WHAT IS A COUPLED FIRE-ATMOSPHERE MODEL ? … AND WHY ARE COUPLED MODELS SO GREAT ?

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What is fire-atmosphere coupling?

Coupling describes the interactions and feedback between a fire and the atmosphere.

We know from fire-ground observations that a fire changes the atmosphere around it. This occurs due to the heat and moisture released by the fire generating local buoyancy, which changes the winds in the near-fire environment, which then alters the fire spread, which modifies the atmosphere etc… etc…

Fire-atmosphere feedback phenomena include inflow at the surface and pyro-cumulus cloud development above a fire. The photo below shows a deep convection column with inflow from all sides.

How do coupled and uncoupled fire-spread models differ?

Uncoupled models are restricted to the earth's surface and simulate fire spread with static weather inputs. In an uncoupled model, the atmosphere is unaware of the fire's presence so any interactions between the fire and the atmosphere will not be resolved.

In coupled models, the combustion of fuel in the fire model releases a heat and moisture flux into the atmospheric model, so the atmosphere `feels' the fire and the surrounding winds flow into the fire as a consequence. This gives us information on the vertical structure of the fire plume as well as how the winds (and resulting fire spread) are modified.

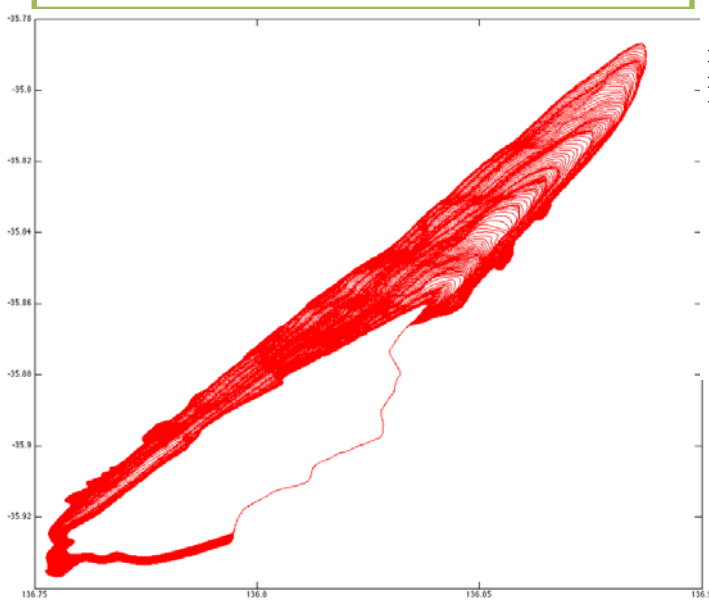
Fire simulation models are increasingly being used for planning fuel reduction burns and mitigating against the impacts of bushfires. It is critical that we establish the appropriate model inputs and appreciate model limitations.

What can be learned from coupled models?

It's very difficult to take detailed observations at a fire ground, so coupled models are a key tool for supplementing observations in order to learn more about how a fire and the atmosphere interact.

Coupled modelling simulations show us that if we want to accurately predict fire behaviour, we need to include the three dimensional feedbacks, since the dynamical processes between the fire and atmosphere can in some circumstances have a dramatic impact on fire behaviour.

The plot below shows fire spread from a coupled simulation at one minute intervals. Background winds were steady, so the isochrones show pulses in fire rate of spread due to fire-atmosphere interactions.



Features seen in coupled models include:

•The ellipse shape of a fire line formed due to convergent winds at the fire flanks.

•Fire plume structure and dynamics, with a closely located updraft and downdraft with vertical speeds comparable to a thunderstorm.

•Mixing down of very dry air from higher atmospheric levels by the fire plume, which can dry surface fuels and increase fire activity.

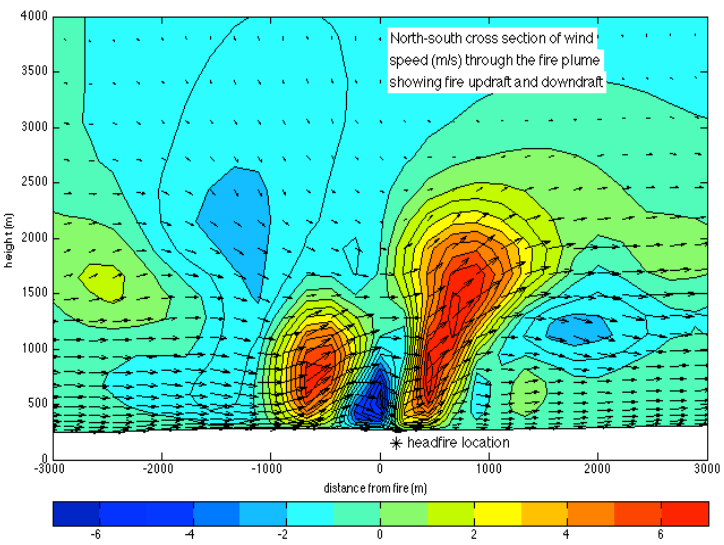
•Fires changing the local winds, including vortex development, which provides a mechanism for faster burning. Also fire spread constrained along a ridge by wind convergence.

•Non-steady state fire spread due to interactions, which is consistent with fire-ground observations.

Which is better: coupled or un-coupled?

Both have their place. Uncoupled models are simpler, quick to run and easier to interpret. But they have limitations for resolving wind driven fire spread, they can only parameterise feedbacks, and they don't give any information on plume dynamics. Coupled models require more interpretation and take longer to run, but are much more detailed.

The plot below shows a vertical cross section showing the structure and height of a fire plume. Such a fire plume analysis is only possible with a coupled model.



What is the future of coupled models?

Coupled models have applications for both research and operations, but at the moment, we don't have a future plan for them in Australia.

Operations Coupled models are still in development and not yet ready for operational use. However, the ultimate goal of model developers is to have coupled simulations running in real time. Increases in computing power mean that real time simulations will be possible in the future. Since fire spread is determined by the fire-modified winds, the coupling process needs to be accounted for in fire spread predictions.

Research With limited research, we've already learnt a lot about fire behaviour by using coupled fire-atmosphere models. There are many unknowns in how a fire and surrounding atmosphere interact to drive fire activity. Since fires will continue to impact Australia, more research into fire-atmosphere interactions is necessary in order to resolve many of our current knowledge gaps.