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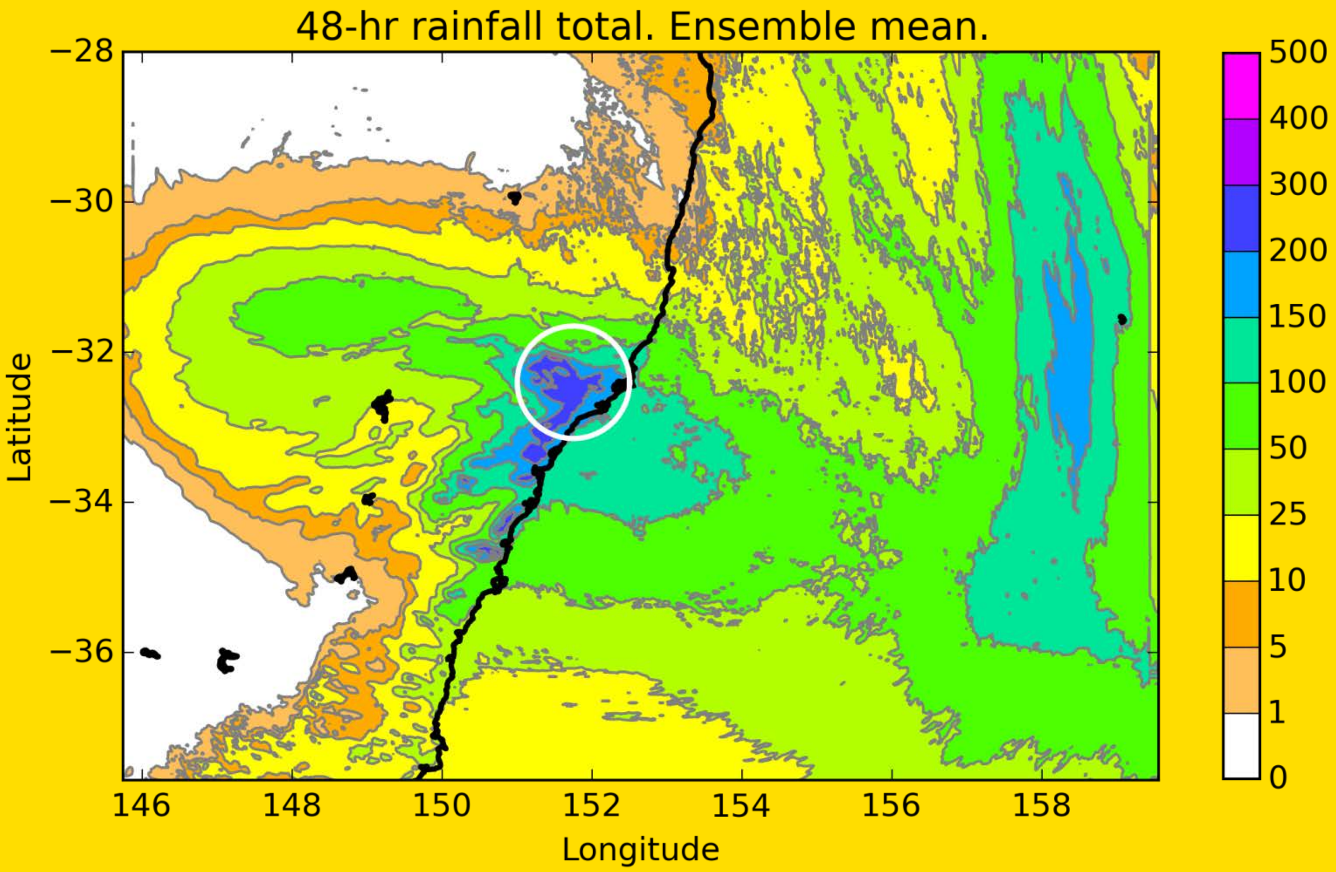
IMPROVED PREDICTIONS OF SEVERE WEATHER TO REDUCE COMMUNITY IMPACT

Annual project report 2014-2015

Jeffrey D. Kepert, Kevin J. Tory, William Thurston, Simon Ching and Robert J. B. Fawcett
Bureau of Meteorology



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Cover: The 48-hour simulated rainfall for the east coast low of April 21-23, 2015.

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EXECUTIVE SUMMARY

We aim to study the dynamics, predictability and processes of severe weather, including fire weather. We seek also to improve forecasts of severe weather, and to better depict forecast uncertainty in these events, thereby facilitating better risk management and more cost-effective mitigation. So far, we have studied ember transport in smoke plumes, pyrocumulus clouds, the meteorology of the Blue Mountains bushfires of October 2013, and the east coast low event of April 2015, four studies which span a wide range of time and space scales and require a range of different methods.

We are building on our existing modelling of bushfire plumes by using it to study ember transport. Embers are added near the base of the plumes and their trajectories calculated from the model winds. At higher wind speeds the embers travel further downstream than at lower wind speeds, as expected. However, the lateral spread is much broader for lower wind speeds. Understanding the spread in landing positions will facilitate the development of computationally affordable and physically realistic means of calculating the expected spotfire distribution in fire spread models.

We have further extended our plume modelling to begin a study of pyrocumulus development. Intense fire plumes in suitably moist environments can lead to cloud development, with intense updrafts and if rain develops the possibility of strong downbursts. Such pyro-convection may lead to enhanced and unpredictable fire spread, increased ember transport and spotting, and further ignitions from pyrocumulonimbus lightning. Our simulations produce realistic clouds, including the formation of rain and strong downdrafts. We will now examine some more cases, with the eventual aim of providing a preliminary forecast tool for pyrocumulus formation.

Although the Blue Mountains fires of October 2013 persisted for several weeks, much of the spread occurred on a single day. While this was expected to be a day of high fire risk, the extreme fire spread was unpredicted and the causes unknown. Our high resolution simulations helped identify the downward extension of high winds aloft in the vicinity of the fire ground, due to mountain wave activity. In addition, the marked wind change on that day was associated with a dry slot, known to worsen fire behaviour due to extremely low humidity.

East coast lows are intense low-pressure systems that form close to the east coast of Australia, most commonly along the New South Wales coast. They can produce severe wind, wave and flood impacts as in the event of 20-23 April 2015, which we are studying. For the first time, we are conducting this study with an ensemble of 24 simulations, rather than just a single forecast. Each simulation begins from a slightly different initial state, giving 24 different, but plausible, forecasts that represent a range of possible outcomes. Collectively, these simulations accurately predict the position and intensity of the low, the strong winds and the rainfall. The differences between them will be analysed to determine how predictable aspects of the event were.

END USER STATEMENT

Paul Fox-Hughes, *Tasmania Regional Office, Bureau of Meteorology*

The work of the researchers in the "Improved predictions of Severe Weather to Reduce Community Impact" project is providing critical insights into a number of areas of weather and weather-related impacts of "high-end" events. The use of ensembles in studying high-impact severe weather events such as the April 2015 east coast low is providing very useful understanding of the phenomena themselves. Importantly, however, this approach will inform the next generation of operational forecasting, for which ensembles will become a routine tool. It will also allow emergency managers to gain a feel for the capability of this approach, and to consider how they might incorporate its insights into their decision-making processes.

Again, meteorologists and land managers need to know what factors led to the extreme fire spread on one day in particular of the Blue Mountains fire – this project has delivered an important advance in the understanding of that event. The influence of topographically-forced winds and connection to upper atmospheric processes in enhancing the fire danger on the day of rapid fire advance clearly demonstrates the importance of considering the potential influence of these factors in forecasting and managing prescribed burns or wildfires in mountainous areas. On a smaller spatial and temporal scale, the large eddy modelling is providing exquisitely detailed simulations of ember transport and pyroconvection. Both of these phenomena are important sources of uncertainty in the behaviour and spread of fires. With further improvements in their understanding, which the research group is working to provide, there is the potential for their impacts to be parametrised into fire behaviour models.

The above studies, and others that the group have completed and are working on, are providing some really useful insights into the weather phenomena under consideration, but also providing an opportunity for forecasters and emergency managers to consider how future operational forecasting approaches might assist in their work. This work is exciting and important, and I look forward to seeing its outcomes in future years of the BNHCRC.

INTRODUCTION

This project, in the monitoring and prediction cluster, aims to use high-resolution modelling, together with the full range of meteorological observations, to better understand and predict several important meteorological natural hazards, including fire weather, tropical cyclones, severe thunderstorms and east coast lows. The outcomes from the project will contribute to reducing the impact and cost of these hazards on people, infrastructure, the economy and the environment.

Work this year has been concentrated in two main areas. The first of these is the use of a sophisticated large eddy model of fire plumes to investigate two important phenomena associated with such plumes: long-range ember transport or spotting, and the formation of pyrocumulus. We have made substantial progress in these areas, and given presentations of the results at several fora, including the 2015 Bushfire and Natural Hazards CRC and AFAC conference.

The second major area has been the analysis of the meteorology during the Blue Mountains bushfires of October 2013. This work relies on a very high resolution simulation of 17 October, when major fire spread occurred and a substantial number of houses were lost. Meteorological phenomena that likely contributed to the fire activity include mountain waves and a dry slot.

Our original project plan included a “place-holder” case study, with the precise event to be determined during the course of the project. In April 2015, a major east-coast low-pressure system (colloquially called an east coast low) affected the New South Wales central coast, producing strong winds, major flooding, high seas and coastal erosion. Over 200,000 houses lost power, and tragically four deaths occurred. In consultation with our end-user committee, we have selected this event for that case study and have commenced the modelling and analysis. For this event, we are taking the novel approach of utilizing a high-resolution ensemble of model simulations, so that we can study the predictability of the event, as well as its meteorology. Such ensembles will be the core of future severe weather prediction, and we expect this study to provide clues to both meteorologists and emergency services personnel as to how best use this new source of information.

This report summarises our activities this year, including presenting some key results from the above component studies. Please note that these are still work in progress, and that results may be updated as we continue the research.

PROJECT BACKGROUND

The project uses high-resolution modelling, together with the full range of meteorological data, to better understand and predict several important meteorological natural hazards, including fire weather, tropical cyclones, severe thunderstorms and east coast lows. The outcomes from the project will contribute to reducing the impact and cost of these hazards on people, infrastructure, the economy and the environment. Specific outcomes will include:

- Improved scientific understanding of severe weather phenomena relevant to Australia.
- Improved knowledge of how to best predict these phenomena, including model configuration and interpretation.
- Contribute to the post-event analysis and "lessons learned" of selected severe events that occur during the course of the project.
- Inform the development of numerical weather prediction (NWP) systems specifically for severe weather.
- Communicate the above knowledge through seminars, conferences and publication in the peer-reviewed literature, to the scientific and operational communities.

Extreme weather often occurs at relatively small scales – here, the devil really is in the detail. For example, the intense extra-tropical cyclone of June 2007 that grounded the Pasha Bulker coal carrier 20 metres off Nobbys Beach (Newcastle) and resulted in nine deaths had only a narrow belt of intense winds and rainfall. Even when the meteorology driving the event is not small scale, small-scale perturbations within the overall framework can have a significant effect, as we have seen in the fine-scale meteorology we simulated for Black Saturday and other severe fire events. Accurate forecasts and understanding of such small-scale processes requires high-resolution modelling. Developing and validating such modelling, and extending it to all hazards, is the first aim of this project.

Forecasts are never perfect, but they are nevertheless useful. Forecasts are especially useful in severe weather events, since they play an essential role in allowing communities, industry and emergency services to prepare. Forecasting therefore underpins the work of emergency services and related agencies, and makes the PPRR (Prevention, Preparedness, Response and Recovery) process more efficient and effective. Because forecasts are uncertain in the severity, location and duration of an event, preparation needs to be more widespread than the eventual impact – but this over-preparation comes at a cost. Detailed prediction of the probabilities of severe impacts would avoid the risk of failing to alert areas with the chance of an impact, while minimising the cost of over-warning. That is, the second aim of this project is, for a small number of selected events, to provide pilot predictions of not just the most likely course of events, but also the level of uncertainty, by identifying plausible alternative scenarios and their likelihoods. For example, Tropical Cyclone *George* made landfall near Port Hedland in 2006 after making a sudden turn towards the coast, resulting in three deaths. The deterministic predictions did not capture this direction change, but the probabilistic systems indicated that such a change, while unlikely, was possible.

A key aim of this project is to develop scientific understanding and to assist with the "lessons learned" from severe events. For example, the Beechworth-Mudgegonga fire on Black Saturday dramatically increased in activity around midnight, while the Margaret River fire of 2011 re-intensified overnight and broke control lines early the next morning. Each of these cases opposed the expected diurnal trend in fire behaviour, but our high-resolution modelling studies identified small-scale meteorological phenomena that explain the unexpected behaviour. Our research thus adds to the collective wisdom of fire-fighters and weather forecasters, improving our ability to manage these events and reducing the risk of adverse outcomes in the future.

The principal NWP modelling system used in this project is ACCESS, the Australian Community Climate and Earth-System Simulator, which is based on the UK Met Office's NWP system and is used operationally within the Bureau of Meteorology and by several other overseas national weather services. It therefore benefits from a wide user base, and the discipline of operational use and continual verification. It is presently the second-best performing operational NWP system in the world. The only system to consistently outperform it for global prediction is a global-only model which cannot be run in the high-resolution limited-area mode necessary to simulate fine-scale meteorology.

For situations where extremely high resolution modelling with a grid spacing of tens of metres, and the capacity to explicitly resolve atmospheric turbulence is needed, we also use the UK Met Office's Large-Eddy Model (LEM). This specialised model is designed not for forecasting, but rather for understanding phenomena that are highly sensitive to turbulence, including boundary layers, fire plumes and convective clouds.

WHAT THE PROJECT HAS BEEN UP TO

EMBER TRANSPORT

We have continued with our study of ember transport within fire plumes.

For this work we use a Large-Eddy Model (LEM) obtained from the UK Met Office. LEMs are designed for the accurate simulation of turbulent flows. Turbulence can be regarded as the superposition of eddies of a range of different sizes. In atmospheric turbulence, the range of spatial scales is from over 1 km down to 1 mm. Explicitly resolving this vast range of scales would be computationally impossible, as the grid size would have to be below 1 mm, and the grid extent over 10 km, far exceeding current computational capacity. However, the most energetic eddies, that do most of the mixing and transport in the atmosphere, are relatively large. LEMs exploit this fact by directly representing these eddies, while parameterising the less important smaller ones. The smaller eddies are also easier to parameterise accurately, being relatively homogeneous (spatially uniform) and isotropic (more symmetric). We run the LEM with a horizontal grid spacing of 50 m in these cases.

The plume is simulated by inserting a heat source, representative of a fire, at the model's lower surface. Plume dynamics are sensitive to the rate at which the plume mixes with the surrounding air (entrainment), and so we first run the model without a fire to spin up realistic turbulence in the boundary layer. We then add an intense heat source, to generate a turbulent buoyant plume similar to that generated by a bushfire. Finally, we take the resulting time-varying wind field, consisting of three-dimensional wind vectors on the model grid, and use it to transport "embers". These embers are blown around by the wind, and also have a fall velocity. Each ember is tracked until it hits the ground. We then collect statistics of landing location and "hang time", for various fire strengths and horizontal wind speeds. Representative ember trajectories are shown in Figure 1.

Unsurprisingly, as the wind speed increases, the travel distance increases. However, the lateral spread of the embers also narrows – in fact, the spread is quite broad at light wind speeds. Further analysis of this work will be aimed at understanding the dynamics of ember transport, especially why the landing zone narrows at stronger winds.

Eventually, we aim to develop simple and cost-effective ways of estimating the landing region and ember hang time, based on these sophisticated simulations. To this end, we have also calculated the transport with time-averaged winds; that is, neglecting the effects of the turbulence in the plume. Naturally, the embers are much less spread in this mode. However, there also appears to be a reduction in the most common landing distance. Figure 1 also shows the difference between these two types of simulations.

These calculations are much cheaper than those including turbulence, so may be feasible for real-time ember transport calculations as part of a bushfire simulator. However, we will first need to solve the difficult problem of correctly accounting for the spread caused by the turbulence.

Such ember transport parameterisations will be useful in the future for estimating the spotting risk in fires, and also as a component of fire-spread models. At present, embers are accounted for in fire-spread models by comparatively crude methods that do not realistically depict the plume, and ignore the further spreading of the landing zone by turbulence.

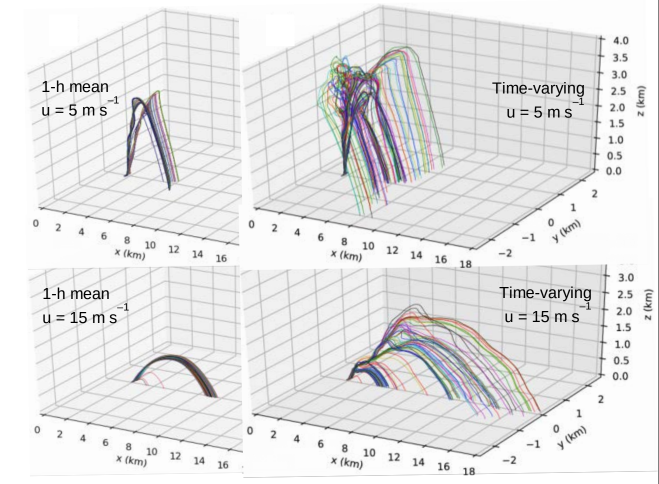

Fig. 1: Simulated ember trajectories in a bushfire plume. The left panels show the trajectories from the time-mean plume, while the right panels illustrate the much greater spread obtained when we account for turbulence. The wind speed above the boundary layer is 5 m s^{-1} (18 km hr^{-1}) in the top panels, and 15 m s^{-1} (54 km hr^{-1}) in the lower.

PYROCUMULUS DYNAMICS

Intense heating by a bushfire causes air to ascend, which if deep enough can cause the formation of cumulus or cumulonimbus clouds in a process known as pyro-convection. This pyro-convection can potentially have a significant impact on fire behaviour by amplifying burn and spread rates, enhancing spotting through plume intensification and igniting new fires via pyrocumulonimbus lightning.

We are further using our expertise in large-eddy simulations to investigate the generation of pyro-convection by bushfire plumes and the sensitivity of this pyro-convection to fire intensity and environmental moisture. Large-eddy simulation (LES) is a modelling technique developed especially for complex turbulent flows such as bushfire plumes. Accurate simulation of such flows requires that the mixing between the plume and the surrounding air be accurately accounted for, as this mixing determines the volume and buoyancy of the plume air. The LES explicitly resolves much of this mixing, and so requires simpler assumptions than normal atmospheric modelling. Hence it is more accurate for such cases.

We have found that moister background atmospheres or more intense fires produce larger, more intense pyro-convective clouds (Figure 2) and if the background atmosphere is moist enough, intense fires can produce pyro-convection even in the absence of any moisture from the combustion. Updrafts within the simulated pyro-convection are well in excess of the fall velocities of typical firebrands and exceed those in the cases where pyro-convection does not occur. The formation of precipitation within the most intense pyro-convective clouds leads to the development of downbursts that cause strong and highly variable winds at the surface. These strong updrafts and downbursts can have significant impacts on fire behaviour. The simulations presented here allow us to explore the conditions under which these potentially dangerous phenomena occur.

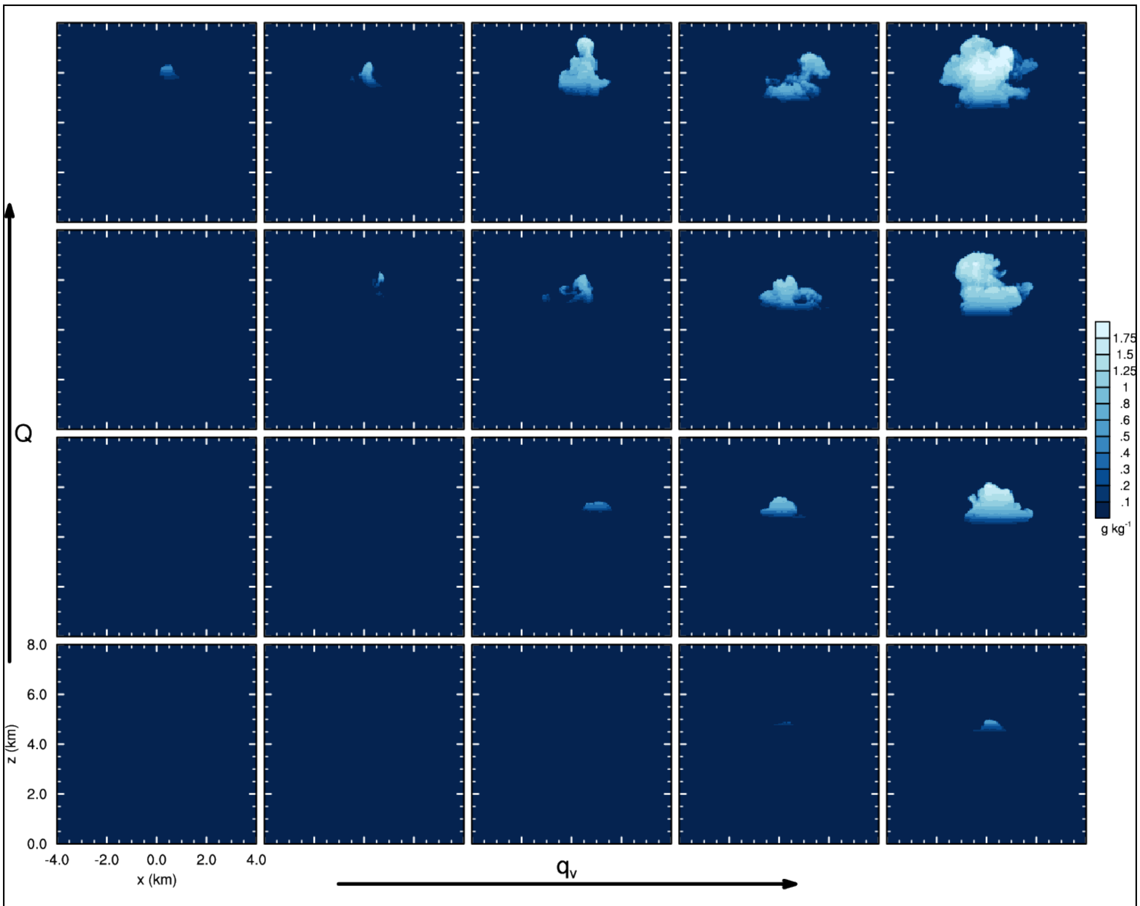

Fig. 2: Pyrocumulus development over a fire plume in the large-eddy model, visualised through vertical cross-sections of the cloud water mixing ratio (g kg^{-1}). These twenty simulations are arranged so that fire intensity increases from bottom to top, and boundary-layer humidity increases from left to right. Pyrocumuli are more developed with a moister boundary layer and more intense fire. The strongest cases produced significant rainfall.

BLUE MOUNTAINS BUSHFIRES OF OCTOBER 2013

We are using state-of-the-art high-resolution numerical weather prediction simulations for three different periods in October 2013, with a specific focus on the Blue Mountains in eastern New South Wales and the weather on the 13th, 17th and 23rd of October 2013. The simulations have been performed using the ACCESS, and involve a sequence of nested limited-area model runs embedded in the ACCESS global model runs, with a finest grid spacing of about 440 metres.

NSW fire fighters attended 1167 bush and grass fires in the four weeks of October 2013, but the most intensive fire activity was between the 13th and the 26th when there were 627 incidents and 164,054 hectares burnt. The afternoon of the 17th proved to be one of the most destructive few hours in the past decade, with more than 200 houses destroyed across the Blue Mountains region. Notable fires within the Blue Mountains region included the State Mine Fire (area 54,862 hectares, perimeter 461 km) and the Mt York Road Fire (9,383 hectares, 99 km) (NSW Rural Fire Service, 2014).

The simulations show marked cool changes crossing New South Wales on the 13th, the 17th and the 23rd. In the vicinity of the State Mine Fire, the simulations across the three days show bands of wind direction variability ahead of the cool changes, taking the form of lines of convergence and divergence in the 10-metre simulated winds. This variability could potentially lead to broadening of fire fronts, and consequently faster fire propagation (Thurston et al. 2015).

Cross-sections from the simulation on the 17th showed a marked downward extension of the strong winds aloft in the general vicinity of the fire ground (Figure 3). Examination of the vertical velocity showed a clear mountain wave signature. The potential for mountain waves to escalate fire behaviour was discussed by Sharples (2009), and we have previously shown that they were probably responsible for overnight escalations in fires at Margaret River (Kepert and Fawcett 2013) and Aberfeldy (Wells et al. 2014). The Blue Mountains case is of particular interest because the phenomenon occurred during the day, rather than at night when the nocturnal inversion provides near-surface conditions very favourable for mountain waves.

The wind change on the 17th was a complex one, manifested in the Blue Mountains area as several small abrupt directional changes, embedded within the general trend of northwesterlies gradually backing to the southwesterlies through the course of the day. The change was also associated with a marked dry slot, with dew-point temperatures plunging to as low as –7.6°C in the AWS at Mt Boyce. Over the ocean, this wind change had a markedly complex structure as it proceeded up the coast during the evening.

Fine-scale surface wind-direction fluctuations were apparent throughout the day. Some of these appear to be related to flow around topography, while others were due to boundary-layer rolls similar to those discussed in Thurston et al. (2015).

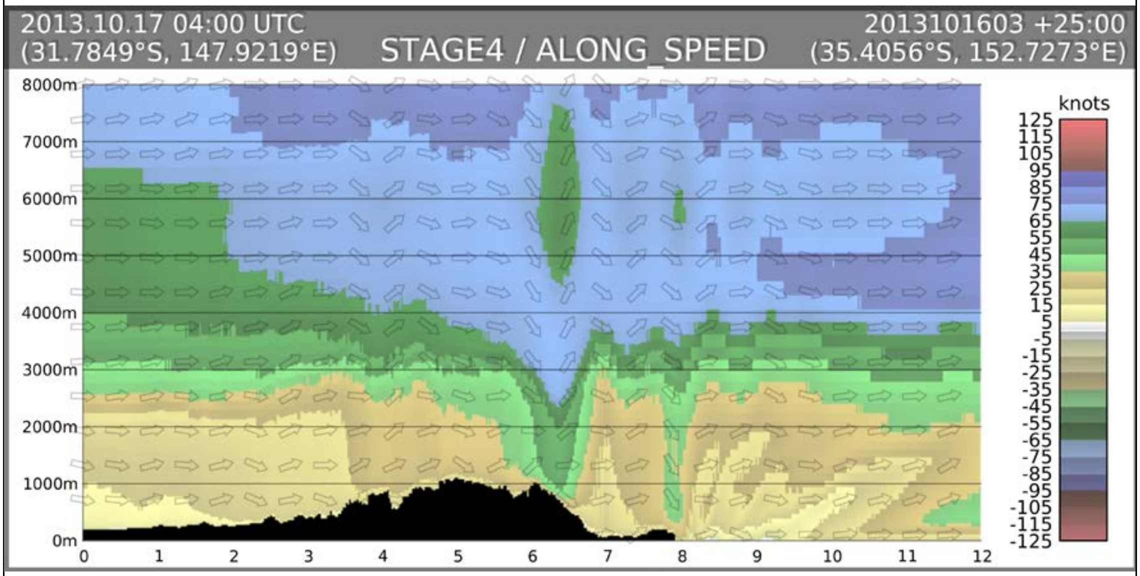

Fig. 3: Cross-section of wind speed over the State Mine Fire on the afternoon of 17 October 2013. Note the downwards extension of the strong winds in the vicinity of the fire (horizontal locational points 6 and 7).

EAST COAST LOW OF APRIL 2015

East coast lows are intense low-pressure systems that form close to the east coast of Australia, most commonly along the New South Wales coast. They are distinct from tropical cyclones, being more characteristic of mid-latitude systems in their energy source and structure. They have been responsible for a number of natural disasters in that region. A prominent recent example was the Pasha Bulker storm of 2007 (Mills et al. 2010), named after the bulk carrier that beached off Newcastle during the event. Although east coast lows form in most years, severe impacts are less frequent.

The event we plan to study occurred during 20-23 April 2015, with the worst impact on 21 April. It was a major flood event for Dungog and Maitland, and caused at least four deaths. Dozens of houses lost their roofs, over 200,000 houses were without power, and 57 schools closed.

Our initial model runs followed the same method as we have used in the past; namely beginning with a global simulation, and then nesting within that to successively higher resolution but smaller domain. The final three model domains had grid spacings of approximately 4 km, 1.3 km and 440 m. These simulations provided a generally good depiction of the location and intensity of the low, including the formation of the much smaller vortices within it that are often associated with the worst weather.

We then prepared an ensemble of 24 simulations of the event. These were initialized from the 24 members of the Bureau's prototype global ensemble prediction system, ACCESS-GE, and followed the usual downscaling approach except that the global initial conditions were of a coarser resolution than used for the initial model run and that the finest resolution was 1.3 km. The nesting was stopped at 1.3 km partly to reduce the computational burden, but also because our initial run showed that this resolution was sufficient to capture the dynamics of the event.

Analysis of the simulations is in its early stages. In Figure 4 we show the forecast rainfall from the event, averaged over the 24 ensemble members, together with the verifying analysis. Clearly, the forecast matches reality very well. None of the individual ensemble members showed such a close match, and one known benefit of ensemble prediction is the generally improved accuracy of the mean forecast over single deterministic forecasts.

However, the mean forecast falls short on peak rainfall in the Dungog area, which is about half as strong as observed. Figure 5 shows plots of the forecast probability of rainfall exceeding 100 mm and 400 mm, defined as the proportion of the ensemble that exceeds these threshholds. Note how the ensemble singles out the Dungog area as being of moderate risk of extreme rainfall.

In east coast lows, the strongest winds and heaviest rain often occur immediately to the south of small-scale lows that form right on the coast within the overall envelope of the larger-scale system. The ensemble shows considerable spread in the timing and location of these systems, indicating that although the area around Dungog carries the highest risk, a substantial part of the coast is at risk of significant rain. Information on the relative risk different locations are expected to face could be very valuable for emergency services preplanning.

These rainfall forecasts could also be valuable as input into an ensemble of hydrological models, giving a prediction of various levels of flood risk. Figure 6 shows a box-and-whisker plot of the hourly distribution of rain within the ensemble, averaged approximately over the catchment upstream of Dungog. This figure confirms the significant risk of sustained very heavy rain over a prolonged period. However, it also shows that some members were predicting relatively light rain in this region. In these cases, the rain mostly fell elsewhere.

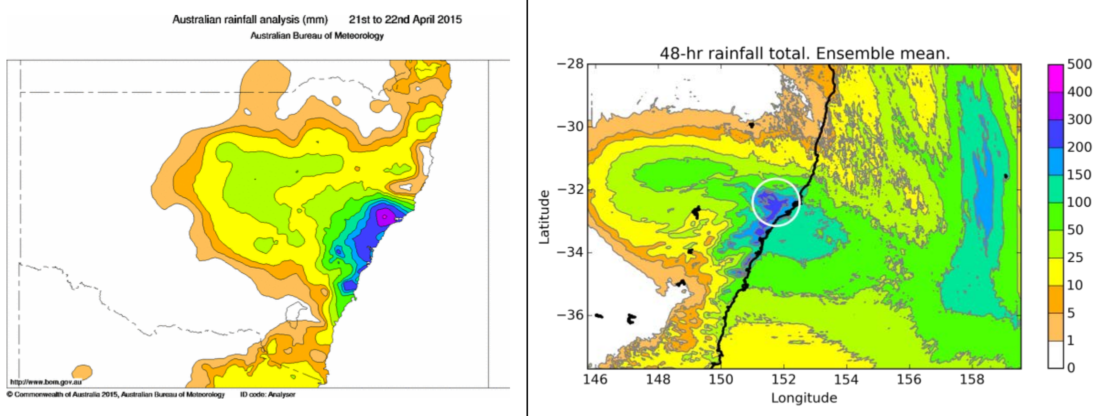

Fig. 4: Observed (left) and ensemble-mean (right) total rainfall over the 48 hours to 9 am and 11 am on the 22nd, respectively. The observed rainfall is taken from the Bureau's operational high-resolution daily rainfall analyses. Dungog is circled in the right-hand image.

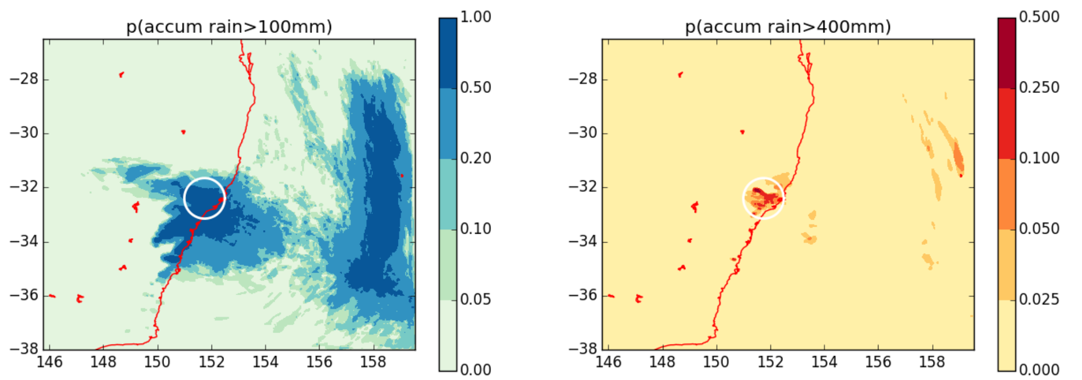

Fig. 5: Probability of rainfall exceeding 100 mm (left) and 400 mm (right) for the 48 hours to 11 am on 22 April 2015. Dungog is at the centre of the white circles.

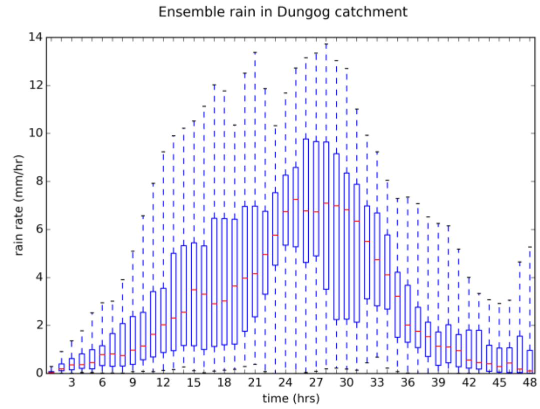

Fig. 6: Box-and whisker plots of hourly rainfall amount from 11 am 20 April 2015. The boxes show the upper and lower quartiles, the red line the median, and the whiskers show the range.

OTHER STUDIES

We continued to contribute to other minor case studies of severe weather events. This year, these included the Sampson's Flat fire of January 2015 in South Australia, and the Warragamba fire near Coonabarabran in New South Wales in January 2013. We presented results of these studies at AFAC Conferences in 2015 and 2014, respectively.

COMMUNICATIONS

The bulk of our communication activities have occurred at science and industry conferences, including those organized by AFAC, AMOS (the Australian Meteorological and Oceanographic Society) and the AMS (the American Meteorological Society). Details are in the next section.

We continue to strengthen our relationships with relevant state and federal agencies, including those with responsibility for bushfires and emergency management. An important aim here is to ensure that these people are aware of the likely future direction of weather services, so as to smooth the eventual path to extracting operational value.

PUBLICATIONS LIST

JOURNAL PUBLICATIONS

Resulting from this project

Thurston, W., K. J. Tory, R. J. B. Fawcett and J. D. Kepert, 2015: Large-eddy simulations of pyro-convection and its sensitivity to environmental conditions. Submitted to *Austral. J. Emergency Mgt.* special issue for AFAC Conference. Not published since the journal special issue was cancelled.

Resulting from other projects

Kepert, J. D. and D. S. Nolan, 2014: Reply to "Comments on 'How Does the Boundary Layer Contribute to Eyewall Replacement Cycles in Axisymmetric Tropical Cyclones?'". *J. Atmos. Sci.*, **71**, 4692–4704, doi:10.1175/JAS-D-14-0014.1

Peace, M., T. Mattner, G. A. Mills, J. D. Kepert, and L. McCaw, 2015: Fire modified meteorology in a coupled fire-atmosphere model. *J. Appl. Met. Clim.,* **54**, 704–720, doi:10.1175/JAMC-D-14-0063.1

Peace, M., T. Mattner, G. A. Mills, L. McCaw and J. D. Kepert, 2014: WRF and SFIRE simulations of the Layman fuel reduction burn. Submitted to *I. J. Wildland Fire.*

Peace, M., T. Mattner, G. A. Mills, J. D. Kepert, and L. McCaw, 2014: Coupled WRF and SFIRE simulations of the Rocky River fire. Submitted to *I. J. Wildland Fire.*

Thurston, W., R. J. B. Fawcett, K. J. Tory and J. D. Kepert, 2015: Simulating boundary-layer rolls with a numerical weather prediction model. In press, *Quart. J. Roy. Meteor. Soc.*

AFAC CONFERENCE 2014

We had a substantial presence at the 2014 AFAC conference in Wellington, principally on the research day. Papers presented that resulted from this project are as follows:

- The effect of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert. This talk presented some early results from the ember transport project.

- Poster: Improved Predictions of Severe Weather to Help Reduce Community Impact by Jeff Kepert, Kevin Tory, Robert Fawcett and Will Thurston. This poster gave an overview of the project.

- Poster: The Effects Of Fire-Plume Dynamics On The Lateral And Longitudinal Spread Of Long-Range Spotting by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert. This poster presented further information on the ember transport work.

In addition, team members are involved in other work, outside of this project, that was presented at AFAC:

- Managing severe weather – progress and opportunities by Jeff Kepert, Mike Naughton and John Bally. This was a review paper focussing largely on ensemble prediction.

- The heatwaves of the 2013 – 2014 Australian summer by Robert Fawcett and John Nairn. This presentation and paper discussed the heat wave events of he previous summer, and how the Bureau's pilot heatwave forecasting service performed.

- Modelling the fire weather of the Coonabarabran fire of 13 January 2013 by Robert Fawcett, Claire Yeo, Will Thurston, Jeff Kepert and Kevin Tory. We began this work under the old Bushfire CRC as a side project, and completed it in the first months of this project. Conference presentation and paper.

- Meteorological and fire behavioural lessons learned from the Aberfeldy Fire, Victoria, 17 January 2013 by Tim Wells, Claire Yeo and Robert Fawcett.

- Fire Danger Indices: Current Limitations and a Pathway towards Better Indices Claire Yeo, Jeff Kepert and Robin Hicks. This poster reported on work which will inform the project aiming to build a new Fire Danger Rating system for Australia.

- Mitigating the Effects of Severe Fires, Floods and Heatwaves Through The Improvements Of Land Dryness Measures and Forecasts Imtiaz Dharssi, Vinod Kumar, Claire Yeo, John Bally and Jeff Kepert.

- An enhanced national Fire Danger Rating System for Australia – where to from here? Panel discussion led by Liam Fogarty, Simon Heemstra, Mike Rumsewicz and Jeff Kepert.

UK MET OFFICE FIRE SYMPOSIUM, DECEMBER 2014

Will Thurston attended this symposium and presented the following papers.

Oral: The effect of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert.

Oral: Modelling the fire weather of the Coonabarabran (NSW) fire of 13 January 2013 by Robert Fawcett, Claire Yeo, Will Thurston, Jeff Kepert, and Kevin Tory.

Poster: Meteorological and fire behavioural lessons learned from the Aberfeldy Fire (Victoria) on 17 January 2013 by Robert Fawcett, Tim Weills, Claire Yeo and Will Thurston.

Poster: Fires and convection: a comparison of two extreme cases in southeast Australia by Andrew Dowdy and Will Thurston.

AMERICAN METEOROLOGICAL SOCIETY 11TH SYMPOSIUM ON FIRE AND FOREST METEOROLOGY, MAY 2015

Oral: The effect of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert.

Oral: Modelling the fire weather of the Coonabarabran (NSW) fire of 13 January 2013 by Robert Fawcett, Claire Yeo, Will Thurston, Jeff Kepert, and Kevin Tory

Poster: Meteorological and fire behavioural lessons learned from the Aberfeldy Fire (Victoria) on 17 January 2013 by Robert Fawcett, Tim Wells, Claire Yeo and Will Thurston.

UNIFIED MODEL USERS GROUP WORKSHOP, JUNE 2015

Oral: Fire modelling at the Bureau of Meteorology by Jeff Kepert, Will Thurston, Kevin Tory and Robert Fawcett.

AMOS CONFERENCE, JULY 2015

Will Thurston attended the annual conference of the Australian Meteorological and Oceanographic Society (Brisbane) and presented the following papers.

Talk: Long-range spotting by bushfire plumes: The effects of in-plume turbulence on firebrand trajectory by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert.

Poster: Large-eddy simulations of pyro-convection and its sensitivity to environmental conditions by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert.

Poster: Modelling the fire weather of the Blue Mountains fires of October 2013 by Simon E Ching, Robert J B Fawcett, William Thurston, Kevin J Tory and Jeffrey D Kepert.

AFAC CONFERENCE, SEPTEMBER 2015

We submitted a number of abstracts to the 2015 AFAC/BNHCRC conference in Adelaide, and Jeff Kepert, Will Thurston and Simon Ching attended.

William Thurston, Kevin J. Tory, Robert J. B. Fawcett and Jeffrey D. Kepert, 2015: Large-eddy simulations of pyro-convection and its sensitivity to environmental conditions. Proceedings of the Research Forum, AFAC 2015 Conference

Poster: Long-range spotting by bushfire plumes: The effects of in-plume turbulence on firebrand trajectory, by Will Thurston, Kevin Tory, Robert Fawcett and Jeff Kepert.

BNHCRC REPORTS

Kevin J. Tory and William Thurston, 2015: Pyrocumulonimbus: A literature review. BNHCRC Report.

Will Thurston, Kevin Tory, Jeff Kepert, Robert Fawcett, 2015: Briefing note: Methodology for pyrocumulus large-eddy simulations – a rationale. BNHCRC Internal Report.

CURRENT TEAM MEMBERS

Jeff Kepert: Project leader. Tropical cyclones, atmospheric dynamics, fire weather, turbulence.

Kevin Tory: Project co-leader. Tropical cyclones, atmospheric dynamics, fire weather.

Will Thurston: Large eddy modelling, plume behavior, pyrocumulus, ember transport, visualization.

Simon (Eng) Ching: Mesoscale meteorology, fire weather, visualization.

Robert Fawcett: ACCESS modelling, climatology, heat waves, fire weather.

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Kepert, J. D. and R. J. B. Fawcett, 2013: Meteorological aspects of the Margaret River fires of November 2011. In Piantadosi, J., Anderssen, R.S. and Boland J. (eds) MODSIM2013, 20th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2013. ISBN: 978-0-9872143-3-1.

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Wells, T., C.S. Yeo and R.J.B. Fawcett, 2014: Meteorological and fire behavioural lessons learned from the Aberfeldy Fire, Victoria, 17 January 2013. *Poster presented at the 2014 Conference of the Australasian Fire and Emergency Services Council and the Bushfire and Natural Hazards Cooperative Research Centre,* Wellington, New Zealand, 2 - 5 September.