Australian Government
Bureau of Meteorology

bushfire&natural HAZARDS CRC

bnhcrc.com.au

COUPLED FIRE-ATMOSPHERE MODELLING PROJECT

Annual Project Report 2016

Jeffrey Kepert, Mika Peace
Bureau of Meteorology
Bushfire and Natural Hazards CRC

Version	Release history	Date
1.0	Initial release of document	15/08/16

Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International Licence.

Disclaimer:
Bureau of Meteorology and the Bushfire and Natural Hazards CRC advise that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, Bureau of Meteorology and the Bushfire and Natural Hazards CRC (including its employees and consultants) exclude all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Publisher:
Bushfire and Natural Hazards CRC

August 2016

Citation: Kepert J, Peace M (2016) Coupled fire-atmosphere modelling: Annual project report 2015-2016, Bushfire and Natural Hazards CRC

Cover: Pyro-convection above the Waroona bushfire on 7 January 2016. Photo supplied by Neil Bennet, Bureau of Meteorology, Perth.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The goal of the project is to improve understanding of fire and atmosphere interactions and feedback processes by running a coupled fire-atmosphere simulation model. Planned outcomes of the project include: preparation of meteorological and simulation case studies of significant fire events, installation and testing of a coupled model on the national computing infrastructure and preparation of training material to support operational implementation of research findings.

Weather forecasting and fire prediction are similar in that skilled practitioners of both rely on a combination of detailed scientific knowledge and objective analysis, juxtaposed with pattern recognition that draws on past experience and a mental inventory of previous events. By preparing detailed case studies and coupled simulations of events in which unexpected or unusual fire-atmosphere interactions occurred, we contribute to both the scientific understanding for fire–atmosphere interactions and the knowledge base of operational meteorologists and fire analysts.

The project has been staffed for just four months, and is commencing work on two main fronts. The first of these is implementing the coupled model ACCESS-Fire (ACCESS is the Australian Community Climate and Earth-System Simulator). We have obtained the source code from Monash University and are preparing for installation and testing. Progress has been slowed a little by a major change in the ACCESS model infrastructure, which has mean that some necessary components for very high resolution simulation are not yet available. We attended an ACCESS training workshop to ensure that we have the necessary skills to properly run the model.

After extensive consultation with end users, we have identified the Waroona fire in Western Australia (WA) in January 2016 as our first case study. This was a significant and complex event, with the impacts including the destruction of the town of Yarloop. We have made good progress on collecting and analysing data and preparing an initial draft report that describes the meteorology and fire activity during the first two days of this event, in collaboration with Western Australian fire scientists. We have also prepared an initial simulation of the event, without fire coupling.

END USER STATEMENT

Dr Simon Heemstra, NSW Rural Fire Service

In the short time that this project has been running considerable progress has been made in setting up the coupled fire-atmosphere model and selecting the first case study. I am pleased that the project team was able to make use of existing model development work done previously by Monash University. The level of end user engagement from the project team has been excellent, and the case study will hopefully provide valuable understanding of coupled fire-atmosphere processes. I look forward to many interesting insights from the project as work on the case study progresses

INTRODUCTION

Large bushfires release substantial amounts of energy into the surrounding atmosphere. This energy release modifies the structure of the surrounding wind, temperature and moisture profiles in three dimensions. The changes driven by the fire can manifest as winds that are similar in speed but opposite in direction to the prevailing winds, pyro-convective clouds and fire-generated thunderstorms. The dynamic feedback loops produced by the fire-atmosphere coupling process can have a dramatic influence on how a fire evolves.

In current operational fire simulation models, simple meteorological inputs are inserted into a linear algorithm for fire spread 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, in many cases, will provide a limited depiction of how a fire may evolve, particularly in a dynamic environment in high terrain where risk is greater. This project explores the ability to model fire-atmosphere interactions through use of a coupled model.

The project uses the premier operational Australian high-resolution weather prediction model ACCESS, coupled to a fire-spread model. The ACCESS model has been used to examine several high impact fire events and has provided detailed insights into the meteorological processes impacting the fire environment. Coupling ACCESS to a fire model builds on previous expertise and provides opportunity for future development of coupled modelling in Australia.

The coupled fire atmosphere model ACCESS-Fire will be installed on national Australian computing infrastructure for research application, with future capability for operational use. The model will be used to run a series of case studies. Detailed examination of high impact events and verification against available meteorological and fire behaviour data will highlight the importance of assessing and predicting the likelihood of fire-atmosphere interactions in anticipating fire evolution. The close links of the project team with operational and training activities in both meteorology and fire will provide a clear pathway for implementing research findings.

The Waroona fire in southwest WA in January 2016 has been selected as the first case study to test the model. Over a two-day period, there were two separate pyro-convective thunderstorm events, triggered by different processes during the diurnal cycle. In addition, analysis of Doppler radar data shows detail of the rapid plume development that contributed to the ember shower which burnt over the town of Yarloop, causing two fatalities.

PROJECT 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 non-linear 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 non-linear and potentially dangerous to fire fighters. Coupled modeling will assist in identifying and understanding the triggers and ingredients that lead to non-linear fire activity. This knowledge will enable risk mitigation activities to be undertaken, both at bushfires and fuel reduction burns.

Coupled models (e.g. WRF-Fire) have previously been used in Australia by several researchers to examine fire-atmosphere coupling processes. This project uses the ACCESS-Fire model, which links directly to high-level operational and research Australian meteorological computing capability. ACCESS-Fire represents an important opportunity for future development as well as potential to provide a fire prediction tool to other countries using the ACCESS and it's overarching Unified Model framework.

Coupled models provide a greater level of detail than uncoupled models, however they are computationally expensive and this (currently) makes them impractical for use as operational tools. One aim of this project in the latter stages is to explore the potential for intermediate complexity models, which would be better suited for operational application. These may be simplified or parameterized models or ingredients based tools.

The strong links between the project team and training and operational activities present a clear pathway to implement research findings and produce training materials from this and related projects. The project focusses on analysing real events, from which patterns can translate directly into operational practice.

WHAT THE PROJECT HAS BEEN UP TO

The project commenced at the end of February 2016. In consultation with stakeholders, the Waroona Fire has been selected as the first case study. Good progress has been made with data collection, analysis and interpretation. Progress with ACCESS-Fire has been constrained by implementation of a significant change to the user interface of the model framework. Contributions have been made to other activities, as described below.

WAROONA CASE STUDY

The Waroona fire burnt south of Perth in January 2016. The case study focuses on the meteorology and fire behaviour during the first two days of the fire, 6th and 7th January. On these days the fire was burning through heavy fuels on the plateau, east of the towns of Waroona and Yarloop. Three separate episodes of interesting and unusual fire activity occurred and these are being examined in detail using a combination of video footage, radar and satellite data, AWS observations and fire spread data. High resolution simulations have been run with ACCESS (no fire –coupling yet). There were two separate pyro-convective events, one in the evening on the 6th and one in the morning on the 7th, with very different dynamics and forcing mechanisms. The pyro-convection on the 7th is of particular interest as it was against general diurnal trends. On the evening of the 7th the fire burnt over the town of Yarloop. Many homes were destroyed and there were two fatalities. Radar data shows a marked increase in plume height and reflectivity returns as the fire approached Yarloop. Extensive spotting was observed on both evenings (6th and 7th), which may be in part attributed to turbulent flow over downslope topography, colloquially known as 'gully winds" or "scarp winds". The case study is being prepared in collaboration with end-users in DPaWS and BoM WA.

ACCESS-FIRE

The code for the fire model has been acquired from Monash University and preparations have been made for installing and testing the code on Bureau of Meteorology IT infrastructure. The ACCESS training course was attended in March.

Progress on ACCESS-Fire has been slowed by the transition from the UMUI model interface to the Rose/Cylc interactive framework. This change has been implemented by the UK Met Office. The new interface is still undergoing development, in particular for nested suites, which are a key requirement for high resolution simulations. We anticipate the technical nesting issues will be resolved in the near future. Related IT activities include training on post-processing tools required for analysing simulation output.

OTHER ACTIVITIES

ACCESS Coupled Fire Modelling Workshop

27 January. ACCESS Coupled Fire Modelling Workshop at Monash University was attended by the project team.

Fire and Fuels conference

11-14 April, Melbourne. The Fire and Fuels conference was attended by both project team members.

ACCESS Training

21-24 March. ACCESS User Training Course, introduction to the Rose-Cylc interface was attended by Mika remotely.

Pinery Fire Report

In November 2015 the Pinery Fire burnt through the Mid North District of South Australia. A meteorological report has been prepared for the coroner by SA meteorologists with significant contributions made by the project researcher.

Operational Roster Support

The SA operational forecasting roster was back-filled by project staff for a week during April.

PUBLICATIONS LIST

No publications stemming from this project, but the following papers from prior related work are all now in press.

Resulting from prior work

Peace, M., Mattner, T., Mills, G. A., Kepert, J. D., and McCaw, L., 2015: Fire-Modified Meteorology in a Coupled Fire-Atmosphere Model. *Journal of Applied Meteorology and Climatology,* **54**, 704–720, doi:10.1175/JAMC-D-14-0063.1

Peace, M., McCaw, L. W., Kepert, J. D., Mills, G. A., Mattner, T., 2015: WRF and SFIRE simulations of the Layman fuel reduction burn. *Australian Meteorological and Oceanographic Journal*, 65: 3-4,302-317

Peace, M., Mattner, T., Mills, G. A., Kepert, J. D., and McCaw, L., 2016: Coupled Fire-Atmosphere Simulations of the Rocky River Fire using WRF-SFIRE, *Journal of Applied Meteorology and Climatology,* **55**, 1151–1168

CURRENT TEAM MEMBERS

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

Mika Peace: Fire weather, mesoscale meteorology, operational forecasting, meteorology training.