



FIRE
AUSTRALIA2025

RHF prediction using wildfire simulation modelling

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Cedaryn





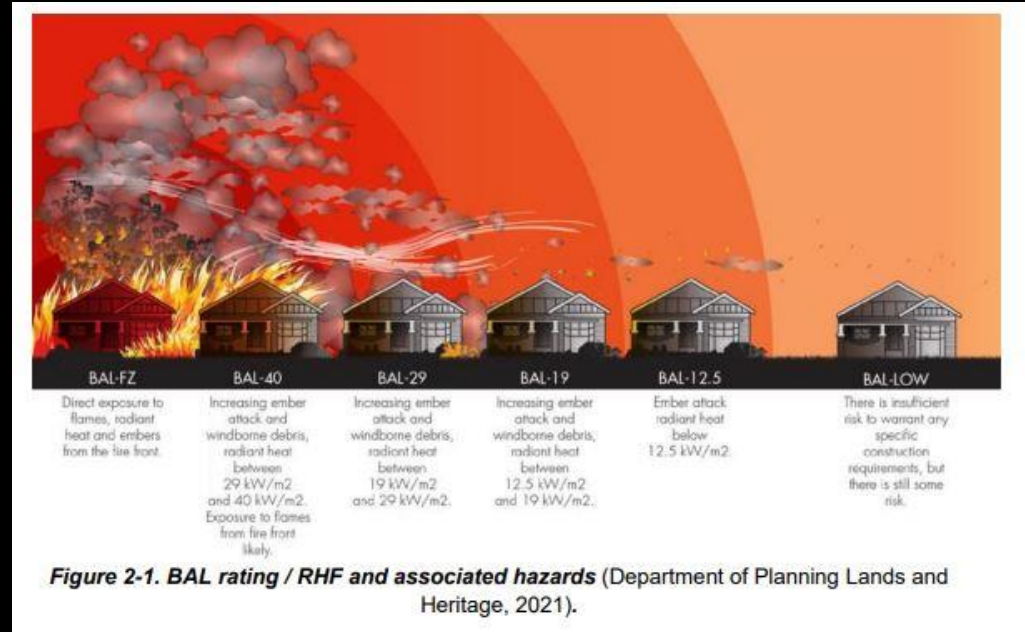
Derivation of wildfire radiant heat flux values using an ensemble of dynamic fire simulation models

What we'll cover today

- Background info
 - Radiant Heat Flux Modelling & BAL Ratings
- Existing Methods to Model RHF – brief overview & limitations
 - Technological solutions to Model RHF
 - Questions

What is RHF Modelling?

- Radiant Heat Flux (RHF) is one of the three major components of bushfire attack (i.e. how bushfires impact assets)
- RHF modelling is used to determine the amount of radiative heat coming out of a theoretical bushfire.
- It is used extensively to determine Bushfire Attack Level (BAL) Ratings for buildings in Australia, using standards such as AS3959.
- It is also used in Australian planning development regulations to determine appropriate setbacks from flammable vegetation and guide development.



RHF Modelling & BAL Ratings

- BAL ratings are often determined by Private Certifiers, etc. through look up tables like this one (method 1) from: AS3959: *Construction of Buildings in Bushfire Prone Areas* based on pre-modelled RHF values
- AS3959 also offers an advanced method whereby users can input data to determine RHF (method 2).
- Many planning regulations across Australia offer similar calculation approaches to Method 2 of AS3959.

AS 3959—2009 34

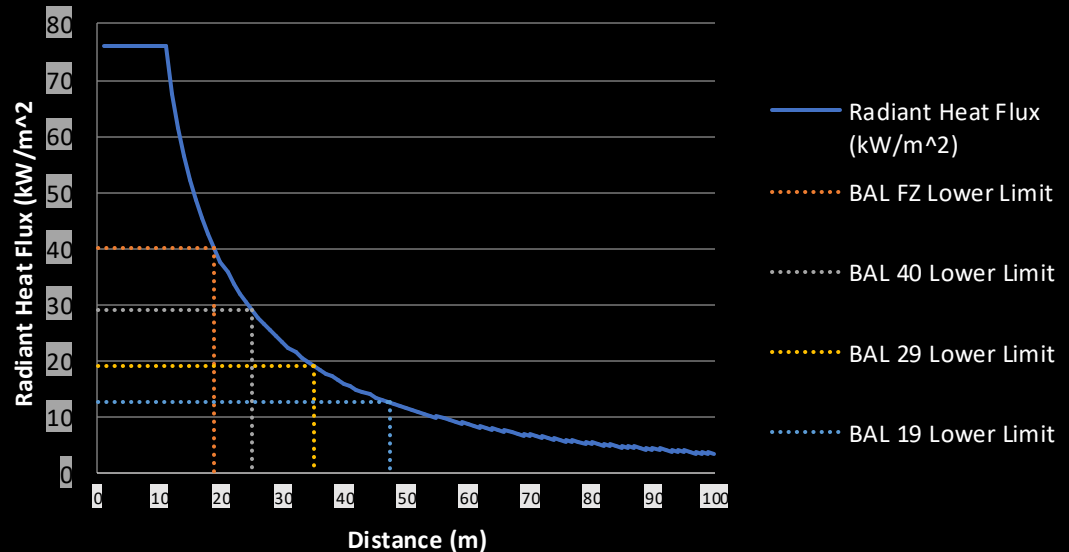
TABLE 2.4.5
DETERMINATION OF BUSHFIRE ATTACK LEVEL (BAL)—FDI 40 (1090 K)

Vegetation classification	Bushfire Attack Levels (BALs)				
	BAL—FZ	BAL—40	BAL—29	BAL—19	BAL—12.5
	Distance (m) of the site from the predominant vegetation class				
All upslopes and flat land (0 degrees)					
A. Forest	<10	10-<13	13-<20	20-<28	28-<100
B. Woodland	<6	6-<9	9-<13	13-<19	19-<100
C. Shrubland	<7	7-<9	9-<13	13-<19	19-<100
D. Scrub	<10	10-<13	13-<19	19-<27	27-<100
E. Mallee/Mulga	<6	6-<8	8-<12	12-<17	17-<100
F. Rainforest	<4	4-<5	5-<8	8-<12	12-<100
G. Grassland	<4	4-<5	5-<8	8-<12	12-<50
Downslope >0 to 5 degrees					
A. Forest	<12	12-<16	16-<24	24-<34	34-<100
B. Woodland	<8	8-<11	11-<16	16-<23	23-<100
C. Shrubland	<7	7-<10	10-<15	15-<22	22-<100
D. Scrub	<11	11-<15	15-<22	22-<31	31-<100
E. Mallee/Mulga	<7	7-<9	9-<13	13-<20	20-<100
F. Rainforest	<5	5-<7	7-<10	10-<15	15-<100
G. Grassland	<4	4-<6	6-<9	9-<14	14-<50
Downslope >5 to 10 degrees					
A. Forest	<15	15-<20	20-<29	29-<41	41-<100
B. Woodland	<9	9-<13	13-<19	19-<28	28-<100
C. Shrubland	<8	8-<11	11-<17	17-<25	25-<100
D. Scrub	<12	12-<17	17-<24	24-<35	35-<100
E. Mallee/Mulga	<7	7-<10	10-<15	15-<23	23-<100
F. Rainforest	<6	6-<8	8-<13	13-<19	19-<100
G. Grassland	<5	5-<7	7-<11	11-<16	16-<50
Downslope >10 to 15 degrees					
A. Forest	<19	19-<25	25-<36	36-<49	49-<100
B. Woodland	<12	12-<16	16-<24	24-<35	35-<100
C. Shrubland	<9	9-<13	13-<19	19-<28	28-<100
D. Scrub	<14	14-<19	19-<28	28-<39	39-<100
E. Mallee/Mulga	<8	8-<11	11-<18	18-<26	26-<100
F. Rainforest	<8	8-<11	11-<16	16-<24	24-<100
G. Grassland	<6	6-<8	8-<13	13-<19	19-<50

How do these RHF Models work?

- These methods are 'point based' and reflect a cross-section of the landscape. They determine RHF decay curves between 2 single points (where the fire is and the receiving point).
- Users select inputs on fire weather, slope, and fuels to model the decay curve (like this one) over distance.

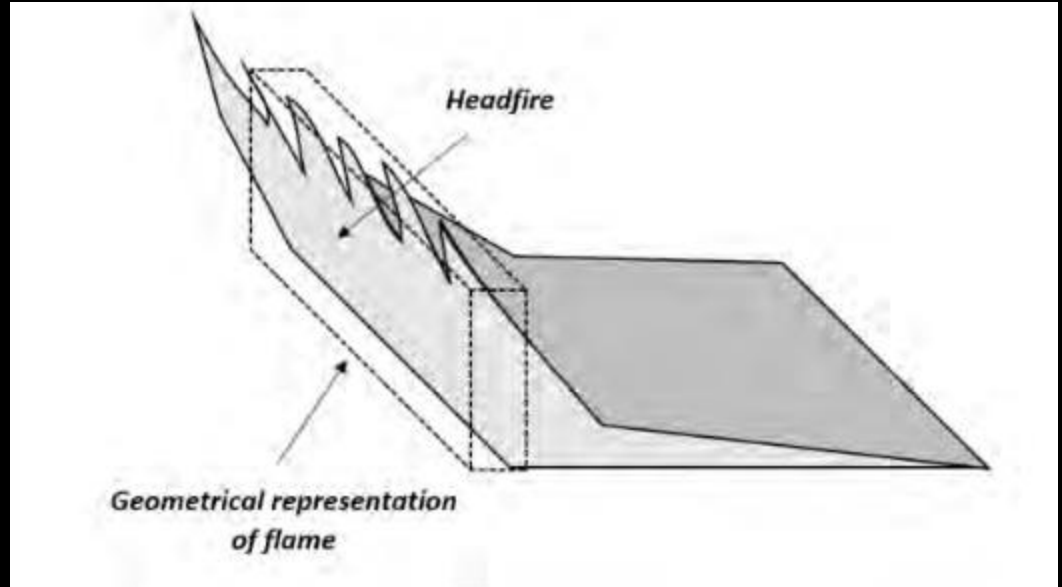
Radiant Heat Flux vs Distance to Vegetation



They adopt simplifications of fire behaviour

The method assumes:

- A headfire width of 100m.
- That the fire has achieved its potential rate of spread (i.e. is not an accelerating fire in its build-up phase).
- Simplified geometries of fire fronts (rectangular heat panel)



(From Penney 2020)

Method Assumptions

The method also:

- Assumes impact by fully developed landscape-scale head fire fronts
- Does not address the impact of flank or backing fires
- Does not consider dominant fire wind directions (i.e. they are omnidirectional)
- All sites with vegetation scales above a certain threshold are treated equally in terms of model inputs
- Various methods have been attempted to address these problems (e.g., the short fire run method by NSW RFS)

(Sites supplied by BlackAsh Bushfire Planning)



Blue Mountains NSW



Copacabana NSW



Kellyville NSW

They require assumptions about the weather

- AS3959 is linked to the Forest Fire Danger Index and Grassfire Danger Index
- The FDI is calculated with various weather variables & landscape conditions
- However, there can be many 'different' combinations of weather variables to make up any given FDI value
- The green cells in the table to the right are all FDI values of 40 made up of different combinations of Temperature and Wind Speed
- It has also been recently superseded by the AFDRS and FBI (2022)


Temp C	Wind Speed km/h														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	18	18	18	19	19	20	20	21	21	22	22	23	23	24	24
26	18	19	19	20	20	20	21	21	22	22	23	24	24	25	25
27	19	19	20	20	21	21	22	22	23	23	24	24	25	25	26
28	19	20	20	21	21	22	22	23	23	24	25	25	26	26	27
29	20	21	21	22	22	23	23	24	24	25	25	26	27	27	28
30	21	21	22	22	23	23	24	25	25	26	26	27	28	28	29
31	22	22	23	23	24	24	25	25	26	27	27	28	29	29	30
32	22	23	23	24	24	25	26	26	27	27	28	29	29	30	31
33	23	24	24	25	25	26	27	27	28	28	29	30	31	31	32
34	24	24	25	26	26	27	27	28	29	29	30	31	32	32	33
35	25	25	26	26	27	28	28	29	30	30	31	32	33	33	34
36	25	26	27	27	28	29	29	30	31	31	32	33	34	35	35
37	26	27	28	28	29	30	30	31	32	33	33	34	35	36	37
38	27	28	29	29	30	31	31	32	33	34	34	35	36	37	38
39	28	29	30	30	31	32	32	33	34	35	36	36	37	38	39
40	29	30	31	31	32	33	34	34	35	36	37	38	39	40	40
41	30	31	32	32	33	34	35	36	36	37	38	39	40	41	42
42	31	32	33	33	34	35	36	37	38	39	39	40	41	42	43
43	32	33	34	35	35	36	37	38	39	40	41	42	43	44	45
44	33	34	35	36	37	38	38	39	40	41	42	43	44	45	46
45	35	35	36	37	38	39	40	41	42	43	44	45	46	47	48
46	36	37	37	38	39	40	41	42	43	44	45	46	47	48	50


$$FDI = 1.2753 * \exp[0.987 \ln(DF) + 0.0338T + 0.0234V - 0.0345RH]$$

But, each unique FDI value can lead to different fire behaviour

T & WS Combination	FDI	Air Temp (C)	Wind Speed @ 10m (km/h)	Vesta 2 Fine Fuel Moisture (%) Daytime	Vesta 2 Combined Fuel Moisture Effect (ΦM) (0-1)	Vesta 2 Prob of Phase II	Vesta 2 Prob of Phase III	Vesta 2 Expected FROS (m/h)	Vesta 2 Expected Flame Height (m)	Vesta 2 Fireline Intensity (kW/m)	McArthur V FROS (m/h) at FFDI 40	McArthur V Expected Flame Height (m) at FFDI 40	McArthur V Expected Intensity (kW/m) at FFDI 40
1	40	46	6	4.1	1.00	1.00	0.00	30	0.4	356	580	6.5	6,845
2	40	45	7	4.1	1.00	1.00	0.03	428	2.8	5,085			
3	40	44	9	4.2	0.99	1.00	0.05	532	3.2	6,317			
4	40	43	10	4.2	0.99	1.00	0.06	583	3.4	6,929			
5	40	42	12	4.2	0.99	1.00	0.10	694	3.9	8,243			
6	40	41	13	4.3	0.99	1.00	0.12	752	4.1	8,931			
7	40	40	14	4.3	0.98	1.00	0.15	813	4.4	9,664			
8	40	40	15	4.3	0.98	1.00	0.19	887	4.7	10,543			
9	40	39	16	4.4	0.98	1.00	0.23	961	4.9	11,425			
10	40	38	17	4.4	0.98	1.00	0.27	1,043	5.2	12,390			
11	40	37	19	4.5	0.98	1.00	0.39	1,245	6.0	14,797			
12	40	36	20	4.5	0.97	1.00	0.44	1,353	6.3	16,080			

- Fuel, topography, relative humidity, and drought factor were held constant.
- Vesta 2 one of the latest & advanced fire behaviour models (2022)

 = current planning regs

 = potential possibilities

Also, real fires are complicated & look different



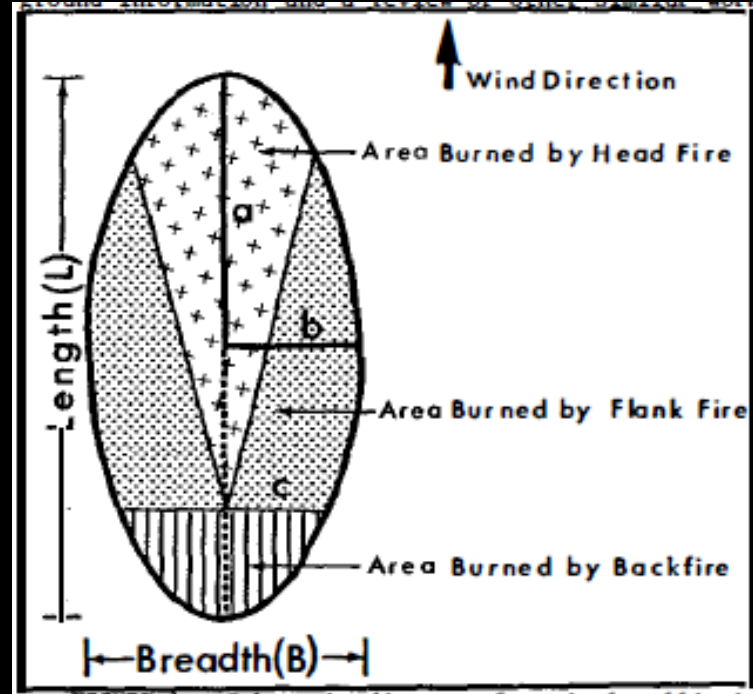
And, fire behaviour varies around the fire perimeter

Fires often burn in an elliptical shape. They have:

- A head (burning with the wind);
- Flanks (partly burning with the wind);
- A 'back' (burning against the wind).

Mathematical representations of these 'fire areas' are available with work from:

- Catchpole
- Alexander
- Van Wagner
- Sharples



So, what do we do?

AS3959 may not get it quite right in some circumstances due to:

- Aggregation of the weather variable into an index (FFDI)
- Restricted fuel geometries
- 1-dimensional point-based assessments
- Restricted use of fire behaviour models
- Special fire behaviour effects (e.g. Extreme fire behaviours)



Point source ignition in restricted fuel geometry



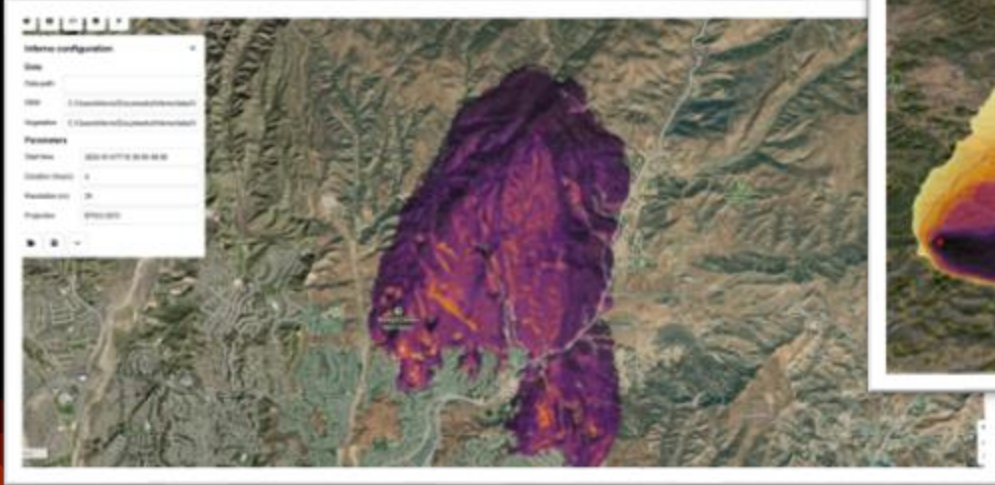
Extreme fire behaviour – e.g. Fire whirls



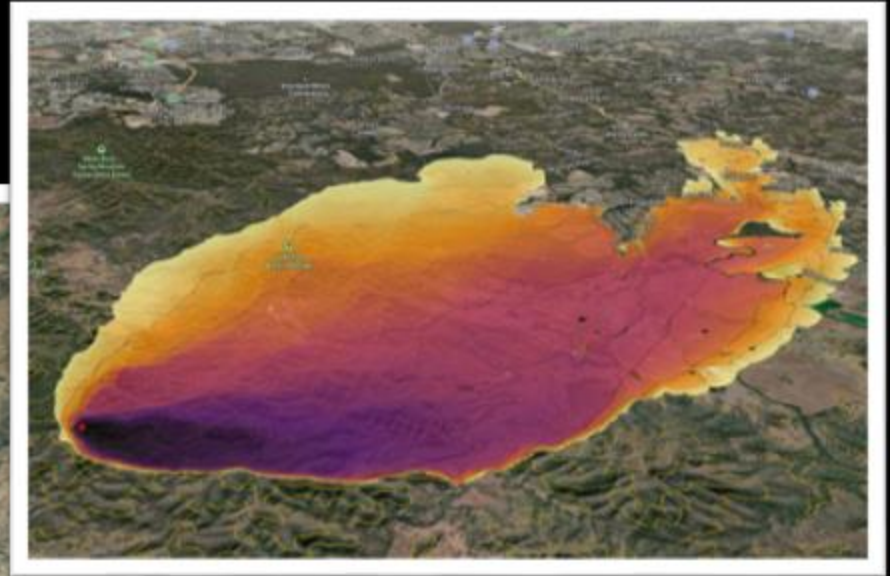
Extreme fire behaviour – e.g. atmospheric effects

Wildfire simulation models

To solve these problems, we can use fire simulation models with full weather profiles:



Simulation United States using Inferno



Simulation west of Logan, Qld using Inferno

Wildfire simulation models

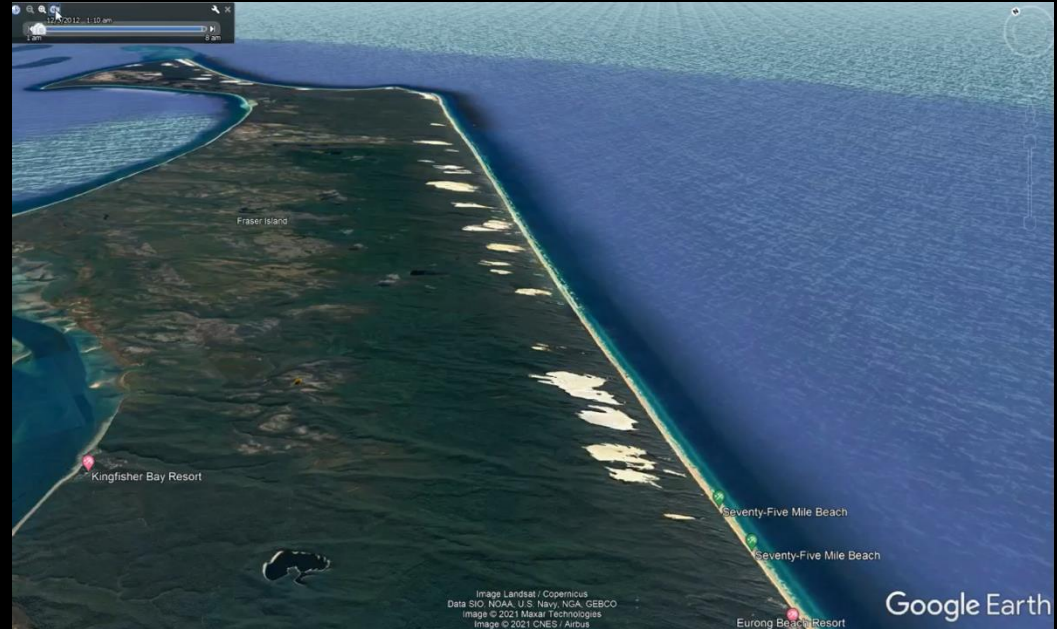
Simulation of fire scenarios can display:

- Flame height
- Fire intensity
- Rate of spread
- Crown scorch
- Animations

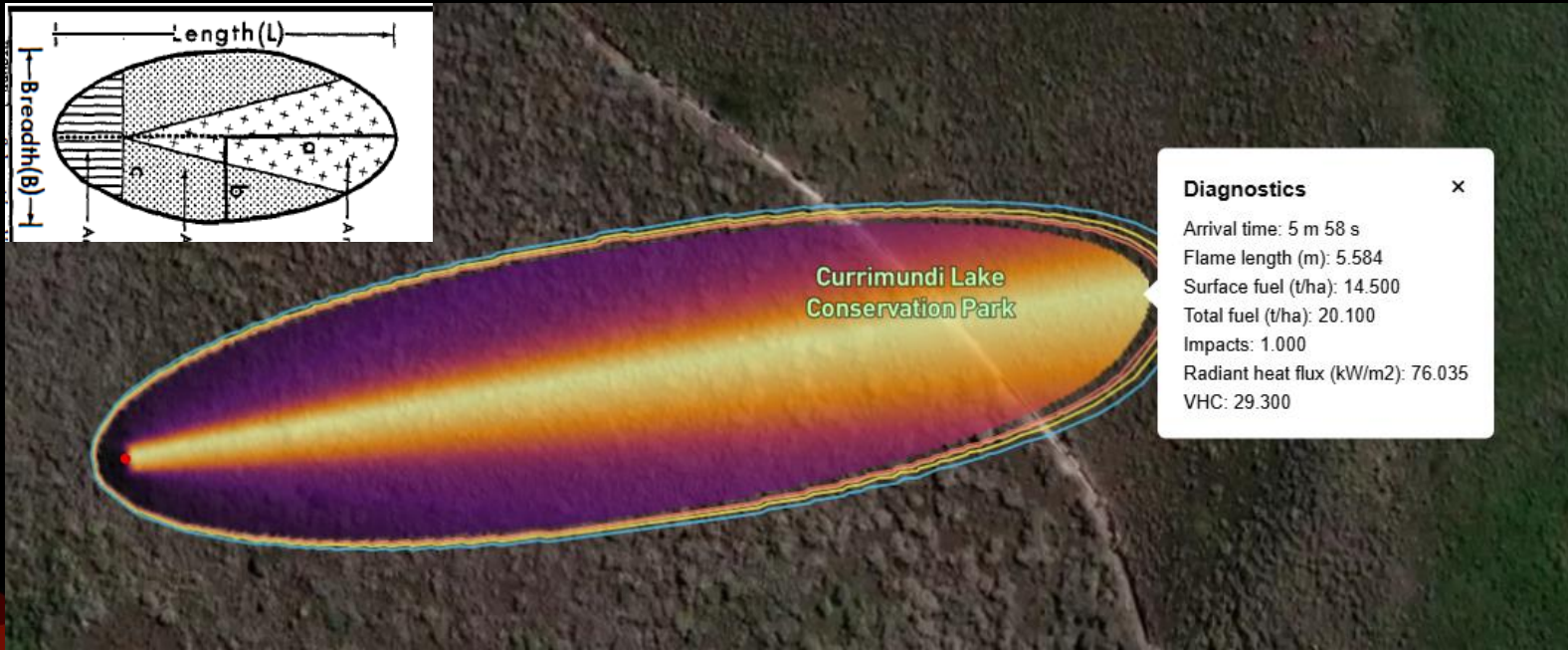
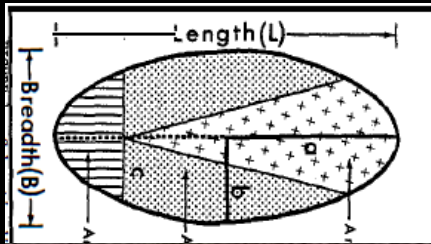
to name a few outputs.

They can use any fire behaviour model and ingest any weather parameters to.....

Simulation using SPARK – K'Gari Island Qld



Generate RHF profiles like this:



Diagnostics

Arrival time: 5 m 58 s
Flame length (m): 5.584
Surface fuel (t/ha): 14.500
Total fuel (t/ha): 20.100
Impacts: 1.000
Radiant heat flux (kW/m²): 76.035
VHC: 29.300

But... there may be many potential fire scenarios

A single simulation won't be enough and might be like throwing a dart at a dart board to answer questions like:

Where and when will a fire start?

What direction will it go in?

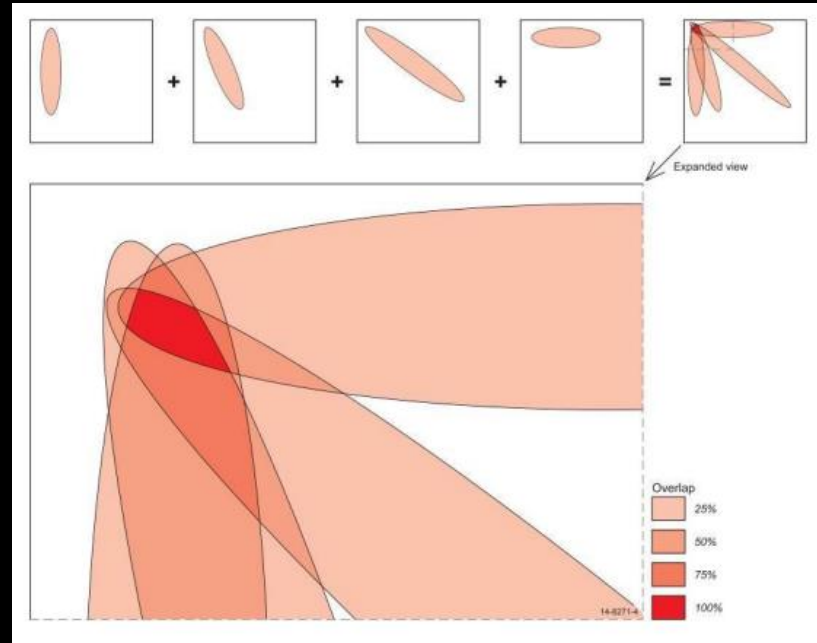
What is the worst-case scenario?

What's the maximum potential RHF?

So, we can complete and aggregate many sims (ensembles)

As there are many, many possible wildfire scenarios, we need a Wildfire Ensemble Capability to:

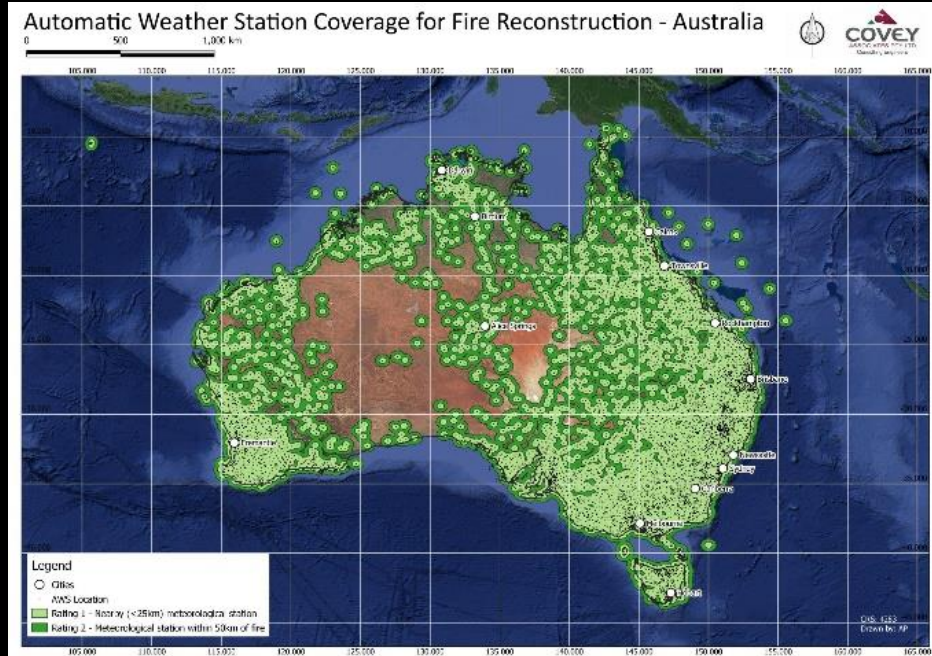
- Spatially calculate thousands of simulations
- Account for different fire ignition locations under different weather
- Aggregate the simulations to find the 'worst case'



But we need to... inform these simulations with local weather analysis



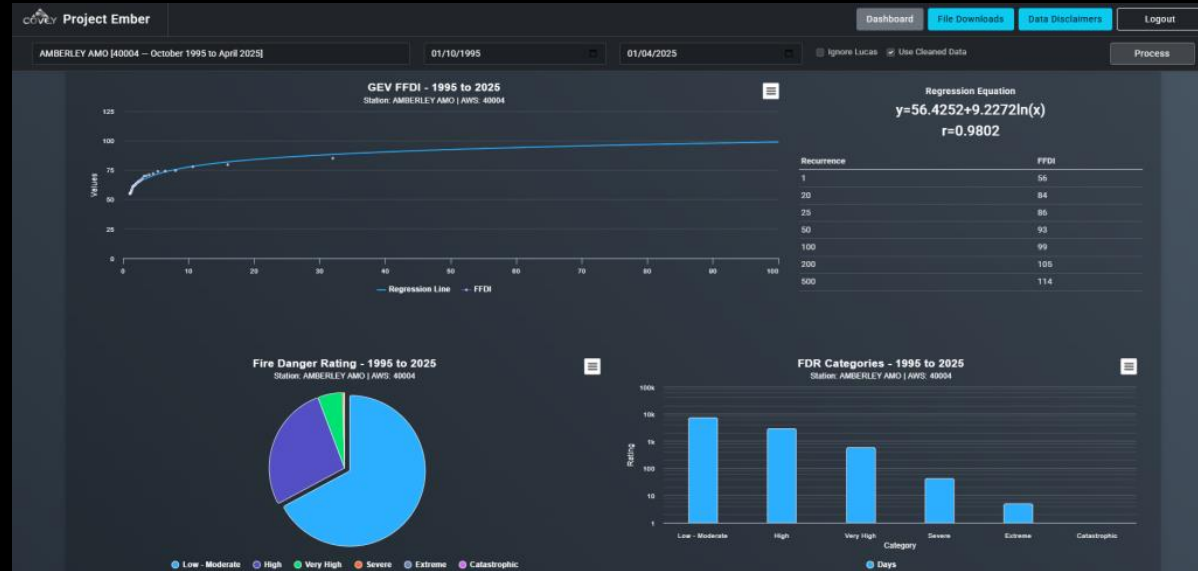
Automatic Weather Station



Automatic Weather Station Locations

Weather Data can be assimilated from various sources

- We can use AWS or BARRA 2 reanalysis data set - modelled historical weather data using Global Climate Models as gridded weather in simulations
- Can be extracted at a spatial point and as a time series
- Aggregate worst-case weather to create synthetic design fires
- Calculate AEP's of fire weather

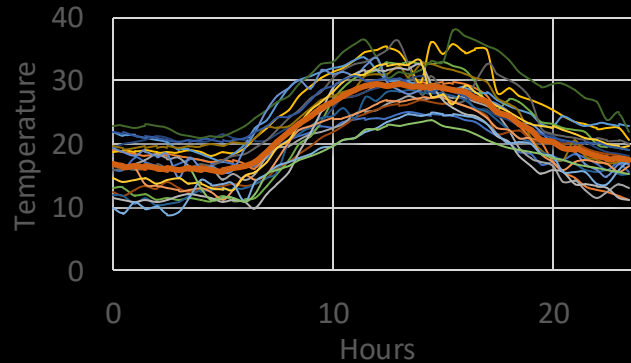


Automatic Weather Station data analysis using Ember
fire weather software

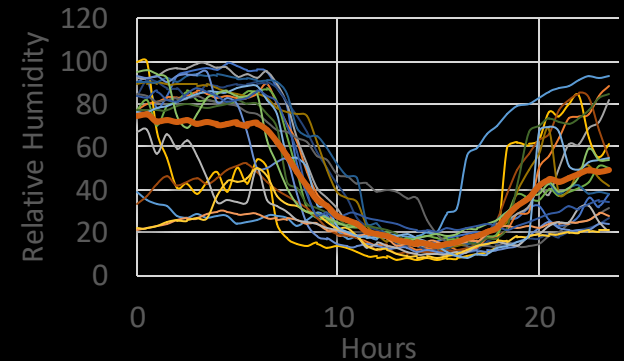
We can identify the worst weather

- Filter weather on various 'indices' – AFDRS, FDI, HDWI
- Aggregate worst-case weather to create synthetic design fires

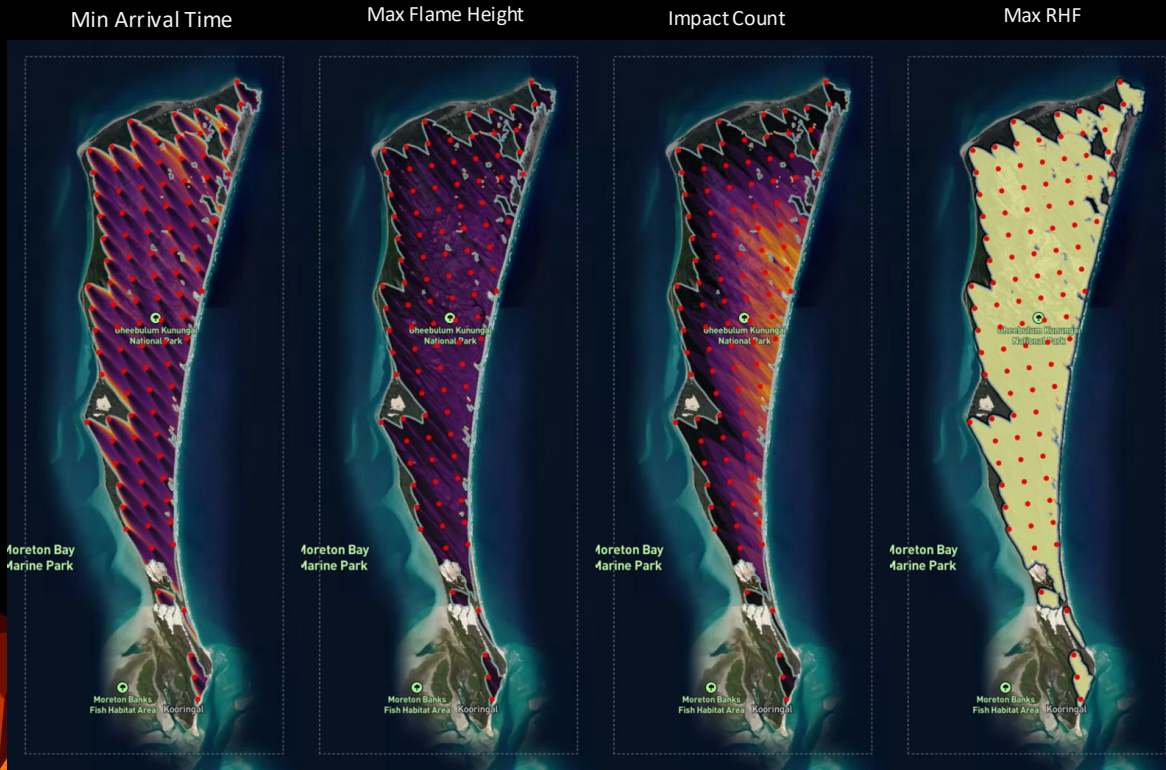
Top 20 *FDI* days
Sunshine Coast Airport AWS 2000 - 2025



Top 20 *FBI* (forest) days
Sunshine Coast Airport AWS 2000 - 2025

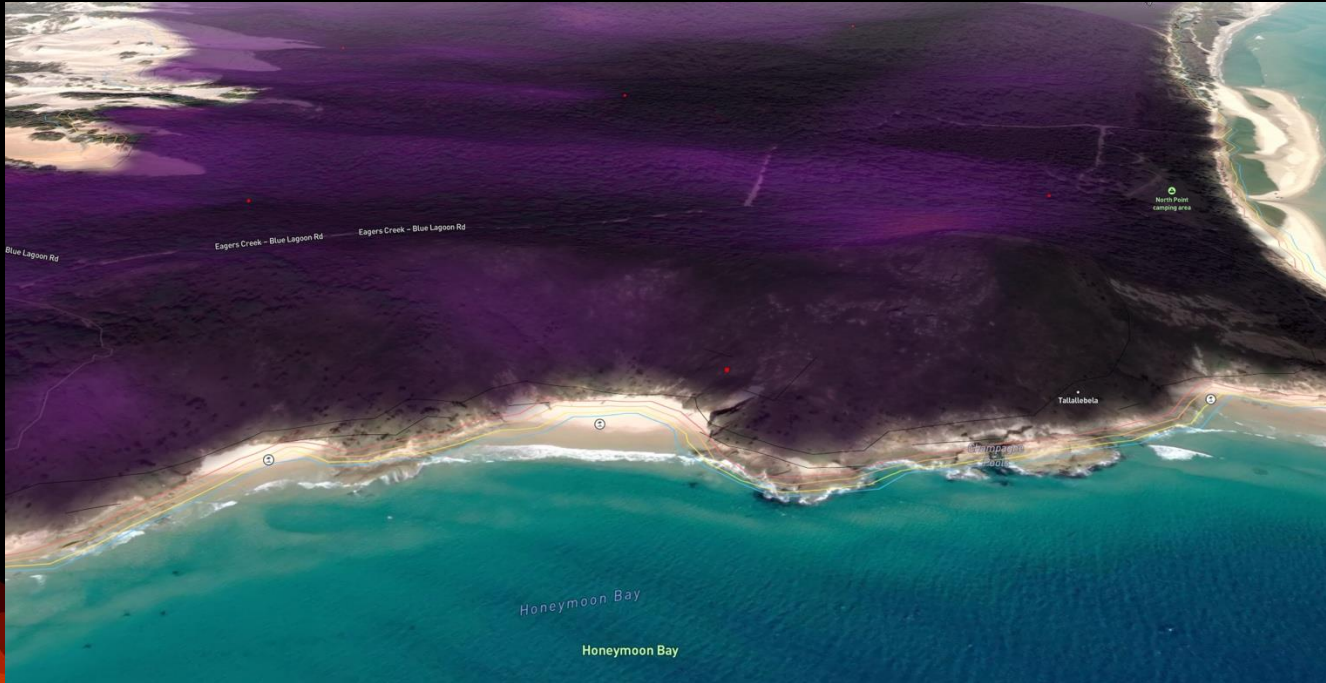


Then apply this data to large areas – e.g. Moreton Island



- Ensembles can be run over large spatial areas
- Can generate various fire behaviour insights as well as RHF contours
- Automatically generate BAL's to structures by incorporating building shape file data into the model

Case Study Example – Moreton Island



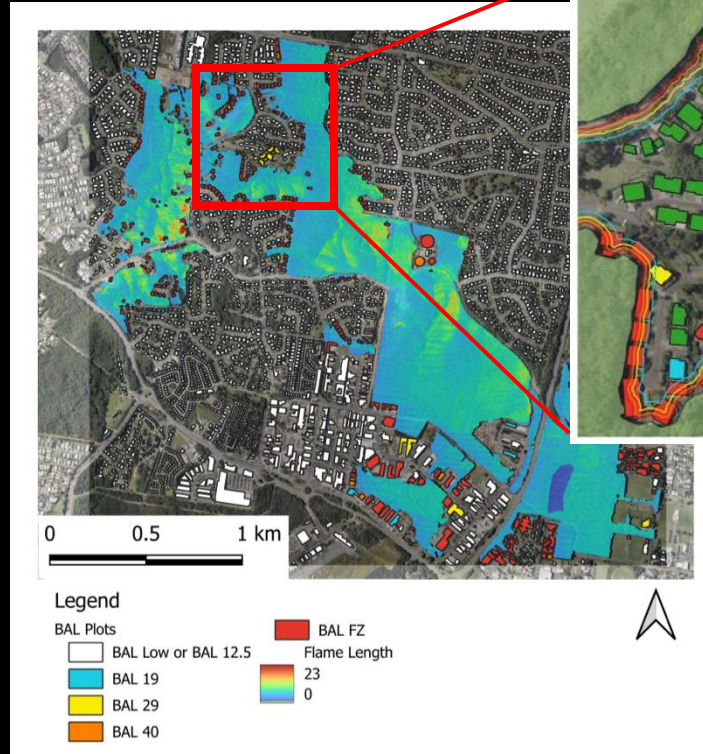
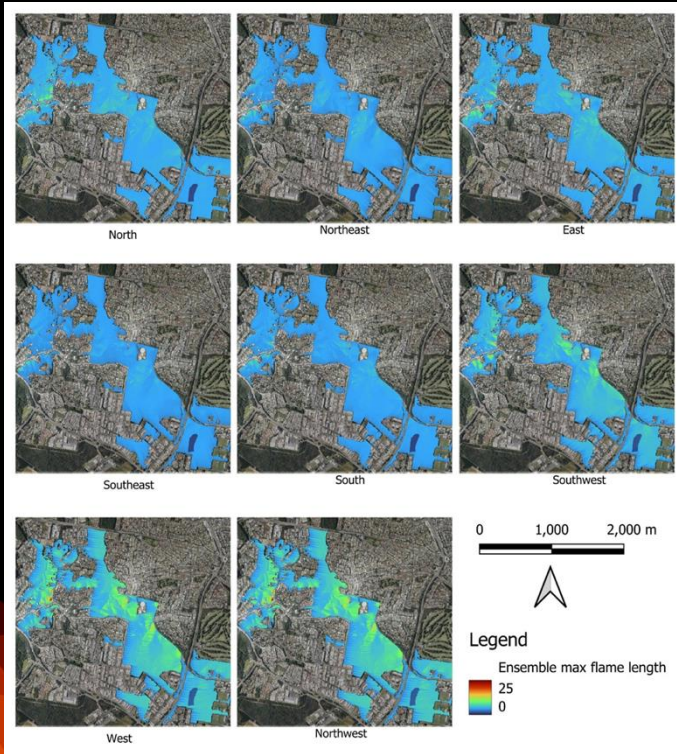
- RHF contours along the beach

Or smaller areas

- Worst fire weather days blow headfires to the beach, away from houses (under westerly winds)
- Houses to the north and west of the fuel experience 'different' headfires under the influence of maritime winds



Weather Ensemble + Ignition Ensemble



Summary

- RHF can be modelled using fire simulators, ingesting detailed fire weather and aspects of fire behaviour
- Simulators can be very flexible, with a wide choice of fire behaviour model algorithms, inputs and outputs
- Models can be set up to answer a wide variety of risk analysis questions and tasks
- May be especially useful for emerging bushfire engineering processes such as the Verification Method under the NCC

Thankyou

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 International Convention Centre, Sydney

 fireaustralia.com.au

