations have been run on the Waroona and Sir Ivan fires. The model configuration is discussed in more detail in the submitted papers and a summary is provided here.

Our simulations used the standard nesting suite with UM version 10.6 (code trunk u-aa753), using the Rose Cylc scheduler. (The Kilmore East simulations were run with UM version 8.5). The global domain used is the N768 (17 km grid spacing) Global Atmosphere 6.0 (GA6.0).

The `UKV OS38' science configuration was used, with 140 vertical levels through a height of 40 km with model levels on hybrid heights of theta or rho surfaces to produce smooth levels over topography. The vertical configuration is the same for all the nested limited area models. The lowest permitted time step of one second was used on the inner nest.

The current model configuration has a series of nested domains at 4 km (0.036°), 1.2 km (0.01°) and 300 m (0.0028°). A fourth nest with a grid spacing of 100 m (0.0009°) was tested, however simulations at 100 m resolution were not continued because our analysis showed that limited extra detail was achieved compared to the 300 m domain, even though there was extra computational expense (a finding consistent with other coupled studies).

The fire model was switched on and coupled to the atmosphere model for Nest 3 (or Nest 4, for trials). The nests run to completion sequentially, so fire coupling only occurs on the innermost nest.

The two-dimensional fire spread occurs on the same grid resolution as the ACCESS output, but at more frequent time increments. Fuel inputs were set in consultation with DPAW and predominantly used the CSIRO empirical formula for forest (or Vesta fire spread model).

For Waroona, constant fuel was considered to be a sufficiently accurate representation for the continuous fuel on and near the base of the scarp. This assumption becomes limited for fire spread over the coastal plain, but was considered acceptable for our simulations as the focus was on examining the periods of extreme fire behaviour prior to the spread across the coastal plain. The options for including variable fuel grids was assessed and experiments with a limited domain were tested for the Sir Ivan fire, where a simple mosaic of constant and variable fuel settings was used. Ultimately, inclusion of detailed variable fuel grids was deemed to be out of scope for this project.

For the Waroona simulations fire ignition on day one was made as a point ignition at 2000 UTC (04:00 local time). Fire ignition on day two was made from a polygon perimeter taken from the fire reconstruction at 0645 UTC (14:45 local time) in order to provide a perimeter that started in approximately the correct position to resolve the evening ember shower processes.

For the Sir Ivan fire, fire ignition was set as a polygon taken from the RFS fire perimeter maps prior to the late morning escalation in fire behaviour.

Any future development of ACCESS-Fire should incorporate variable fuels. We have discussed with end-users and stakeholders the option of including the fuel data prepared for the Australian Fire Danger Ratings System (AFDRS).

WAROONA AND SIR IVAN CASE STUDIES

WAROONA FIRE CASE STUDY

This description uses excerpts from the submitted paper (see reference on page 29)

Abstract

The Waroona fire burned 69,000 hectares south of Perth in January 2016. There were two fatalities in the town of Yarloop and 170 homes were lost. During the first two days of the fire, extreme fire behaviour occurred on several occasions, which didn't reconcile with the near surface conditions customarily used to assess fire risk. Two evening ember storms were reported and pyrocumulonimbus cloud (cumulonimbus flammagenitus) developed on both days.

The coupled fire-atmosphere model ACCESS-Fire has been run to explore the processes surrounding the extreme fire behaviour during the Waroona fire. ACCESS-Fire incorporates a meteorological component and a fire spread component. In these simulations, the CSIRO forest fire (Vesta) spread model is used. The meteorological numerical weather prediction model is the Australian ACCESS version of the UK Met Office Unified Model.

In this study we report on the skill of the coupled model in reproducing surface fire spread, using constant fuels in complex terrain. The periods of extreme fire behaviour that are the focus of this study are the deep moist convection as an indicator of pyrocumulonimbus cloud on the first day and the fire-atmosphere interactions surrounding the ember showers that developed as the fire burned down a steep local scarp under the influence of a near-surface wind maximum on both evenings.

The simulations provide useful insights into the complex processes surrounding the periods of extreme fire behaviour; therefore suggestions are made for applying the learnings from this case to operational meteorological practices that support fire agencies and for potential future development and use of ACCESS-Fire.

Selected figures from the submitted paper

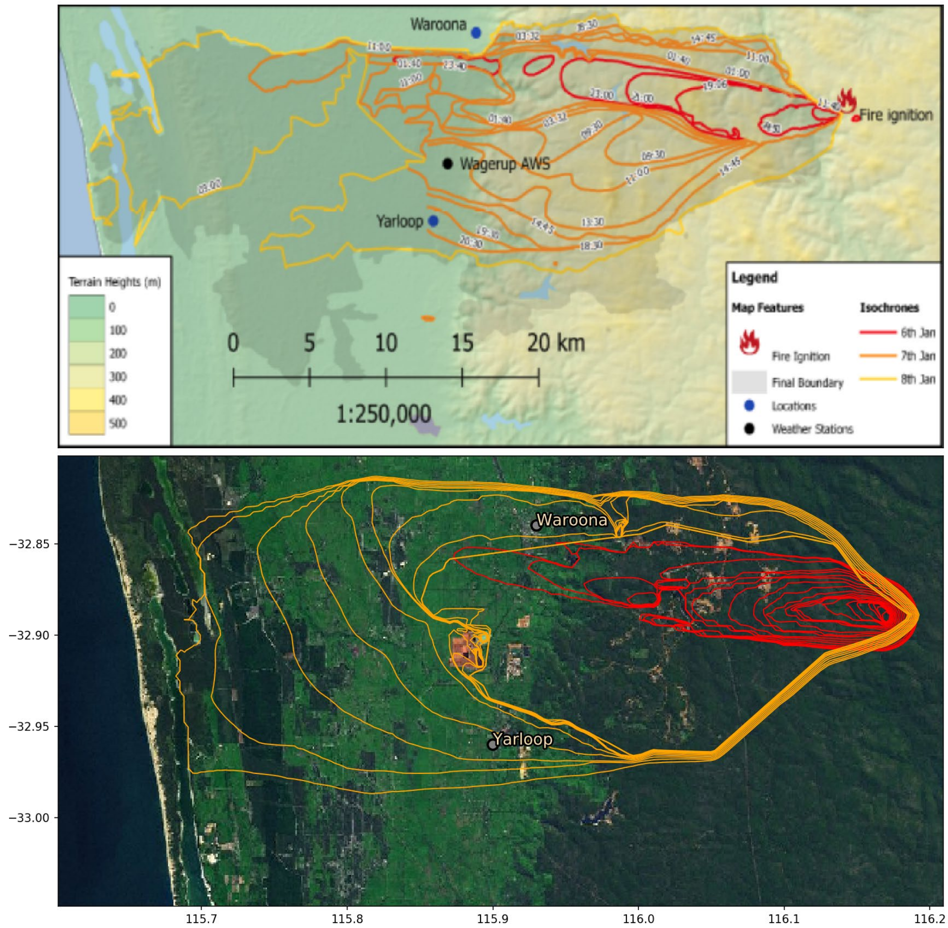

Figure 1: Top: fire spread from reconstruction; red contours show 6 January, orange contours show 7 January, grey area shows final perimeter. Bottom: Hourly isochrones of fire spread from ACCESS-Fire simulation on 6 January in red initialised at 0400 WST and on 7 January in orange initialised at 1445 WST.

Figure summary: The simulated fire spread verifies well against the observed fire spread for the two time periods, allowing for assumptions of constant fuel and with no suppression in the model.

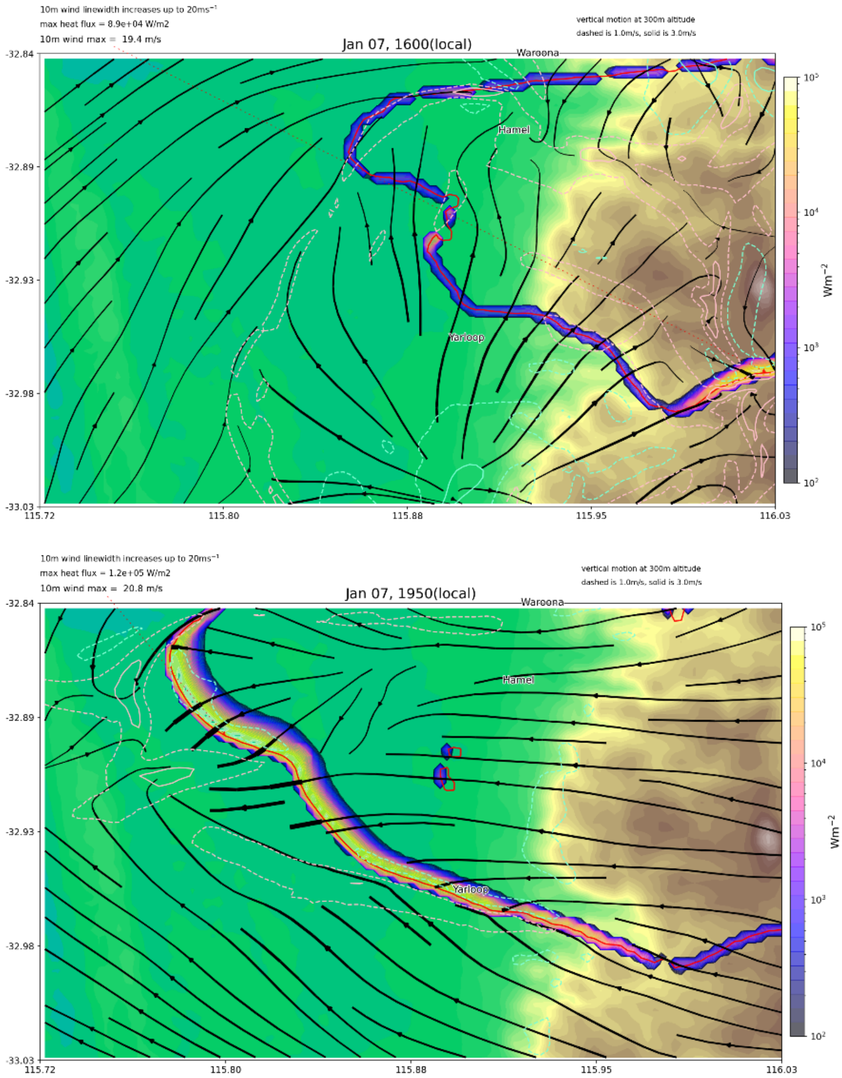

Figure 2: Simulated fire intensity (purple-yellow, note the log scale), topography (shaded green-brown) and streamlines at 1600 WST (top) and 1950 WST (bottom). Wind speed is indicated by thickness of the streamlines.

Figure summary: The figure shows that the afternoon fire intensity at the hottest time of day, is less than the fire intensity in the evening period, when fire behaviour is expected to decrease in typical diurnal patterns. The coupling process produced a more intense fire at the time of the reported ember shower.

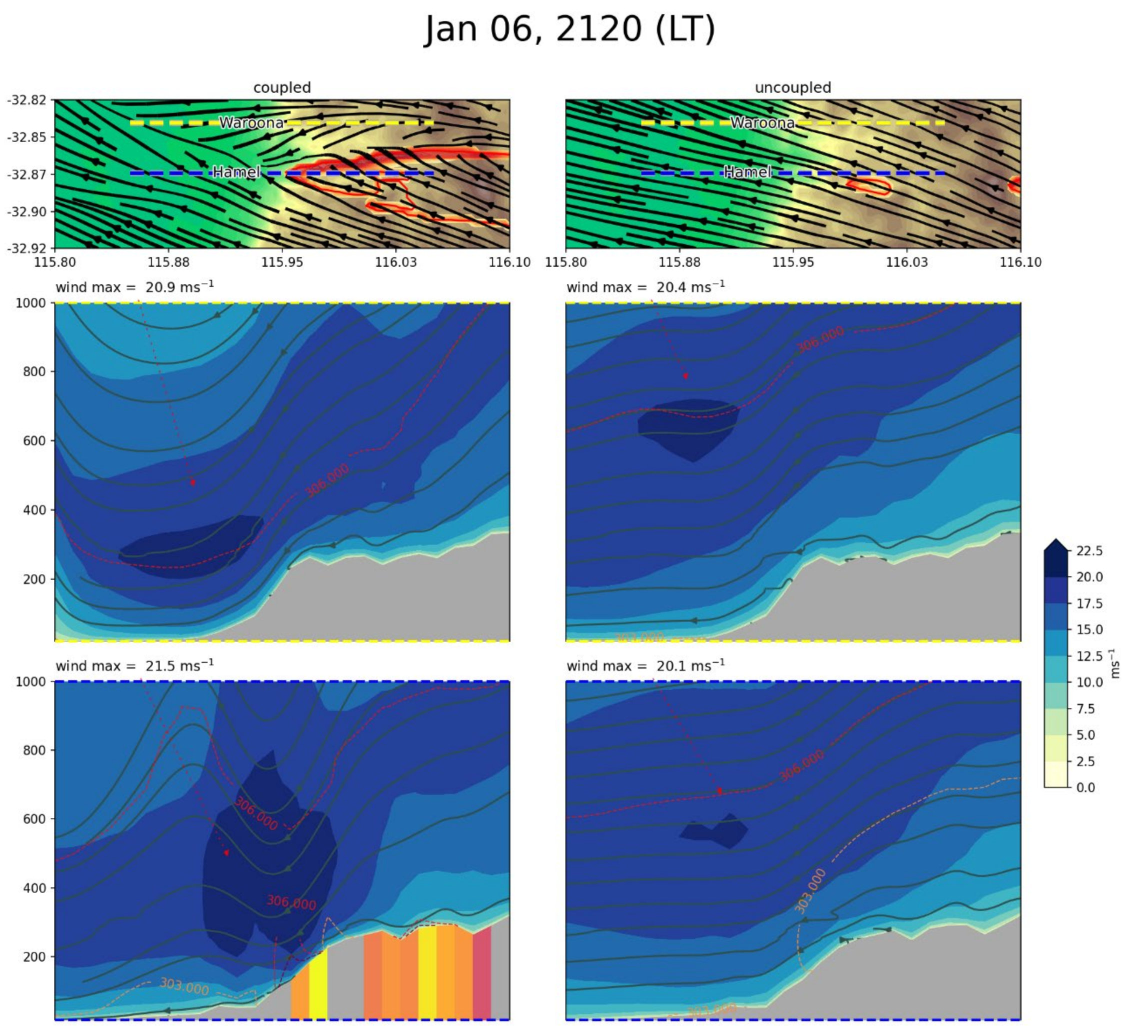

Figure 3: ACCESS-Fire cross sections (lower two plots) along the two transects shown in the top plot. Left plots show fire coupling enabled, right plots have no coupling between the fire and atmosphere. Top plot: yellow-red shaded perimeter shows fire intensity, green-brown shading shows topography and streamlines show wind direction. Lower plots: blue shading shows wind speed (m/s), black lines show streamlines and orange-pink shows approximate position of fire. Grey shows topography.

Figure summary: The coupling process (1) brings the jet maximum closer to the surface and (2) enhances the maximum wind speed and (3) the streamlines show low level wave mechanisms and turbulence favourable for ember transport.

Waroona fire key findings

- Very good fidelity is seen between the fire reconstruction and the simulated fire perimeter on the first day of the fire using the Vesta / CSIRO forest fuel fire spread model. The locations of known spot ignitions were included in order to produce the known fire spread.
- The focus of the analysis has been on two aspects of the fire activity; the pyrocumulonimbus on 6 January and the interactions between the fire plume and the downslope winds in the late afternoon to evening periods

on 6 and 7 January. Both aspects were well resolved by the coupled model.

- Downslope winds over Waroona on the first evening produce strong interactions with the fire plume and resulted in an environment highly favourable for mass spotting.
- Development of deep moist convection and cloud formation was simulated which is consistent with pyrocumulonimbus cloud at the time and location of pyrocumulonimbus over the Waroona fire on 6 January.
- Simulated fire intensity increased by more than an order of magnitude in the coupled simulations as the fire approached Yarloop on the second evening and interacted with the above-surface winds.
- The results from the simulations are important because they represent processes that can only be reproduced through including fire-atmosphere coupling in the simulations.

SIR IVAN FIRE CASE STUDY

This description uses excerpts from the submitted paper (see reference on page 29)

Abstract

The Sir Ivan Dougherty fire burned 55,000 hectares in New South Wales on 12 February 2017. In the lead-in days, record temperatures were recorded and the fire conditions on the day were described as the `worst ever seen in NSW'. Forecast weather conditions were hot, dry and very windy with a frontal wind change during the afternoon. `Extreme' to `Catastrophic' fire weather was predicted and the potential for extreme fire behaviour was identified several days in advance.

The coupled fire-atmosphere model ACCESS-Fire has been run to examine the processes surrounding the extreme fire behaviour at the Sir Ivan fire. Several fire-interaction features are produced in the simulations. Linescan imagery and simulated heat flux from the fire perimeter both show increased intensity on the northern fire flank in response to gradual backing winds ahead of the main frontal wind shift. Temporal and spatial variability in fire activity, seen as pulses in fire intensity and fireline wind speed, develop in the simulations in response to boundary layer rolls in the wind fields. Deep moist convection consistent with the observed pyrocumulonimbus (pyroCb) cloud is simulated over the fire at around the time of the frontal wind change, and matches guidance from the 'PyroCb Firepower Threshold' tool, which showed transient favourable conditions. After the wind change, short-lived near surface and elevated vortices indicative of organised rotation developed on the northern flank of the fire in a location that corresponds with radar observations of rotating structures.

The features in the coupled simulations are consistent with extreme fire behaviour phenomena at the Sir Ivan fire. The coupling process captures mechanisms that cannot be produced in uncoupled fire predictions and are not captured in current operational meteorological forecast products provided to fire agencies.

This paper links the features from coupled simulations to those described in other studies and suggests pathways to embed the learnings in operational practice.

Selected figures from the submitted paper

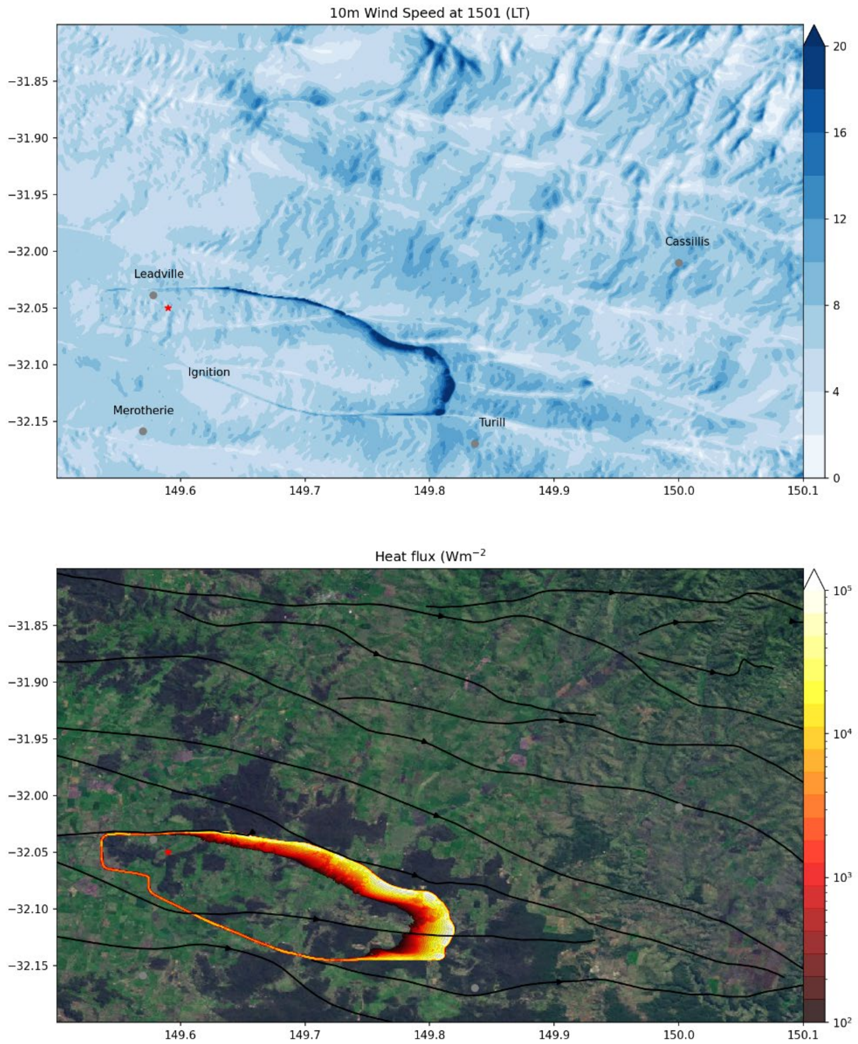

Figure 4: Simulated wind speed (top) and heat flux (log scale, bottom) at 1501 AEDT.

Figure summary: Boundary layer roll features are evident in the wind speed (also seen in wind direction). The wind speed at the fire front is significantly faster than the environmental wind speed as a direct consequence of the coupling process. The heat flux is substantially higher on the north eastern flank of the fire in response to a gradual backing wind direction ahead of the main synoptic northwest to southwest wind shift.

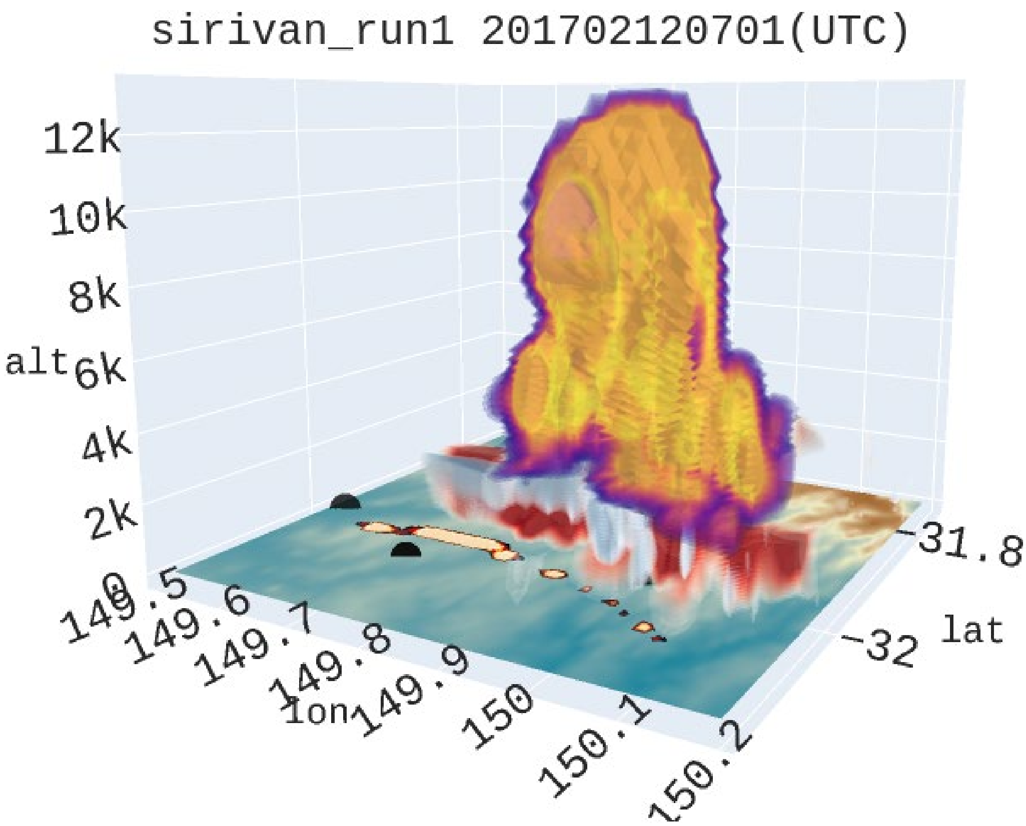

Figure 5: Three dimensional visualisation of cloud structure and fire heat release at 1800 AEDT. Dimensions in x, y, and z are longitude, latitude, and altitude above ground level respectively. Purple to yellow shading shows cloud content as liquid water and ice content above 0.1 g/kg. Red and blue shading shows vertical motion between 3-6 m/s1 up to 2 km altitude above ground level. Near the surface black-red-yellow shading is shown for potential temperature greater than 311 K, where fire heat release is highest. Ground level shows a teal to brown contour of altitude.

Figure summary: ACCESS-Fire produced deep moist convection consistent with the structure of pyrocumulonimbus at the same time and location as the observed pyroCb.

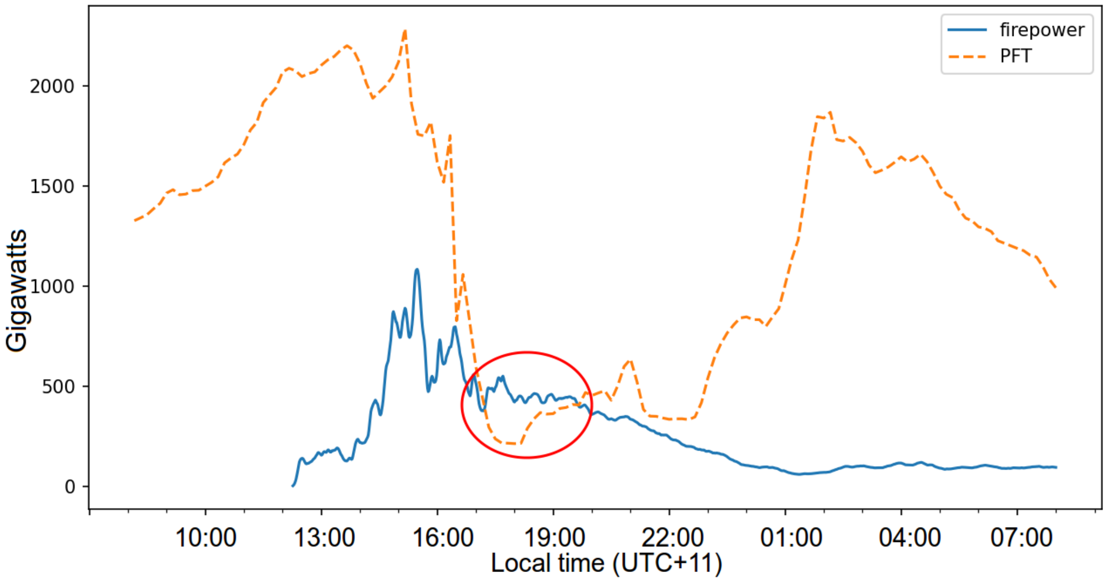

Figure 6: Pyrocumulus Firepower Threshold (orange), calculated from the ACCESS diagnostics following the method of Tory & Kepert (2019); and firepower (blue), taken from integrated firepower on the simulated firefront.

Figure summary: The simulated PFT (energy required for deep moist convection to occur) exceeded the simulated firepower (energy released by the fire) at the time the pyroCb occurred near the wind change (red ellipse).

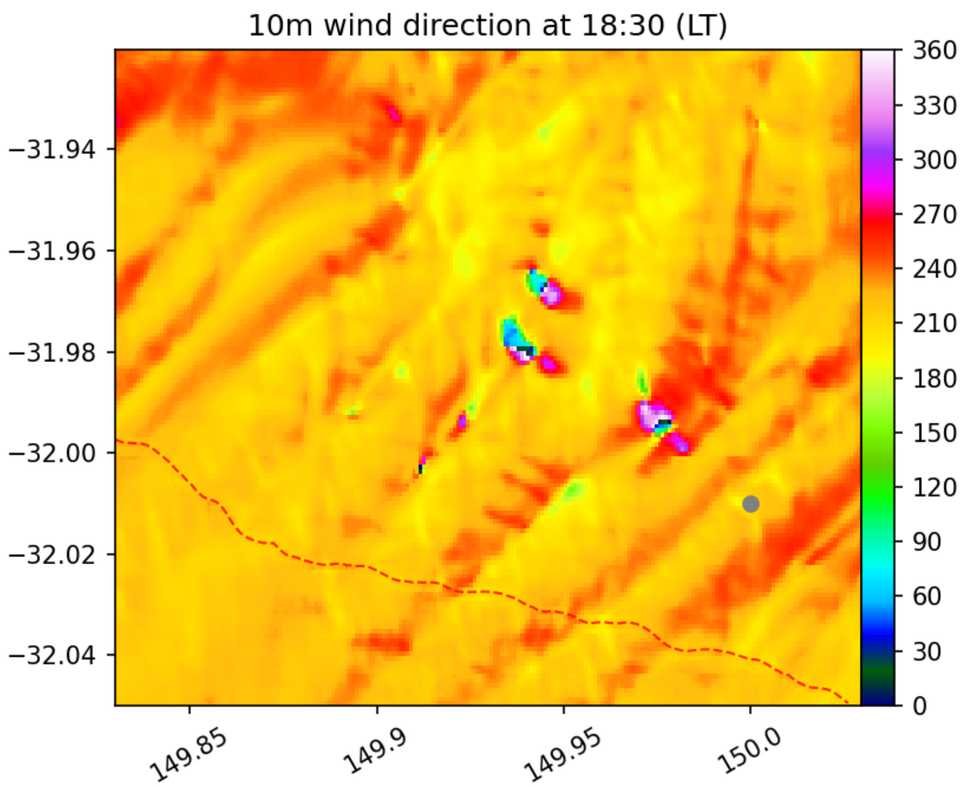

Figure 7: Wind direction at 10 m at 1830 AEDT. Red dashed line show fireline location.

Figure summary: ACCESS-Fire developed features in the surface wind fields consistent with the development of vortices ahead of the main fire front.

Sir Ivan fire key findings

- The northwest to southwesterly wind change that impacted the fire during the afternoon was simulated with a gradual shift in direction. This caused an early increase in fire intensity on the northern flank which would present an early risk to fire fighters ahead of the `forecast' wind change
- The increased fire intensity on the northern flank and elevated risk ahead of the main change highlights the opportunity for more nuanced depiction of temporal and spatial detail from numerical weather prediction model output.
- Fire intensity along the head fire and flanks varied temporally and spatially in response to cellular boundary layer rolls. Pulses in fire intensity developed in direct response to the boundary layer rolls at a scale too coarse to capture in an operational model. The influence of these pulses on fire intensity and other elements of fire behaviour has potential to impact fire fighter safety, so further research into these features would be valuable.
- Deep moist convection consistent with pyrocumulonimbus cloud developed near the timing of the wind change in a location and with a timing that verified well against the observed pyroCb. The simulated and observed pyroCb was short-lived in the highly sheared environment.
- Three fuel settings were tested (low, medium and high). The low fuel did not produce deep moist convection, the high and medium fuel settings simulated cloud consistent with pyroCb over the fire.
- The sensitivity of fuel inputs to trigger deep moist convection indicates that our settings in the Unified Model are appropriate to resolve the energy fluxes into the boundary layer. More testing is required against a range of conditions to establish efficacy, however the result indicates that ACCESS-Fire presents a useful tool for exploring the processes surrounding deep moist convection above a fire.
- Comparison of the simulated heat fluxes that produced deep moist convection against the Pyrocumulus Firepower Threshold analysis showed excellent consistency, as both approaches captured the short-lived favourable conditions for deep moist convection near the wind change.
- Small features consistent with vorticies formed ahead of the northern flank of the fire front after the wind change. Elevated features in the wind fields developed consistent with the timing and location of elevated rotating structures on radar.

DISCUSSION PAPER

COUPLED FIRE-ATMOSPHERE MODELLING DISCUSSION PAPER

Published in MDPI Atmosphere 2020 as:

Lessons Learned from Coupled Fire-Atmosphere Research and Implications for Operational Fire Prediction and Meteorological Products Provided by the Bureau of Meteorology to Australian Fire Agencies.

Authors: Mika Peace, Joseph Charney and John Bally

Abstract

(Excerpt from the published discussion paper)

Coupled fire-atmosphere models are simulators that integrate a fire component and an atmospheric component, with the objective of capturing interactions between the fire and atmosphere. As a fire releases energy in the combustion process, the surrounding atmosphere adjusts in response to the energy fluxes; coupled fire-atmosphere (CFA) models aim to resolve the processes through which these adjustments occur. Several CFA models have been developed internationally, mostly by meteorological institutions and primarily for use as a research tool. Research studies have provided valuable insights into some of the atmospheric processes surrounding a fire. The potential to run CFA models in real time is currently limited due to the intensive computational requirements. In addition, there is a need for systematic verification to establish their accuracy and the appropriate circumstances for their use. The Bureau of Meteorology (the Bureau) is responsible for providing relevant and accurate meteorological information to Australian fire agencies to inform decisions for the protection of life and property and to support hazard management activities. The inclusion of temporally and spatially detailed meteorological fields that adjust in response to the energy released by a fire is seen as a component in developing fire prediction systems that capture some of the most impactful fire and weather behaviour. The Bureau's ten-year research and development plan includes a commitment to developing CFA models, with the objective of providing enhanced services to Australian fire agencies. This paper discusses the operational use of fire predictions and simulators, learnings from CFA models and potential future directions for the Bureau in using CFA models to support fire prediction activities.

Executive Summary

(Excerpt from the discussion paper)

This discussion paper was prepared as part of the BNHCRC (Bushfire and Natural Hazards Cooperative Research Centre) "coupled fire atmosphere modeling project". The key deliverables of the project were the development of the ACCESS-Fire (ACCESS is the Australian Community Climate and Earth-System Simulator) code that was written by Monash and Melbourne universities and the preparation of detailed case studies of two high impact fires. This discussion paper aims to capture the learnings on coupled fire-atmosphere modeling arising from project activities as well as learnings from operational deployments inside fire agencies during high-impact events.

In a changing climate, we are seeing increasing impacts from bushfires and demands for large scale hazard reduction burns, as well as increasing community expectations for information during natural hazard events. Accurate and timely fire predictions generated by simulation models are a key component towards meeting future information needs, and fire agencies are responding to this by expanding their cohort of fire behaviour analysts. As the Bureau engages more strongly with fire agency partners to meet current and future needs, delivering relevant, complex meteorological numerical weather prediction capability and interpretation is vital. Coupled fire-atmosphere modeling has shown that some of the most impactful and unexpected fire behaviour occurs as a consequence of fire atmosphere interactions. Therefore, future innovative services that appropriately capture the potential for extreme fire behaviour are required to execute the Bureau strategy and to deliver impact and value to its customers.

This paper provides a summary of the main CFA models and highlights key contributions they have made to understanding fire and atmosphere interactions. The processes resolved by CFA models that are not captured in current surface-based predictions are particularly pertinent to Bureau capabilities in simulating atmospheric processes. We also describe current operational arrangements for fire weather products and services linking fire meteorologists, fire behaviour analysts (FBAns), Australian digital forecast database (ADFD), incident weather forecasts (IWFs) and briefings, and suggest opportunities for enhanced services.

The final sections present a case for future needs of fire predictions and simulators and make recommendations for potential Bureau activities to meet these future needs. The favoured long-term option is for collaborative development with CSIRO (Commonwealth Scientific and Industrial Research Organisation) and the Bureau of the Spark and ACCESS-Fire models as a pathway that would meet the operational imperatives of fast and flexible simulator capability in tandem with the capacity to run a more complex coupled simulator for research purposes and during extreme or challenging fires.

The preparation of this paper has involved consultation with fire and meteorology experts, a process that has highlighted the varying and sometimes conflicting viewpoints held by individuals in these traditionally separate scientific disciplines. Progress in developing a fire simulation capability that leverages the complexity of numerical weather prediction (NWP) and integrates fire fuel models to sufficiently capture dynamic feedback will require the collaboration of multiskilled and multidisciplinary teams.

KEY MILESTONES

Key milestones in the original project plan were unavoidably delayed due to IT delays related to model stability as well as issues resulting from changes to the UM framework and required developments to the fire code. Milestones were further adjusted in response to operational demands of the 2019-20 fire season as the prolonged impacts during the season resulted in an unprecedented demand for operational staff across multiple jurisdictions for a period of several months.

ACCESS-FIRE DEVELOPMENTS

Substantial developments have been made to the ACCESS-Fire model as described in the *Research Approach* section above.

WAROONA CASE STUDY

A detailed paper on the Waroona fire has been published in Journal of Southern Hemisphere Earth Systems and Science (JSHESS). Engagement and training activities related to this publication have been provided on request to a wide group of end-users in the Australian fire community.

Meteorological drivers of extreme fire behaviour during the Waroona bushfire, Western Australia, January 2016 Peace, M., McCaw, L., Santos, B., Kepert, J., Burrows, N. and Fawcett, R.

http://www.bom.gov.au/jshess/papers.php?year=2017

WAROONA ACCESS-FIRE SIMULATIONS

The Waroona simulations and analysis have been completed. A manuscript has been submitted to an international fire journal as:

Simulations of the Waroona fire with the coupled atmosphere-fire model ACCESS-Fire Authors: Mika Peace, Jesse Greenslade, Harvey Ye and Jeff Kepert.

SIR IVAN ACCESS-FIRE SIMULATIONS

The Sir Ivan simulations and analysis have been completed. A manuscript has been submitted to an international meteorological journal as:

Simulations of the Sir Ivan Dougherty fire with the coupled atmosphere-fire model ACCESS-Fire Authors: Mika Peace, Jesse Greenslade, Harvey Ye and Jeff Kepert.

COUPLED FIRE-ATMOSPHERE MODELLING DISCUSSION PAPER

The discussion paper has been published:

Lessons Learned from Coupled Fire-Atmosphere Research and Implications for Operational Fire Prediction and Meteorological Products Provided by the Bureau of Meteorology to Australian Fire Agencies Authors: Mika Peace, Jay Charney and John Bally.

UTILISATION AND IMPACT

SUMMARY

The project team has a strong reputation for actively engaging with both technical and non-technical audiences and specialist end-users across Australia. The project has been widely recognised for outreach activities through engaging and communicating research findings with end-users, internal and external stakeholders, local and national media and the broader community.

The project team has also been widely recognised for providing operational support in fire agencies during high impact events. Formal recognition of this contribution includes the honor of the 'Bureau Excellence Award' in 2019.

UTILISATION POTENTIAL

The main technical achievement of the project is development and delivery of the ACCESS-Fire model and demonstration of its capability through completion of the two case studies. There are three research utilisation themes stemming from the project. (1) ACCESS-Fire is available for use by other researchers and research institutions and can be used to explore fundamental fire and atmosphere interaction processes. (2) Future potential for operational use of ACCESS-Fire can be road-mapped, including discussions on how and when to run the coupled model and the data inputs and outputs required. (3) ACCESS-Fire can be run on a broader set of case studies to build a more extensive set of lessons learned.

There are two operational utilisation themes stemming from the project:

1) Training on the processes identified in the case studies to Australian FBANS, Fire Meteorologists and Embedded Meteorologists so that they can identify similar scenarios and incorporate knowledge of potential risks in their predictions, forecasts and briefings.

2) The findings can inform development of operational tools to identify locations favourable for downslope winds.

AGENCY OPERATIONAL SUPPORT

During the 2016, 2018 and 2019-20 fire seasons, the project team provided operational expertise across multiple jurisdictions including CFS, QFES and RFS. Support was provided in a specialist Embedded Meteorologist and liaison capacity in response to requests for assistance from external agencies and by internal Bureau Incident Management Teams.

CFS, South Australia. - October and November 2016 and 2019 and February 2020.

QFES, Queensland – November 2018 and November and December 2019, when the state of Queensland responded to unprecedented fires. Support in the Queensland Disaster Management Centre was requested to provide science and meteorological interpretation.

Recognition of the 2018 contribution was through an invited presentation to AFAC 2019 with Andrew Sturgess and commendation from the QFES Commissioner and QLD Premier. The November 2019 deployment included briefings to the Prime Minister, Deputy Prime Minister and Premier**.**

RFS, New South Wales - Embedded Meteorologist in the State Operations Centre during December 2019 and January and March 2020. Included briefings to the Premier and award of the 'NSW Premier's Bushfire Emergency Citation'

State Emergency Centre SA – State Operations Centre meteorologist during the 'State Blackout' severe thunderstorms and tornado breakout in September 2016, including briefing the SA Premier.

CONTRIBUTION TO ROYAL COMMISSION AND BUSHFIRE INQUIRIES

Members of the project team were reassigned to work on the Bureau's response to the Royal Commission between March and August 2020, preparing the numerous reports and science submissions for the Royal Commission and the SA and NSW State Inquiries. Although the assignment does not directly link to project outcomes, it draws on the capability developed and invested in by the CRC. Through the involvement of the project team, the expertise developed through the CRC program has been applied to the Royal Commission and State Inquiry responses.

NCI AND HPC RECOGNITION

The Australian National Computing Infrastructure and High Performance Computing group have shown considerable interest in the project over the past 12 months, particularly in view of the destructive impacts of the 2019-20 fire season. NCI and HPC engagement includes:

- Invited presentation to the Australian Leadership in Computing Symposium (2019)
- Description of ACCESS-Fire in the NCI media release for the Gadi supercomputer and interview for the NCI annual report

Invitation to speak at the virtual HPC Artificial Intelligence Conference.

HAZARD NOTE

Following publication of the Waroona case study, a Hazard Note was requested by the BNHCRC and NSW RFS. The Hazard Note was prepared in collaboration with Nathan Maddock and Kay Ansell and published in June 2018.

NATIONAL TRAINING AND ENGAGEMENT

The project team have responded to numerous invitations to present at a range of external forums to both specialist and non-specialist audiences.

CONFERENCES, SEMINARS AND SPECIALIST TRAINING

International conferences and seminars

American Meteorological Society Fire and Forest Meteorology Symposium, Boise, Idaho (2018). Three oral presentations: Waroona case study; ACCESS-Fire; and BoM Fire Research Activities.

University of Utah, USA, "Bushfires in Australia" (2018)

UK Met Office, Exeter, UK "Bushfires in Australia", (2018)

Accepted presentation to American Meteorological Society Fire and Forest Meteorology Symposium 2020 (delayed to 2021 due covid19)

Australian conferences

Fire Behaviour and Fuels conference (2016)

AFAC (2018): Oral presentation, Poster, Panel session.

Fire Behaviour and Fuels Conference (2019): Oral presentation, International Panel Session (Women in Fire). Poster

AFAC (2017): Oral presentation and poster.

MODSIM (2017) Stream keynote and Workshop.

Natural Resource Management, SA. Invited talk (2018)

Workshops and seminars

Fire Weather Workshop: Downslope Winds (2019)

NFDRS project workshop (2018)

AMOS 10 years since Black Saturday, organising committee, session chair and panel member/speaker at evening public session. (2019)

BARRA workshop, SA (2019)

Climate Change Workshop: Informing Climate Change response in SA (2019)

UK Met Office UM Users tutorial in Exeter, UK, 4-8 June 2018, and online June 2020.

Extreme Weather Desk Workshop and the Weather and Environmental Prediction Workshop (2018).

'Science Conversations', Bureau of Meteorology (July 2018)

ACCESS Coupled Fire Modelling Workshop at Monash University (2016).

Science and Innovation Group seminar (2020)

NSW Forecasting Centre workshop (2020)

Bureau of Meteorology WA seminar (2018).

BNHCRC and end-user events

RAF Melbourne, October 2017 (RMIT).

SA DEWNR and CFS seminar (2016)

Research Driving Change Showcase, National Wine Centre (2017).

Invited seminar series CFS (2020)

FBAN network seminar for AFAC (2017)

CAWCR Workshop presentation (2017)

NSW FBANs virtual workshop (2020).

FBAN training to NSW RFS (2018).

Presentation to AFAC Predictive Services Group (2020)

Mount Macedon International Study tour presentation (2018)

Perth and southwest WA seminar series (2017) (DFES, Cockburn, BoM Forecasting Centre and Busselton DPaWs)

Working groups

Contributions to the BoM Spot Fire Forecast Review, the Australian Fire Danger Ratings project (AFDRS), the BoM Embedded Meteorologist group and the BoM Fire Weather Working group.

Other activities

Major revisions of chapters for the AFAC Fire Weather Training Manual . AFAC Fire weather training chapter review

Ongoing collaboration with Kevin Tory on the BNHCRC PFT project and utilisation and the PyroCu blog.

Collaboration on the Extreme Weather Desk fire outlook trial (dry lightning, PyroCb potential, wind changes and entrainment potential).

REQUESTED EXTERNAL TALKS AND ENGAGEMENT

Presentations

Science in the Pub – Fire (2018)

South Australian Museum (2019)

SA Council event invited by CFS (2017)

Don Wallace Memorial Lecture to the Australian Hydrographic Society (2019).

Selected extended radio interviews

ABC Radio SA. Live interview at Writers Week for International Women's Day.

ABC Radio SA. Live interview on the first day of summer.

ABC Radio SA. Live interview at ABC studios on meteorology and fire research.

ABC Radio WA from AFAC on fire weather

ABC Radio SA. Interview on Fire Tornadoes. (2018)

ABC Radio National Fire weather expert (2018)

ABC Radio southwest, WA. Extended interview on fire weather (2017)

5AA Radio, SA. Extended interview on fire weather 12 months after the Pinery Fire, (2017)

5AA, Radio SA. Interview on extended fire season. (2018).

Print and online media articles

Advertiser story 'Feel the Heat' (2019)

Advertiser article ' Fire Fury' double page spread with Clare Peddie (2019)

Online ABC story 'Fire Weather conditions in Australia and what makes a bad day", with Kate Doyle (2019).

Other activities

Invitation to ' Early Career Research' panel at Adelaide University 'Women in Mathematics' day and poster promoting 'Women in Mathematics' (2019).

'Women in Mathematics Day' online video (2020)

STEM Professionals in Schools CSIRO program at Mitcham Primary school, South Australia (ongoing).

NEXT STEPS

The project completed on 30 September 2020. What happens next?

AMS CONFERENCE

The American Meteorological Society Fire and Forest Meteorology conference scheduled for May 2020 was delayed due to Covid-19. It is no longer a project deliverable due to timing, but is an approved post project activity. It is anticipated that due to Covid-19 travel restrictions the project team will attend virtually in May 2021. Following the fires in the Australian 2019-20 and USA 2020 summers, the conference will be a valuable forum for sharing experiences and learnings and establishing future collaborations and research priorities.

BNHCRC EXTENSION PROJECT

A proposal has been accepted by the BNHCRC and end-users to run a series of case studies on high impact fires that occurred during the 2019-2020 summer. The five fires are: Badja (NSW), Stanthorpe (Queensland), Kangaroo Island (South Australia), Yanchep (Western Australia) and Corryong (Victoria).

FUTURE USE OF ACCESS-FIRE

ACCESS-Fire is now running successfully and simulations have produced valuable and compelling evidence of some of the fire and atmosphere interactions that drive both extreme and unexpected fire behaviour. The extent and impacts of fires are forecast to increase in a changing climate and this presents a need for predictive methods that include the effects of fire-atmosphere interactions. ACCESS-Fire is a capability that can contribute to this imperative; therefore continued development is widely supported, particularly in view of the growing international interest in coupled fire-atmosphere models.

FUTURE DEVELOPMENT OF ACCESS-FIRE

The project team are in discussions with senior Bureau colleagues, our end-users and the BNHCRC regarding future development and use of ACCESS-Fire, as the CRC transitions to a new National Research Centre for Disaster Resilience.

Colleagues in Australian universities have expressed interest in using the current version of ACCESS-Fire to explore fundamental processes such as deep moist convection. Future collaboration with the universities will aim to be complimentary through alignment of their work on the fundamental science aspects and our focus on case studies and operational potential.

We have presented our work at the UK Met office UM workshop. This forum renewed connections with UK colleagues and invited discussion and plans to formally include the fire code in the official UM version release, which will further broaden opportunities for international collaboration.

PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

1 **Meteorological drivers of extreme fire behaviour during the Waroona bushfire, Western Australia, January 2016** Peace, M., McCaw, L., Santos, B., Kepert, J., Burrows, N. and Fawcett, R. Journal of Southern Hemisphere Earth Systems Science, 2017. http://www.bom.gov.au/jshess/papers.php?year=2017.

2 Lessons learned from coupled fire-atmosphere research and implications for operational fire prediction and meteorological products provided to Australian fire agencies (2020) Mika Peace, John Bally and Joseph Charney.

JOURNAL ARTICLES SUBMITTED

3 **Simulations of the Waroona fire with the coupled atmosphere-fire model ACCESS-Fire** (2020) Mika Peace, Jesse Greenslade, Harvey Ye and Jeff Kepert. Submitted.

4 **Simulations of the Sir Ivan Doherty fire with the coupled atmosphere-fire model ACCESS-Fire** (2020) Mika Peace, Jesse Greenslade, Harvey Ye and Jeff Kepert. Submitted.

HAZARD NOTE

5 *Extreme Fire Behaviour: Reconstructing the Waroona Fire Pyrocumulonimbus and Ember Storms*., Peace, M., Kepert, J., BNHCRC Hazard Note, June 2018.

ARTICLES

6 *Lessons learned from a multidisciplinary investigation into the Waroona fire*, Mika Peace, Jeffrey D Kepert, Lachlan McCaw, Neil Burrows, Bradley Santos, Robert Fawcett Australian, Journal of Emergency Management, 2017.

CONFERENCE PAPERS AND EXTENDED ABSTRACTS

8 *Lessons learned from a multidisciplinary investigation into the Waroona fire*. Mika Peace, Jeffrey D Kepert, Lachlan McCaw, Neil Burrows, Bradley Santos, Robert Fawcett **AFAC 2017**.

9 *Simulations of the Waroona fire with the ACCESS-Fire coupled fire atmosphere model*. Mika Peace, Jeffrey Kepert and Harvey Ye. Proceedings from the Bushfire and Natural Hazards CRC & AFAC Conference Perth, 5 – 8 September 2018 (not peer reviewed).

10 *Science in operations; QFES response to the 2018 Queensland fires*. Andrew Sturgess (QFES) and Mika Peace (BoM, BNHCRC). AFAC 2019.

11 *ACCESS-Fire: coupled fire-atmosphere modelling*. Mika Peace, Jeff Kepert, Harvey Ye (Bureau of Meteorology and BNHCRC). AFAC 2019.

REFLECTIONS

The project experienced a succession of technical challenges with ACCESS-Fire. Such setbacks are typical of a project that works with advanced and complex simulation capability, however the extent and prolonged nature of the setbacks in this case was not anticipated. Our experience has been that managing a project reliant on technical success, particularly one which is leading-edge and requires developing new capability in the team, is extremely challenging. Such innovative work relies heavily on sponsors who provide support with a long-term focus and who appreciate that time is required to overcome setbacks. We are fortunate to have had such support for our endeavors from the CRC, our end-users, and our Bureau project sponsor Dr Beth Ebert.

The technical setbacks and time spent in operations required adjustment to the original project plan timelines. We therefore thank the BNHCRC for their understanding in allowing flexible deadlines and repeatedly negotiating project timelines and deliverables, as this flexibility to shifting priorities has enabled the project team to provide operational support when it was most needed.

The work completed through this project has been accomplished with a small project team comprising approximately one full time equivalent staff member. We believe that a significant body of work and end-user engagement has been achieved by the team, despite the setbacks and diversions along the way.

TEAM MEMBERS

RESEARCH TEAM

Dr Mika Peace. Lead researcher. mika.peace@bom.gov.au

Mika's professional background is in operational meteorology. Her varied roles with the Bureau of Meteorology have taken her all around Australia. In 2010 she received a scholarship to undertake a research doctorate in fire weather.

Her current role is in fire research in the Science and Innovation Group. She is investigating the role of fire-atmosphere interactions, and how they influence fire behaviour.

She collaborates with key stakeholders in fire agencies and land management groups to develop understanding of how the atmosphere in three dimensions will drive fire behaviour. Ultimately, this helps predict where and how a fire will spread.

When required during high impact weather situations, Mika takes an operational role; briefing key stakeholders on the weather situation and assessing the likely impacts on the community.

She regularly presents at conferences and workshops as well as invited media interviews and science events in the community.

Dr Jeff Kepert. Project lead. jeff.kepert@bom.gov.au

Jeff began his career with the Bureau as a forecaster, before moving into training and then research. As a researcher, Jeff has spent most of his career on tropical cyclone and bushfire meteorology, but also worked for a while on data assimilation. He is prominent nationally and internationally, having convened major conferences, edited journals and served on the Australian Standards Wind Loading committee.

Jeff particularly values working as a researcher for the Bureau, because it not only provides an environment to do high standard research on interesting weather, but also the opportunity and support to see that research used to improve our ability to manage severe weather, thereby saving lives, property and money.

Dr Harvey Ye. Technical lead. harvey.ye@bom.gov.au

Harvey has a background in electronic engineering. He has a PhD on image compression. He joined the Bureau specialising in the processing/analysing of large climate and weather data sets, before expanding his focus to both numerical weather prediction and climate models.

His role in the coupled fire-atmosphere model project has been the technical lead in the development, improvement and running of the coupled fire-atmosphere model.

He enjoys working on the computation side of all sorts of scientific problems, while learning new concepts/theories along the way.

Dr Jesse Greenslade. Data analyst. jesse.greenslade@bom.gov.au

Jesse's background is in manipulating and analysing large data sets of physical systems. His first research involved estimating chemical emissions from natural environments within Australia, at the Centre for Atmospheric Chemistry, Wollongong. After finishing a PhD. in 2019 combining atmospheric chemical modelling and remote sensed data sets, he started manipulating and analysing large data sets for the Bureau of Meteorology.

His current role involves analysis of coupled fire-atmosphere model outputs as a researcher in the Science and Innovation group. The end goal is to better understand extreme fire behaviour and weather feedbacks in complex topographical systems by looking at case study simulations of historical fires.

He enjoys presenting results at conferences, and discussing outputs with peers, and learning about the complex modelling and programming required to understand natural systems.

END-USERS

Many of our end-users are also collaborators on various project deliverables or colleagues and team members during operational periods. We thank them for their ongoing support, partnership and insights.

End-user representative	End-user organisation	Engagement
John Bally	AFAC Predictive Services (ex BoM)	Lead end-user and collaborator
Simon Heemstra	Bureau of Meteorology (ex RFS)	End-user
Laurence McCoy	RFS (NSW)	End-user
Lachie McCaw	DPAWS(WA)	End-user and collaborator
Mike Wouters	DEW (SA)	End-user
Mark Chladil	TAS Fire	End-user

REFERENCES

1 Toivanen, J., Engel, C. B., Reeder, M. J., Lane, T. P., Davies, L., Webster, S., and Wales, S. Coupled Atmosphere-Fire simulations of the Black Saturday Kilmore East Wildfires with the Unified Model. Journal of Advances in Modelling Systems (2018).