Case studies of ACCESS-Fire model weather interactions for Waroona (2016) and Sir Ivan (2017) bushfires.

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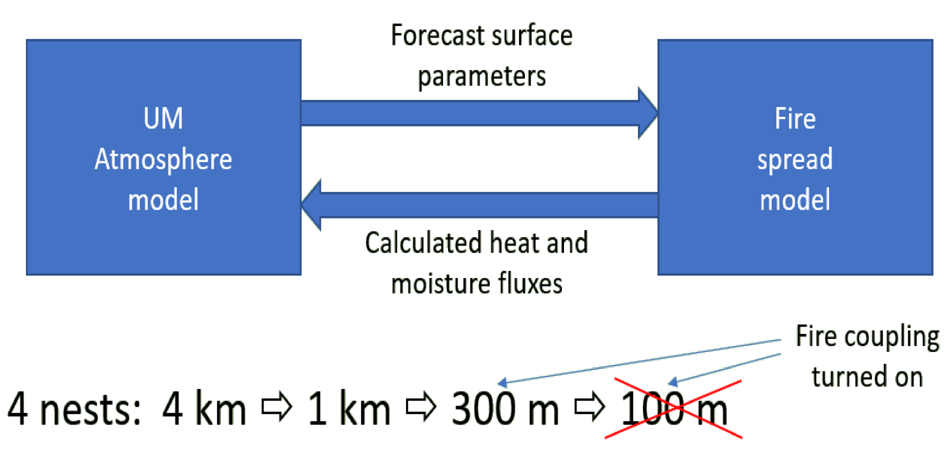
bushfire&natural HAZARDSCRC

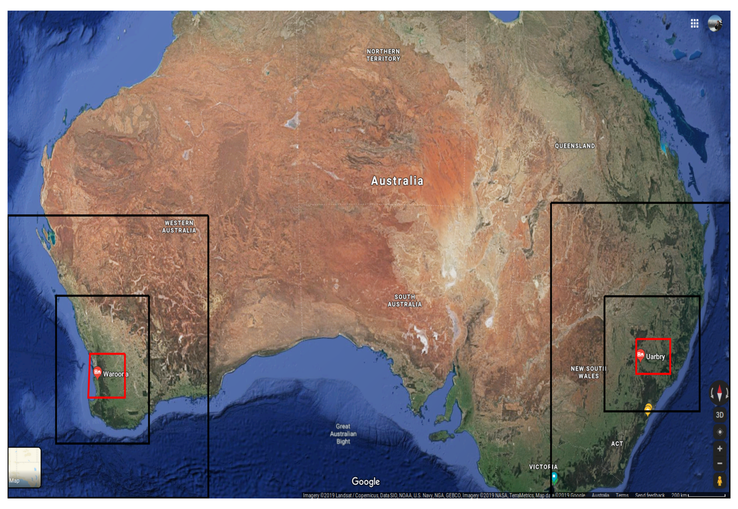
Summary

After coupling UM to a Fire model, we see important feedbacks and even Pyrocumulonimbus cloud formations within the UM output. Fire spread and weather feedbacks are reasonable but sensitive to physical model parameters.

Introduction

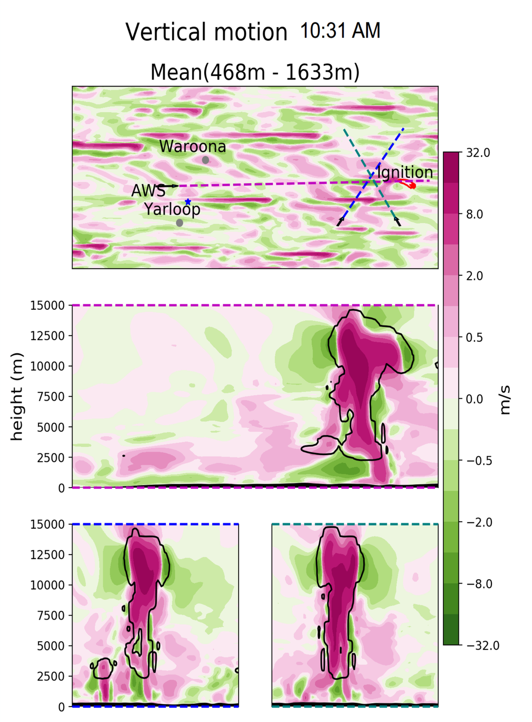
Fires are a damaging and wide ranging seasonal occurrence for much of Australia, mitigated in part by national and state based fire fighting agencies and volunteers. A major factor in the effectiveness of their efforts is the fire danger index that attempts to predict where the worst fires may occur. One issue with the current system is that it does not take into account atmospheric processes that are affected by local topography (such as down-slope wind flows) or wind and weather feedback (such as cumulonimbus driven wind gusts) [Peace 2017, Coen 2018].
This project examines two case studies with the intent of examining these processes as modelled by the Unified Model (UM) set up using Australian Community Climate and Earth-System Simulator (ACCESS) settings coupled to a fire model [Toivanen et al. 2019]. UM is the numerical atmospheric model run by the Bureau of Meteorology to provide weather forecasting services within Australia. The fire model estimates fire spread and intensity between UM time steps, with feedback into the UM for several fields.
The first case study is the January 2016 fire near Waroona, south of Perth, which included unexpectedly bad conditions that were exacerbated by the local escarpment and wind gusts at the edge of a pyrocumulonimbus cloud (PCB). The second is the February 2017 fire near Uarbry, which was large but appropriately predicted by the fire danger index.

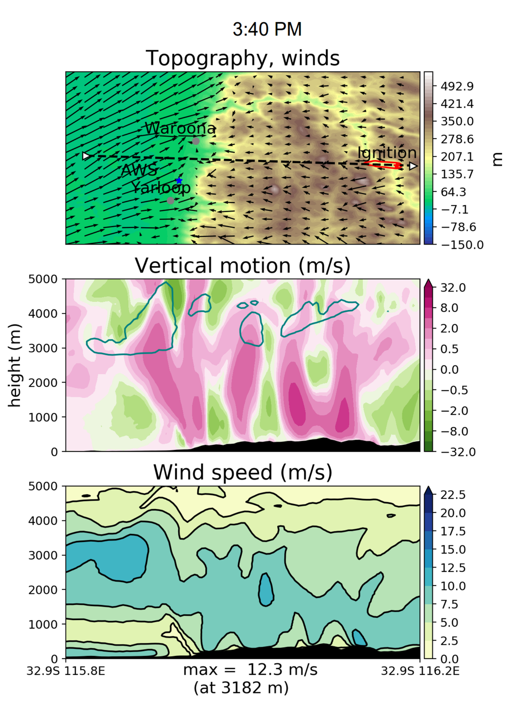




Model runs

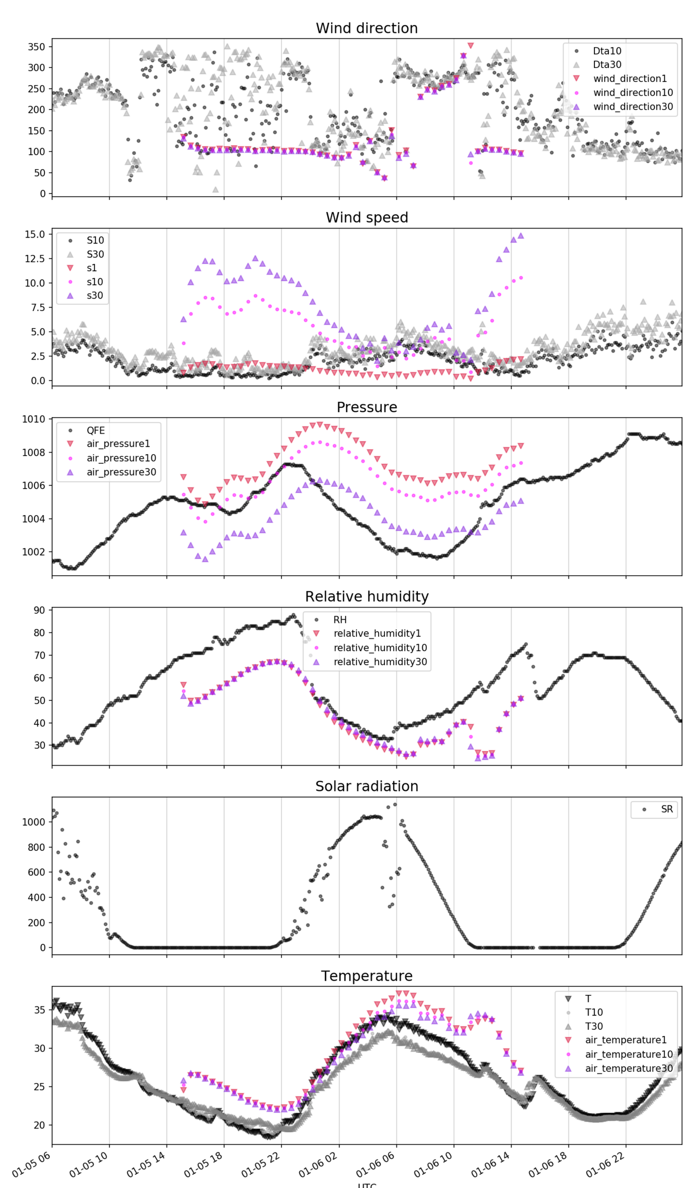
	Waroona - orig	Waroona - new	Sir Ivan - orig
Temporal resolution (internal/output)	1 second / 30 minutes	1 second / 10 minutes	1 second / 30 minutes
Run start	2016 Jan, 5, 11PM → 21H	2016 Jan, 5, 11PM → 24H	2017 Feb, 12, 5AM → 24H
Notables	Crashed	Increased BL stability	Increased BL stability



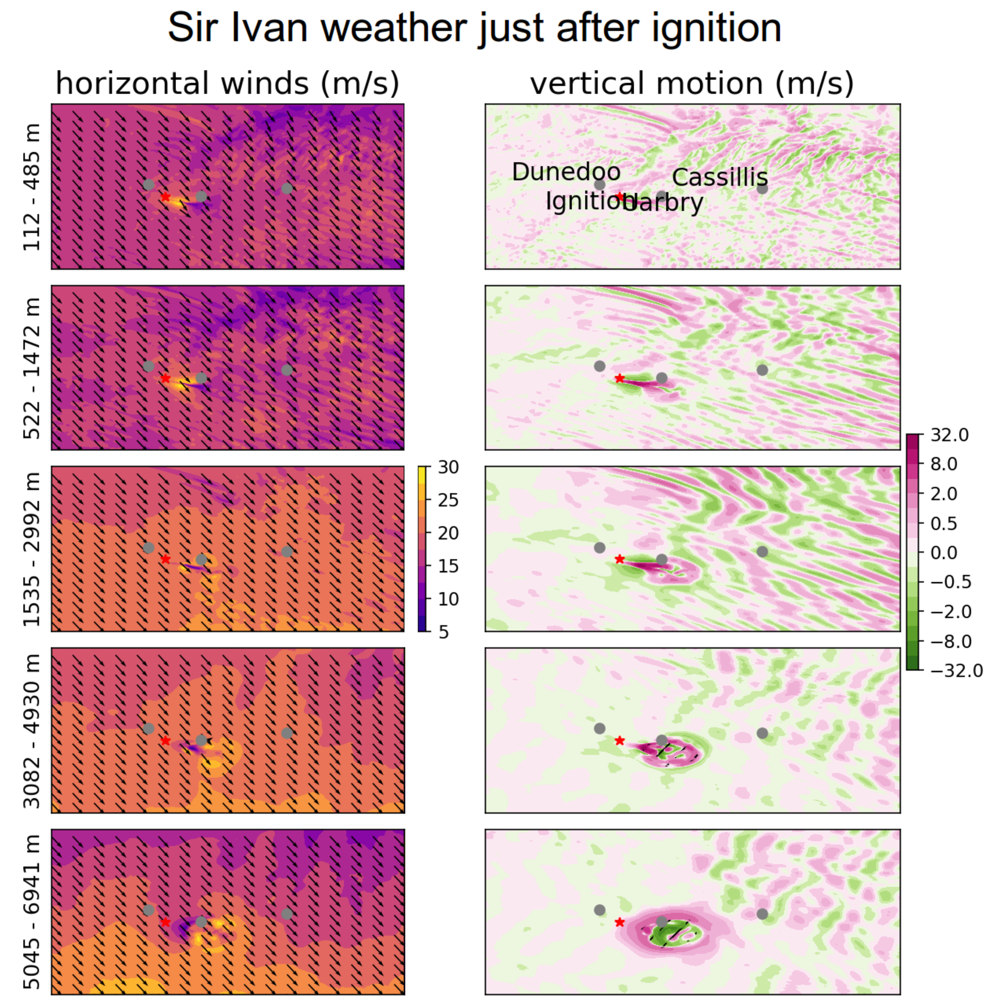


Both the Sir Ivan and Waroona fire simulations show strong feedback throughout the troposphere immediately after the fire ignition, and along the front of the fire expansion.
The original Waroona fire simulation shows clear PCB near the fire front, over a few hours. This is not seen in the more recent model run.

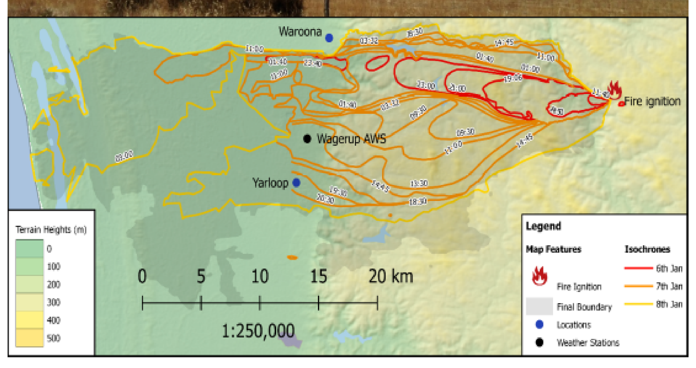
The Sir Ivan appears to include brief pyrogenic cloud formation (potentially PCB) due to powerful upward motion driven by the heat output especially where the fire expands rapidly.



Sir Ivan weather just after ignition



The two fires



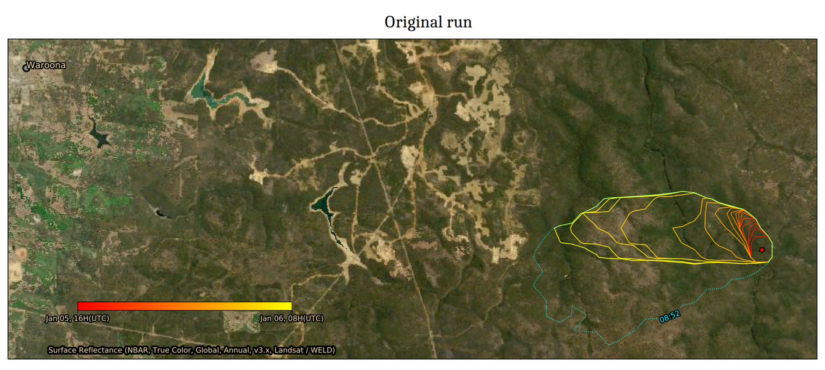
Waroona fire

- 6-7 January 2016.
- 166 homes destroyed.
- **Did not reconcile with FDI's.**

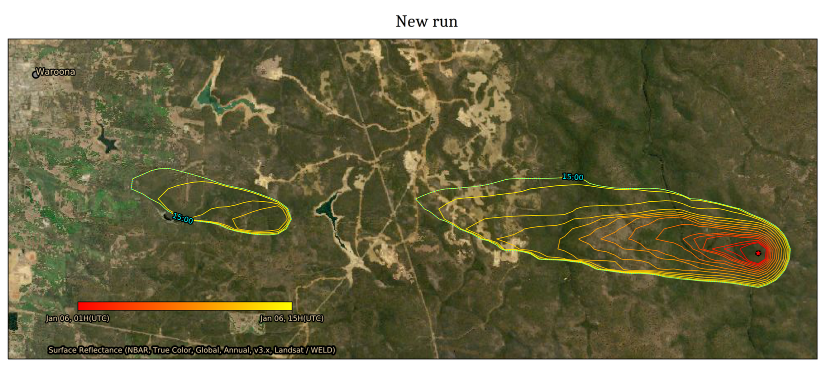
Sir Ivan fire

- 12 February 2017
- 55 homes lost.
- NSW worst fire conditions ever
- **'Catastrophic' conditions identified several days in advance.**

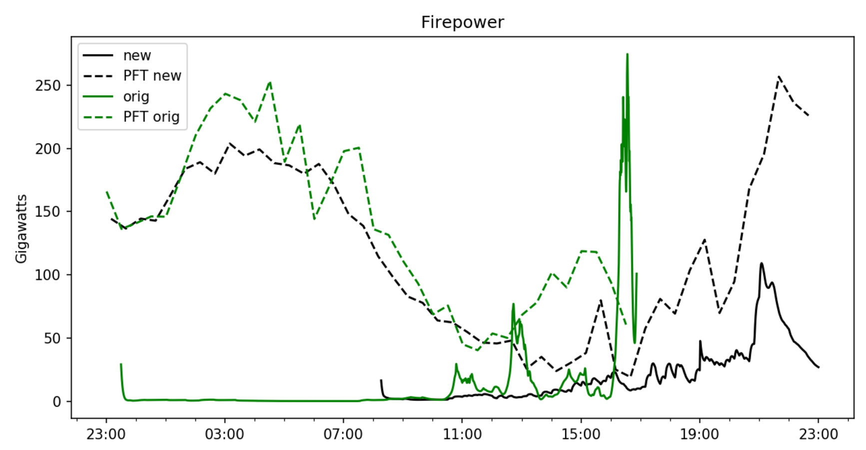
Fire progression and power



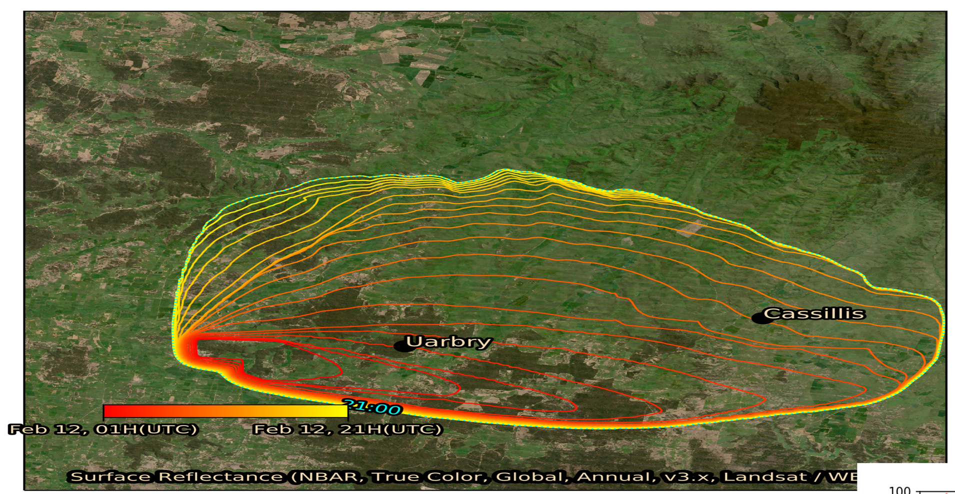
The original Waroona simulation started slowly around midnight, before taking off around 11AM and spreading rapidly until just before 9AM when the run crashed.



The new Waroona simulation spread in a more stable manner after ignition at 8AM, with spotting at 8PM. This simulation had increased stability in the mixing layer, so as to prevent the simulation crashing and to slow down the fire expansion towards observed expansion rates.



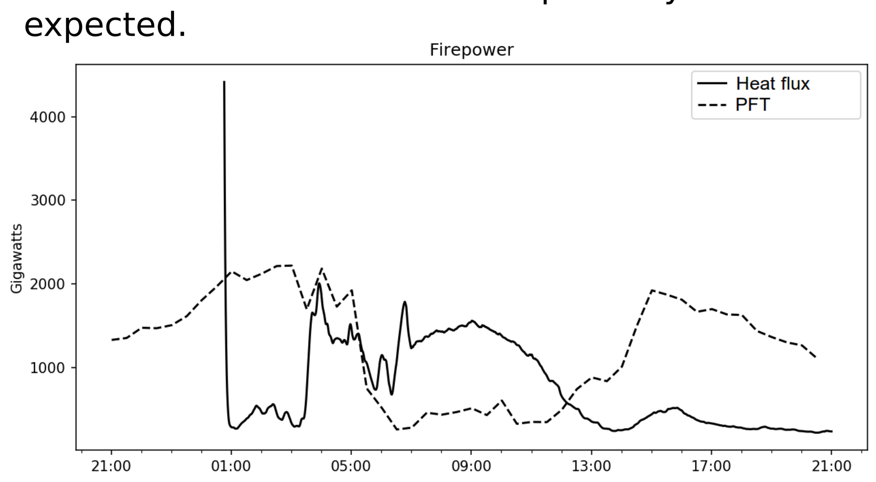
The time series shows the fire power (simulated sensible heat flux) along with an estimate of how much power is required to produce PCB (the dashed PFT lines). The original run shows a couple of time windows where the fire power exceeds that required to for PCB, and indeed shows PCB formation at these times.

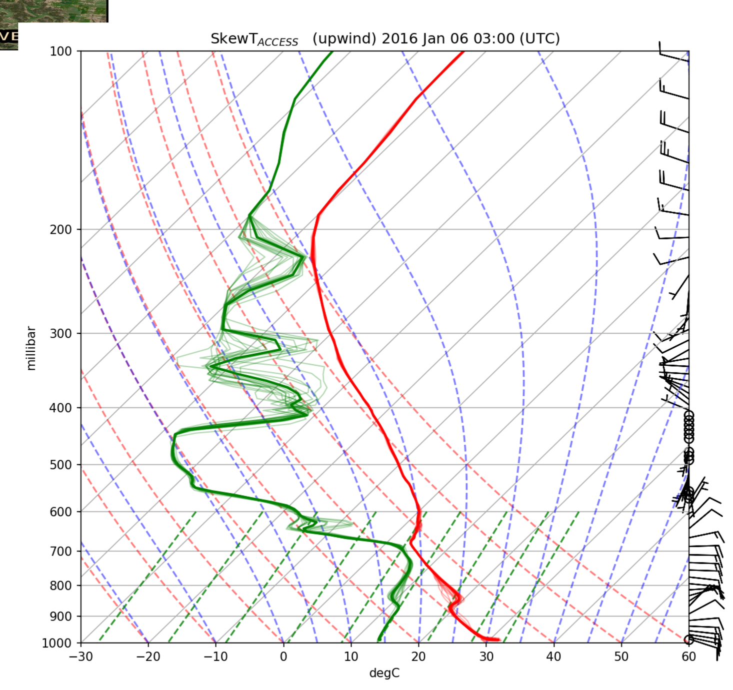


$$PFT = C\,(Z_{fc})^2\,U\,b_{fc}$$

PFT: PCB Fire power Threshold
C : constant
Z_{fc} : free convection altitude
U : wind speed
b_{fc} : extra heat to escape mixing level

The Sir Ivan simulation starts with a bang, and exhibits consistently high heat flux for a long time. There are several hours where pcb may be expected.





References:

Peace et al. (2017). Meteorological drivers of extreme fire behaviour during the Waroona bushfire. DOI:10.22499/3.6702.002
Coen, J. (2018). Fire. *Some Requirements for Simulating Wildland Fire Behavior Using Insight from Coupled Weather — Wildland Fire Models*. DOI:10.3390/fire1010006
Toivanen, J. et al. (2019). *Coupled Atmosphere-Fire Simulations of the Black Saturday Kilmore East Wildfires With the Unified Model*. Journal of Advances in Modeling Earth Systems. DOI:10.1029/2017MS001245