Fire-Atmosphere Interaction

France - Australia Bushfire Science Workshop
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Australian Government Bureau of Meteorology
bushfire&natural HAZARDS CRC
Australian Government Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

Aim s

1. PyroCb Prediction

    - *The pyrocumulonimbus firepower threshold (PFT)*

    - *Kevin Tory*

2. Coupled Fire-Atmosphere Modelling

    - *ACCESS-Fire*

    - *Mika Peace*

3. Ember Transport in Bushfire Plumes

    - *Predicting where spotfires can form*

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What is the *PFT*?

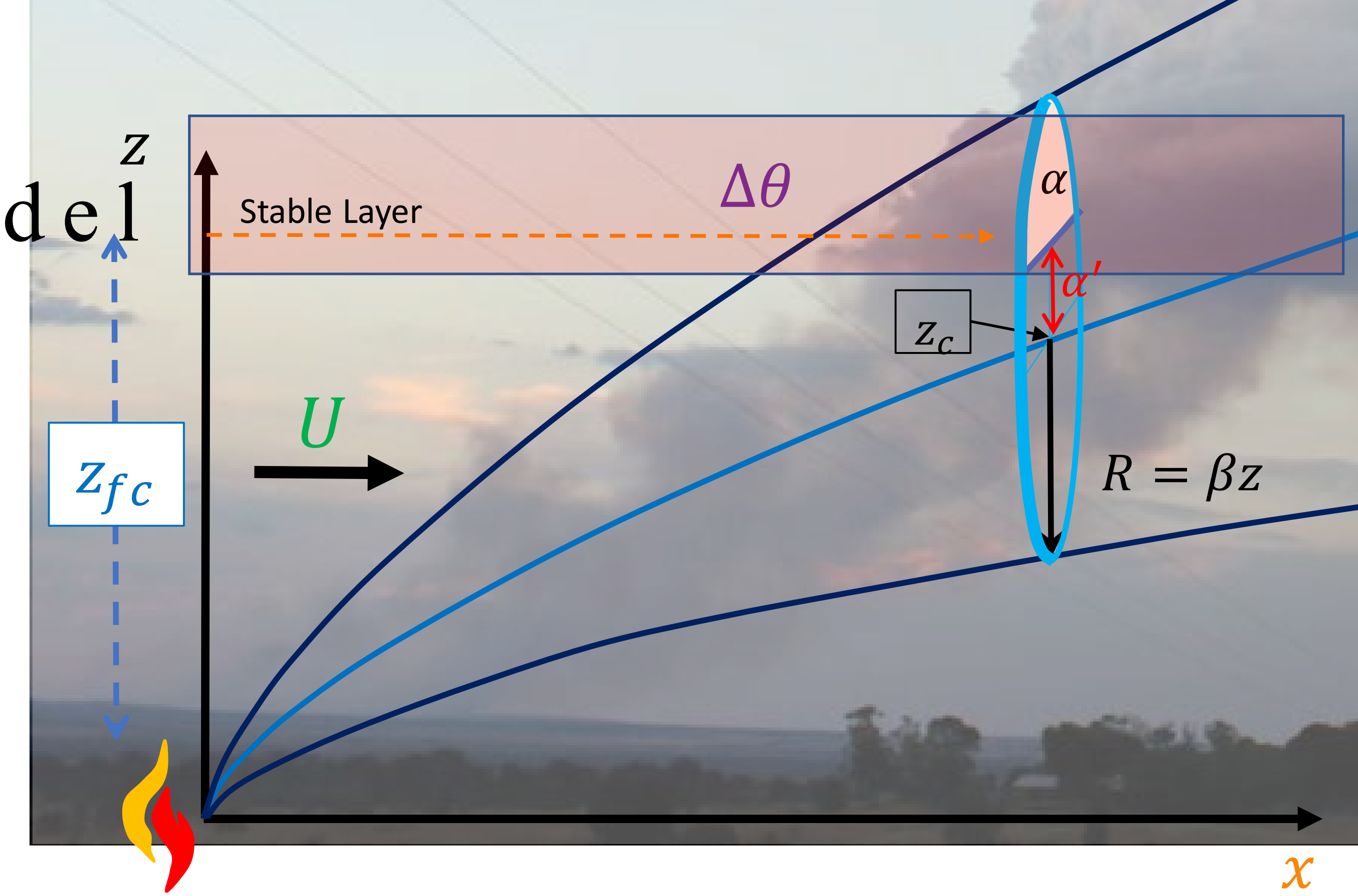
Minimum heat flux (firepower) required for pyroCb to form.

Varies with the atmospheric environment

1. Insufficient firepower
2. Sufficient firepower

Inglewood Fire, 5 Dec 2016: Nick McCarthy

Use Briggs Plume Model



An equation for the buoyancy distribution within a Briggs plume is inverted:

- $PFT = \boxed{\sim \text{Constant}} (z_{fc})^2 U \Delta\theta$

- z_{fc} : The larger z_{fc} the higher the plume must rise (more firepower required).
- U : The stronger U the more firepower required to counter the plumes tendency to bend over.
- $\Delta\theta$: A larger capping inversion requires a hotter plume and thus more firepower.

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Using the PFT

Substantial *PFT* differences between events.

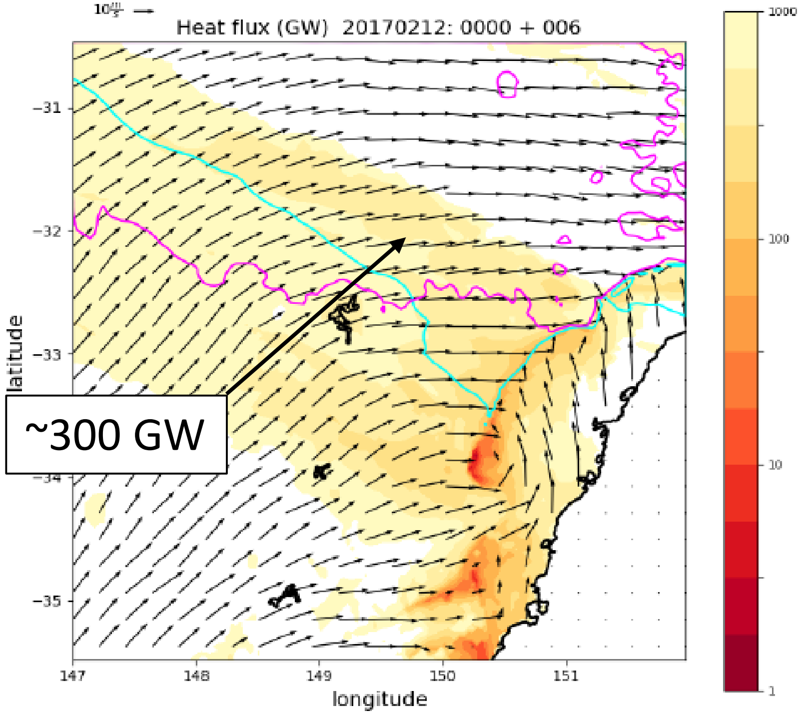
Vastly different "threat" values?

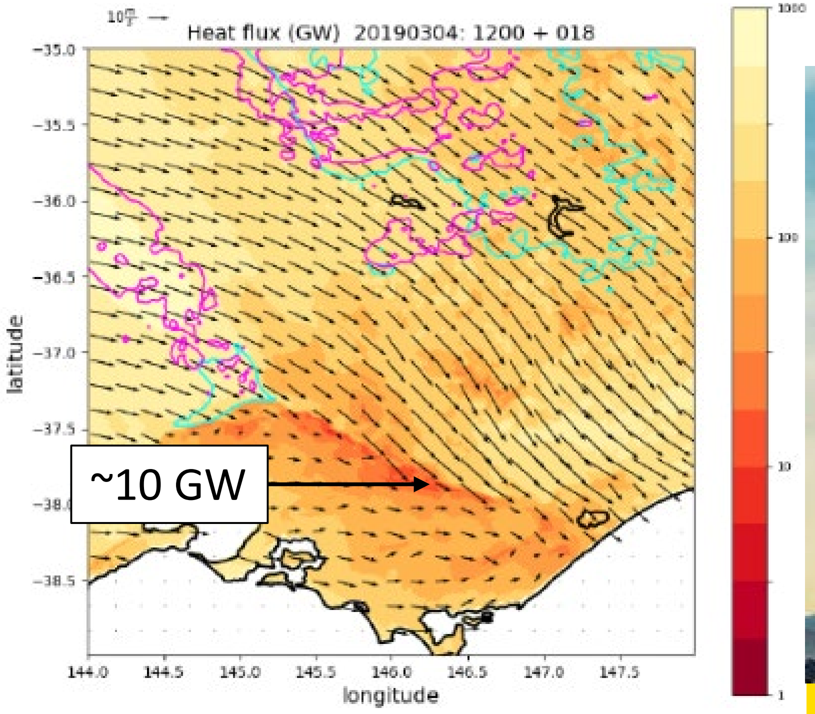
PyroCb conditions at Sir Ivan were much less favourable than Licola.

However, Sir Ivan had extreme fire conditions, potentially much hotter fire.

Plumes like: Cool-Moist-Calm
Fires like: Hot-Dry-Windy

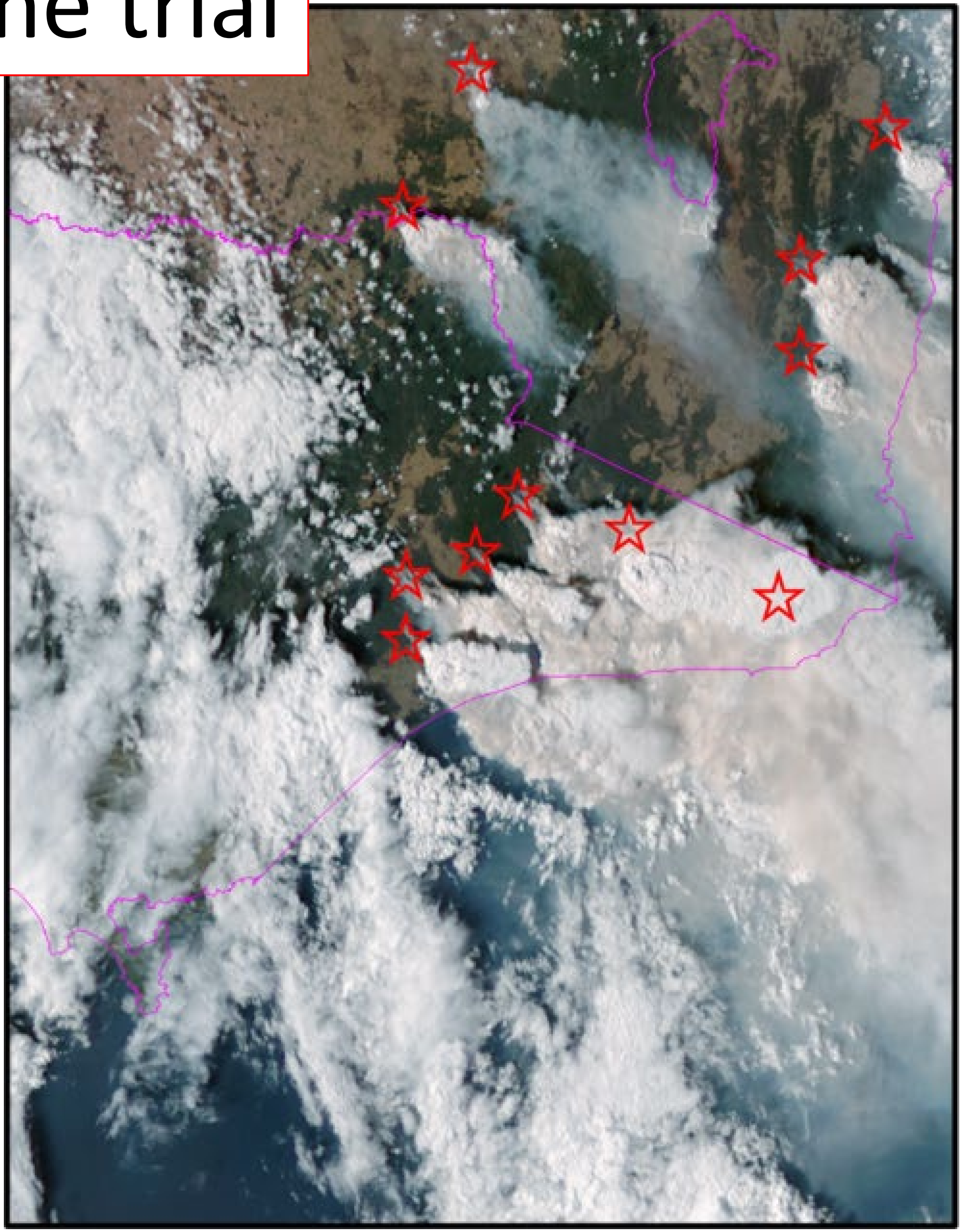
PyroCb need a "just right" ratio of
Cool-Moist-Calm/Hot-Dry-Windy
PFT-flag attempts to detect this "sweet spot"

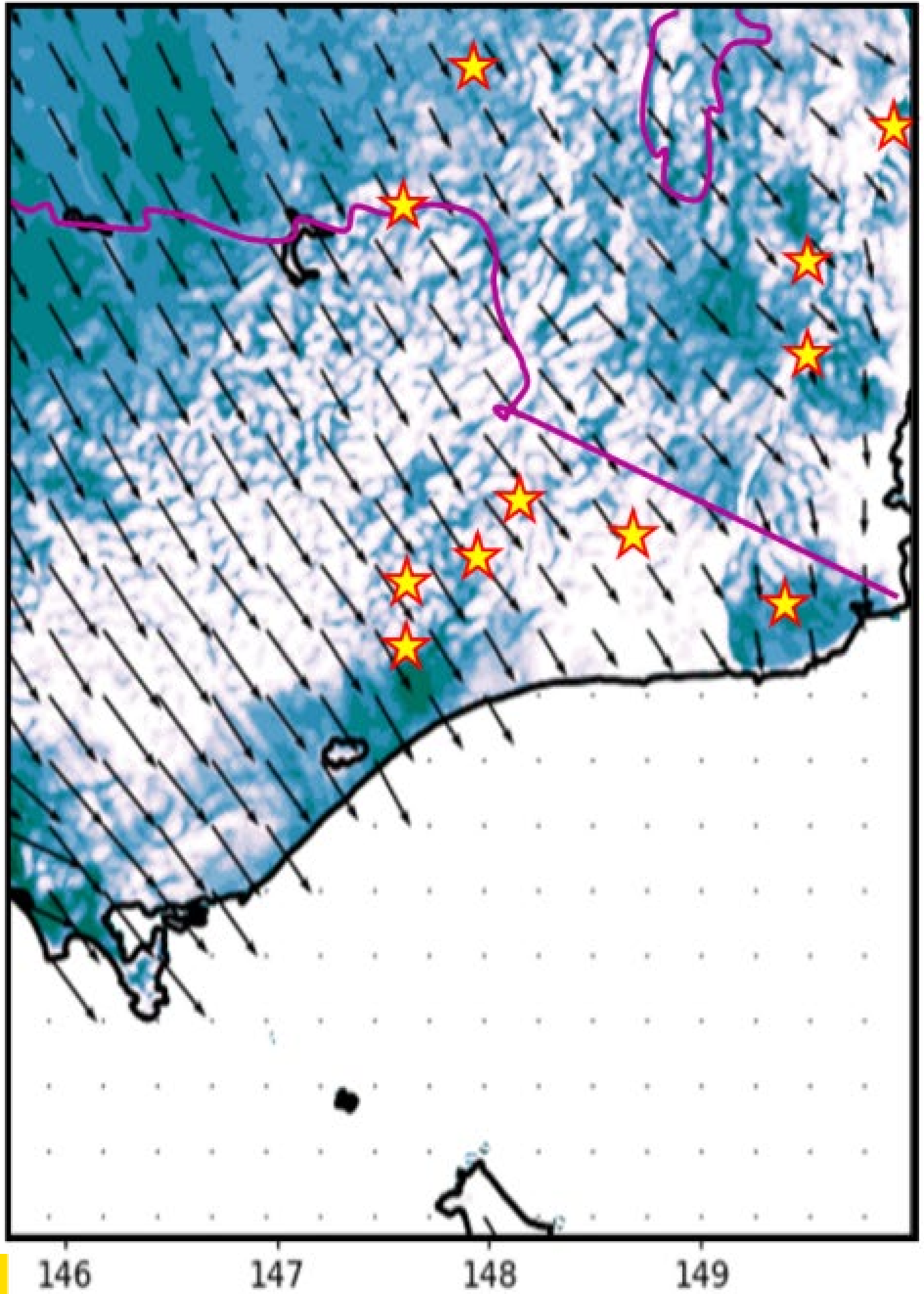




PFT Real-time trial

30 December 2019
Most active day of
the season

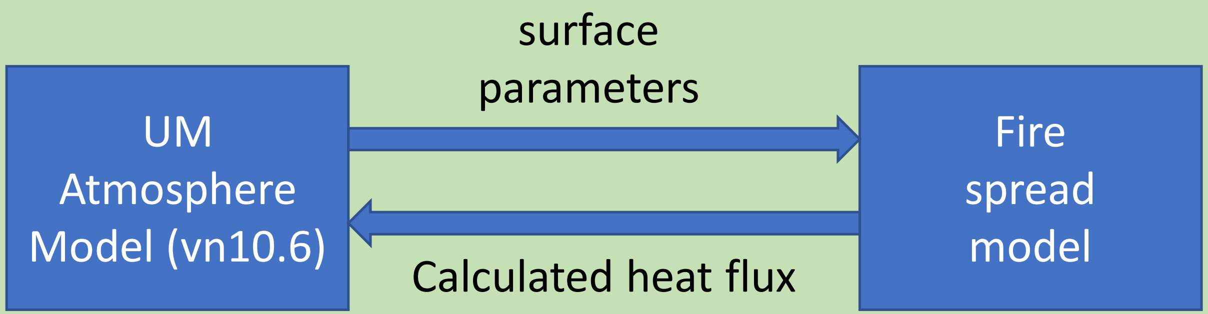




ACCESS-Fire

Model description

- The original code was developed in Melbourne and Monash Universities for Black Saturday simulations
- Basic structure:



coupling on

- 4 nests: 4 km ⇨ 1 km ⇨ 300 m ⇨ 100 m
- Simulations were based on the standard nesting suite and run on NCI (raijin/gadi).

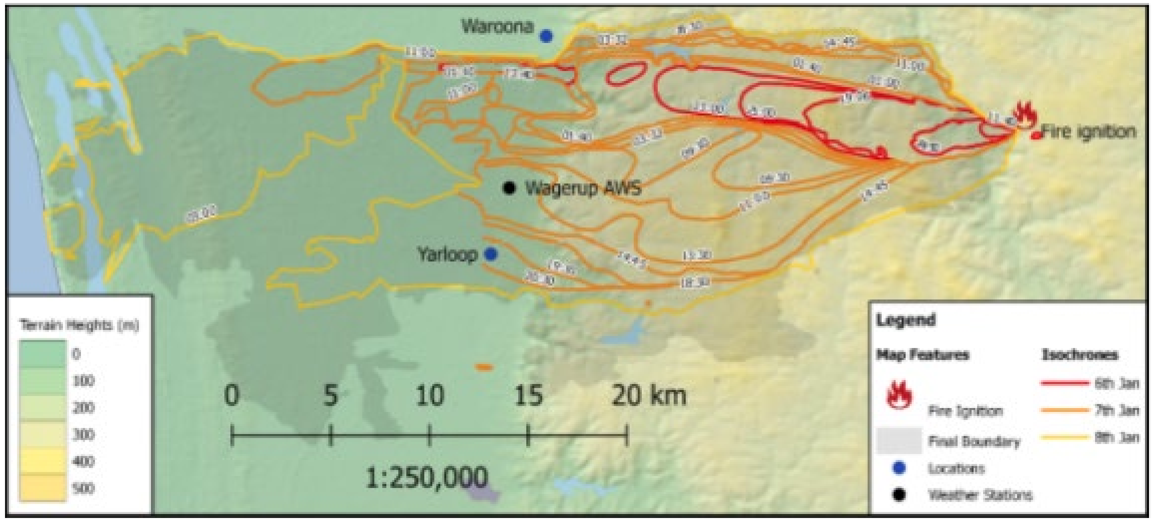
Simulated Fire Spread

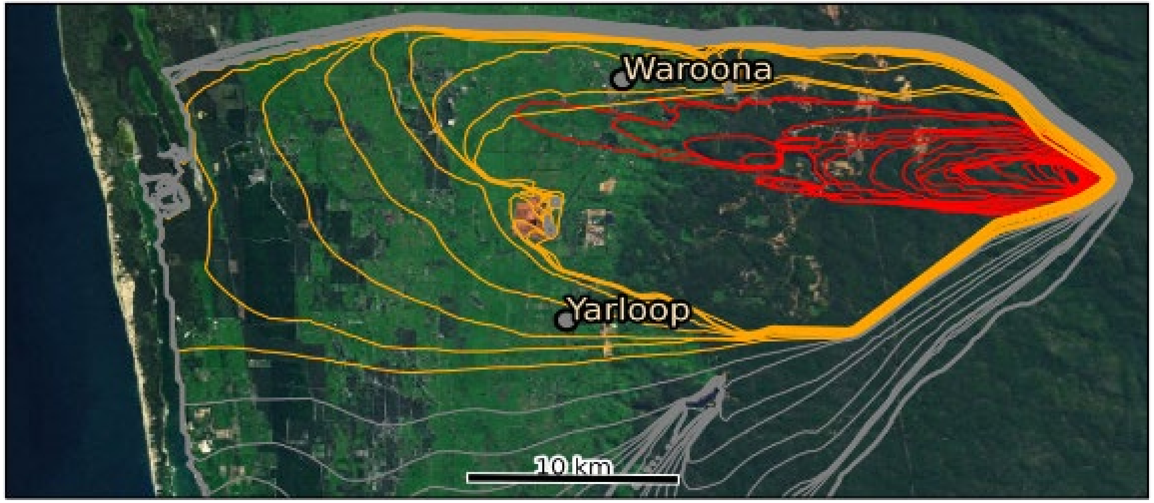
Initialised from ignition point / polygon, observed spotfires included.

Strong downslope run on first evening (red)

Second day spread towards southwest, impacted Yarloop in the evening (orange).

Model does not include impact of firefighting, lighter fuels on coastal plain.





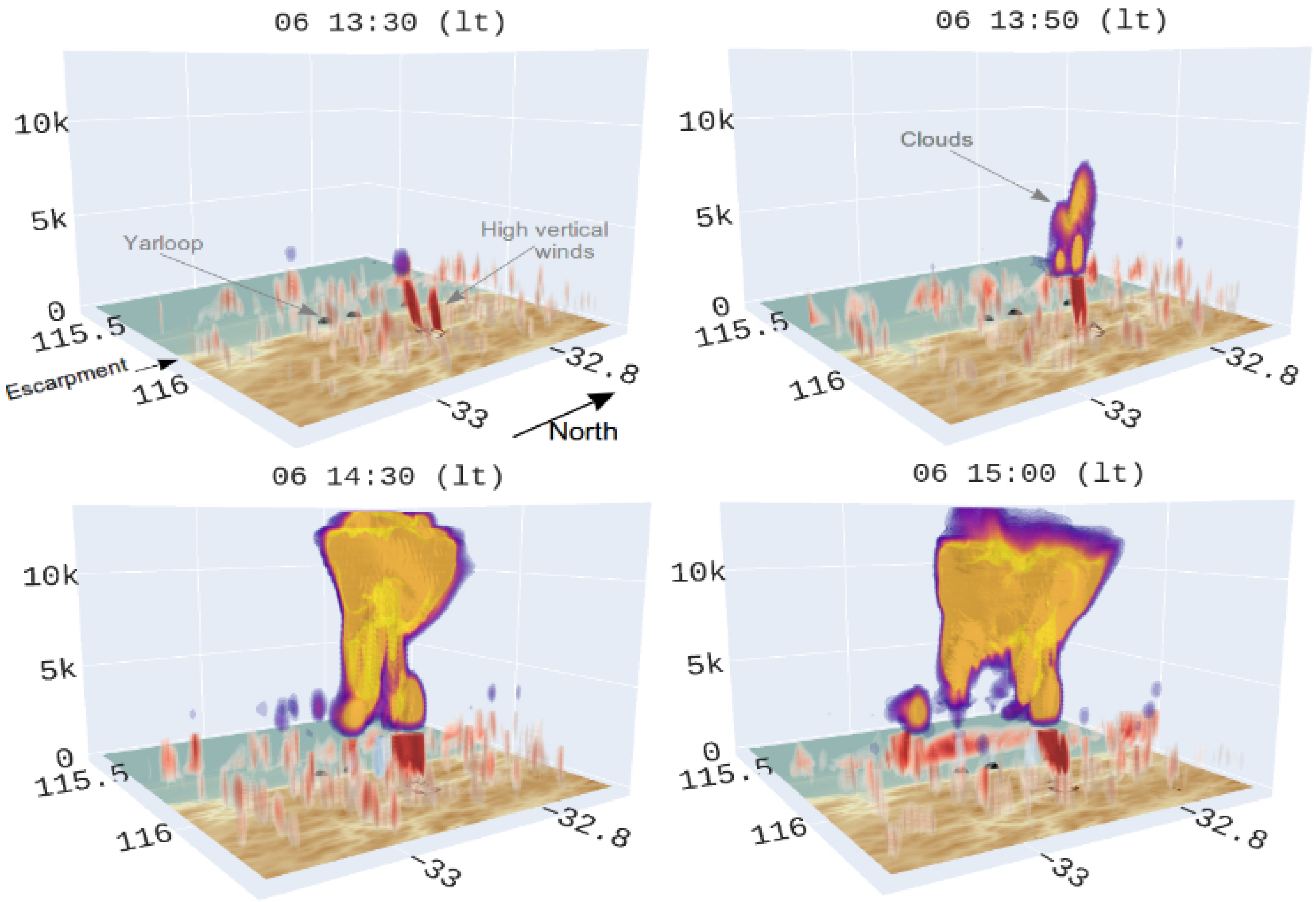
PyroCb Formation

Model simulated the formation of a pyroCb.

Red / blue = strong updrafts / downdrafts

Purple / orange = cloud

PFT and model firepower agreed!

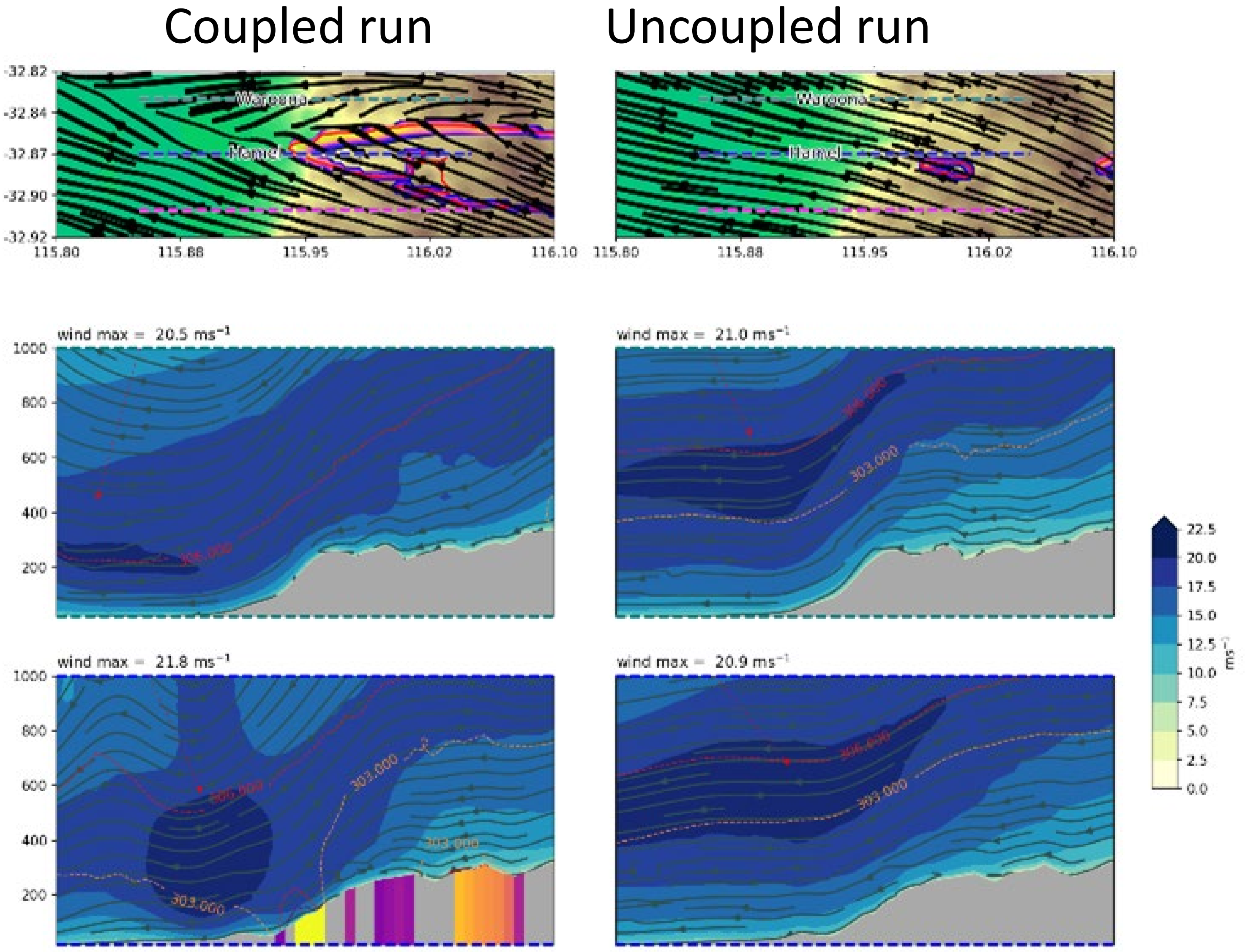


Downslope Winds and the Ember Storm

- Major ember storm late afternoon as the fire reached the bottom of the scarp.
- Strong downslope winds often develop in evening.
- Fire encountered heavy fuels.

- Yarloop (popn ~500) destroyed.

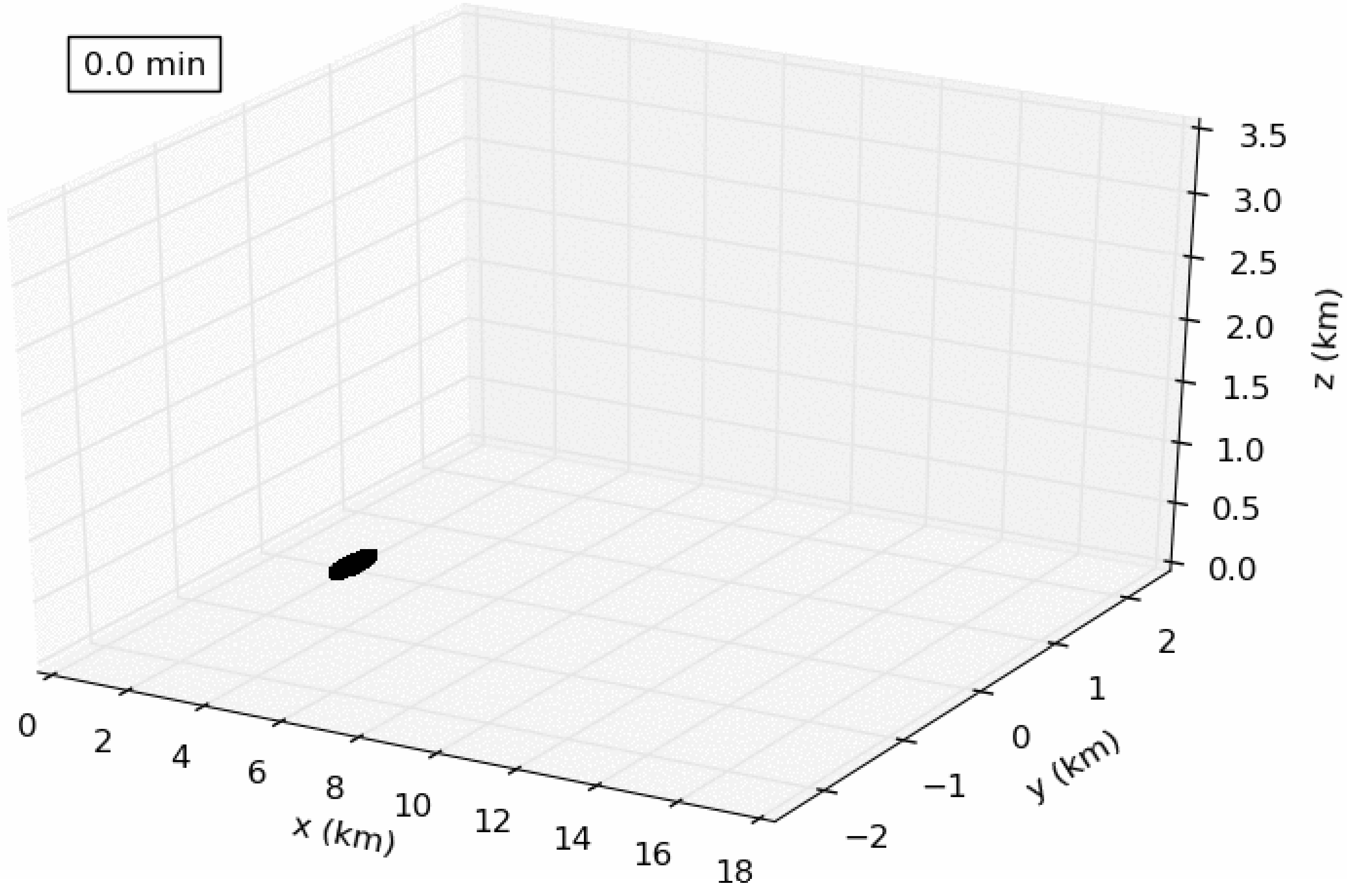
- Coupled model shows stronger winds, closer to surface.



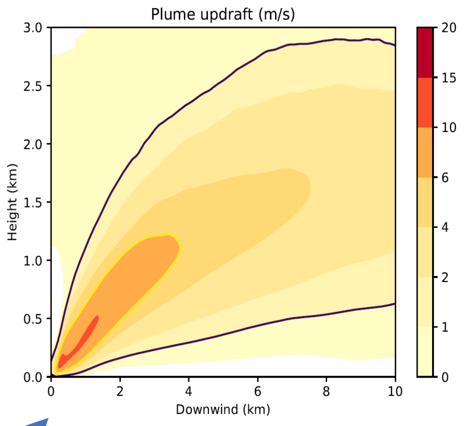
Ember Transport Parameterisation

- Used a large-eddy model to study turbulent plumes and ember transport (Thurston et al. 2017 IJWF).
- Learned important things about ember transport, but much too slow for real-time use.

- The problem: Reduce thousands of hours to a few seconds, without sacrificing too much accuracy.

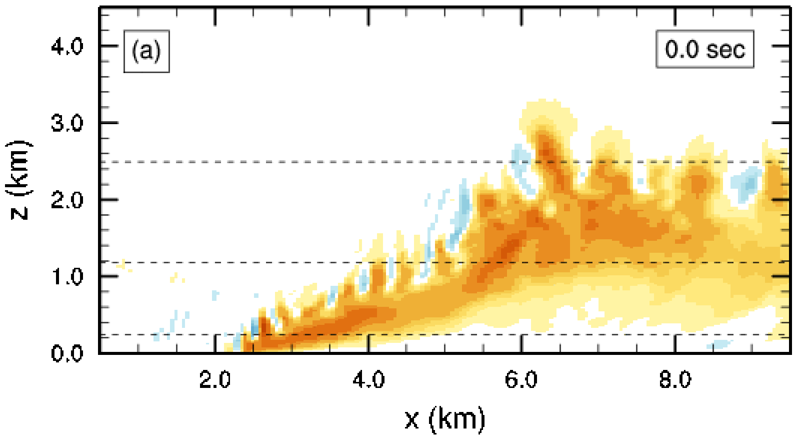


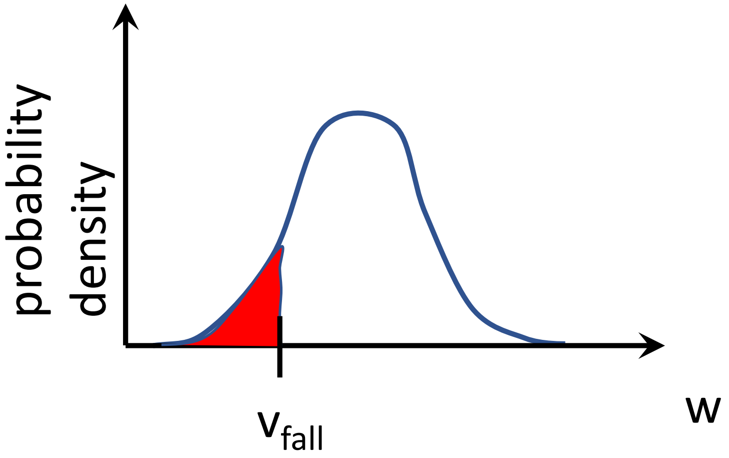
Ingredients

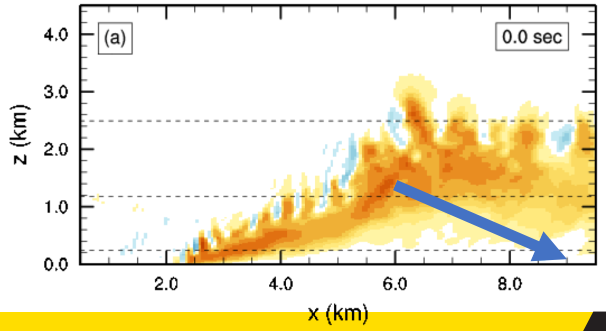


Four components:

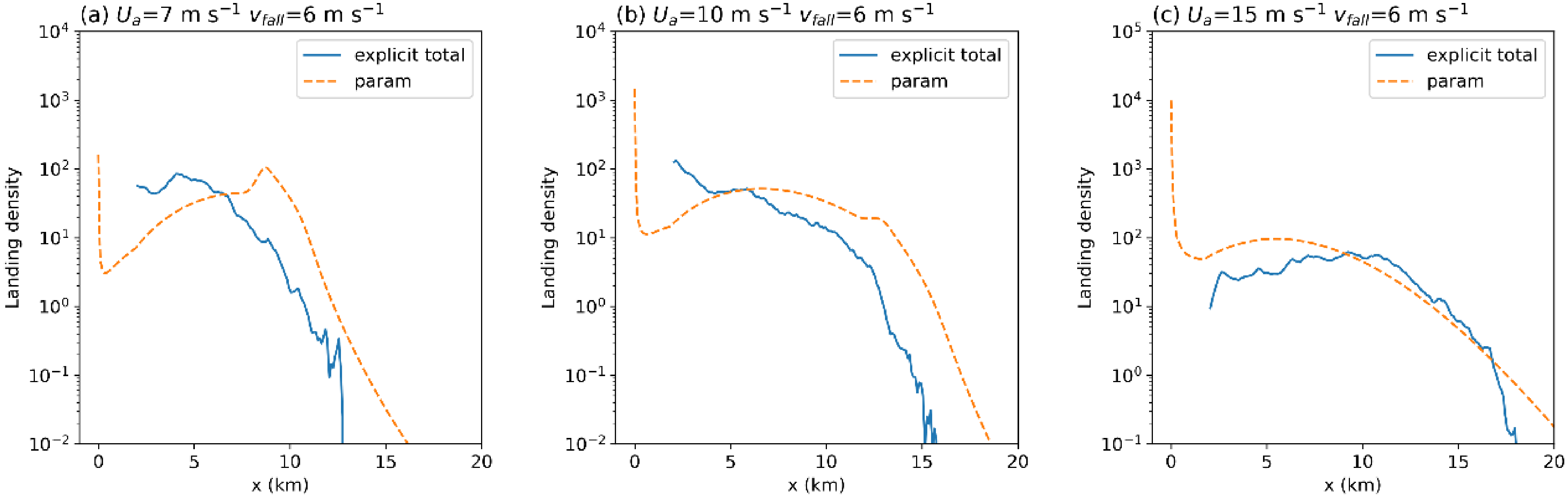
- The mean plume
- Turbulence in the plume
- Ember transport in the plume
- Ember transport below the plume







Comparison to LEM: $v_{fall} = 6$ m s^{-1}

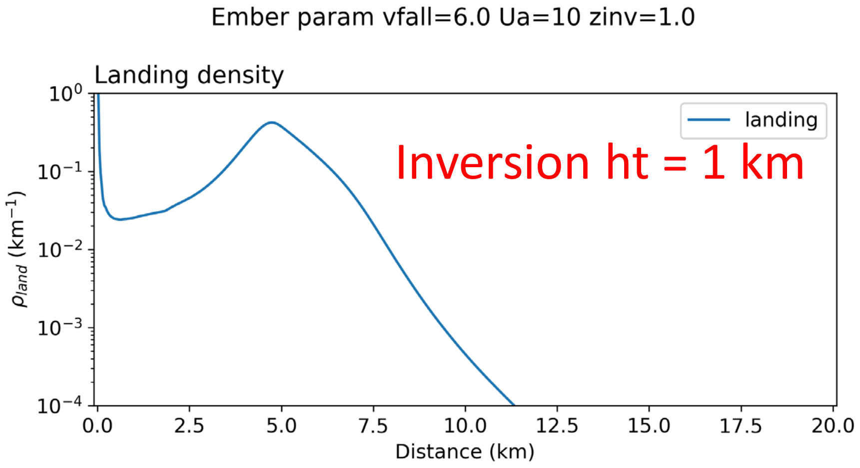


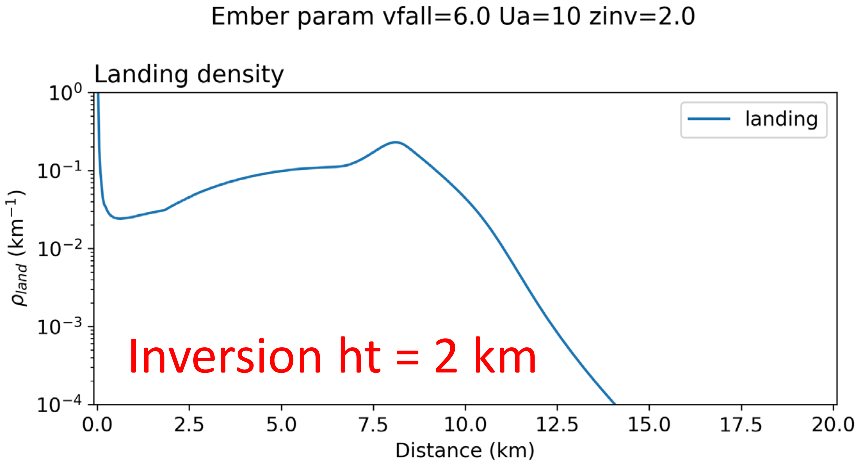
- Cross-stream total density
- Blue = LEM, orange = parameterisation

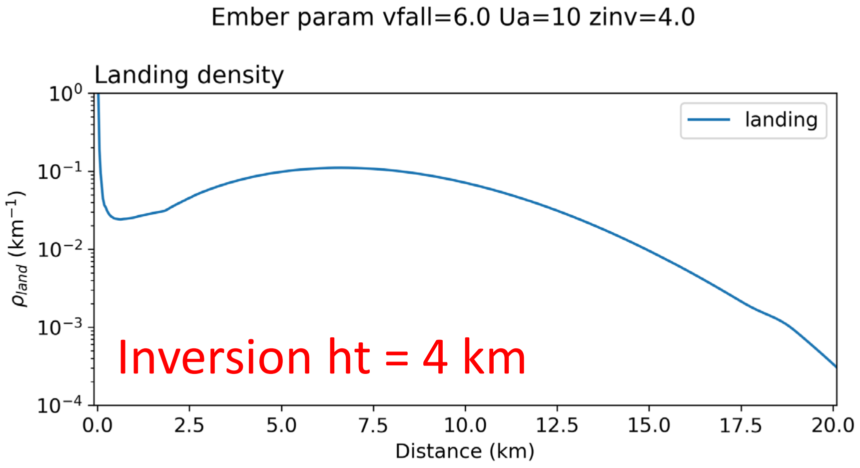
Inversion height

- Three simulations, all with v_{fall} = 6 m s^{-1} and wind speed = 10 m s^{-1}.
- Fire power = 19.6 GW.
- Inversion at 1, 2 and 4 km.

- A low inversion strongly limits long-range transport because it limits plume updraft strength.







Summary

Fire and atmosphere have a strong two-way interaction

If we want to understand and predict large fires, we need to account for this.