



# BUILDING BUSHFIRE PREDICTIVE SERVICES CAPABILITY

**Dr Stuart Matthews** – NSW Rural Fire Service

**John Bally** – Bureau of Meteorology

**Dr Adam Leavesley** – ACT Parks and Conservation Service

**David Pearce** – Country Fire Service South Australia

**Simeon Telfer** – Dept of Environment, Water and Natural Resources South Australia

**Associate Prof Khalid Moinuddin** – Bushfire and Natural Hazards CRC, Victoria University

**Associate Prof Jason Sharples** – Bushfire and Natural Hazards CRC, University of New South Wales

**Dr Jeff Kepert** – Bushfire and Natural Hazards CRC, Bureau of Meteorology

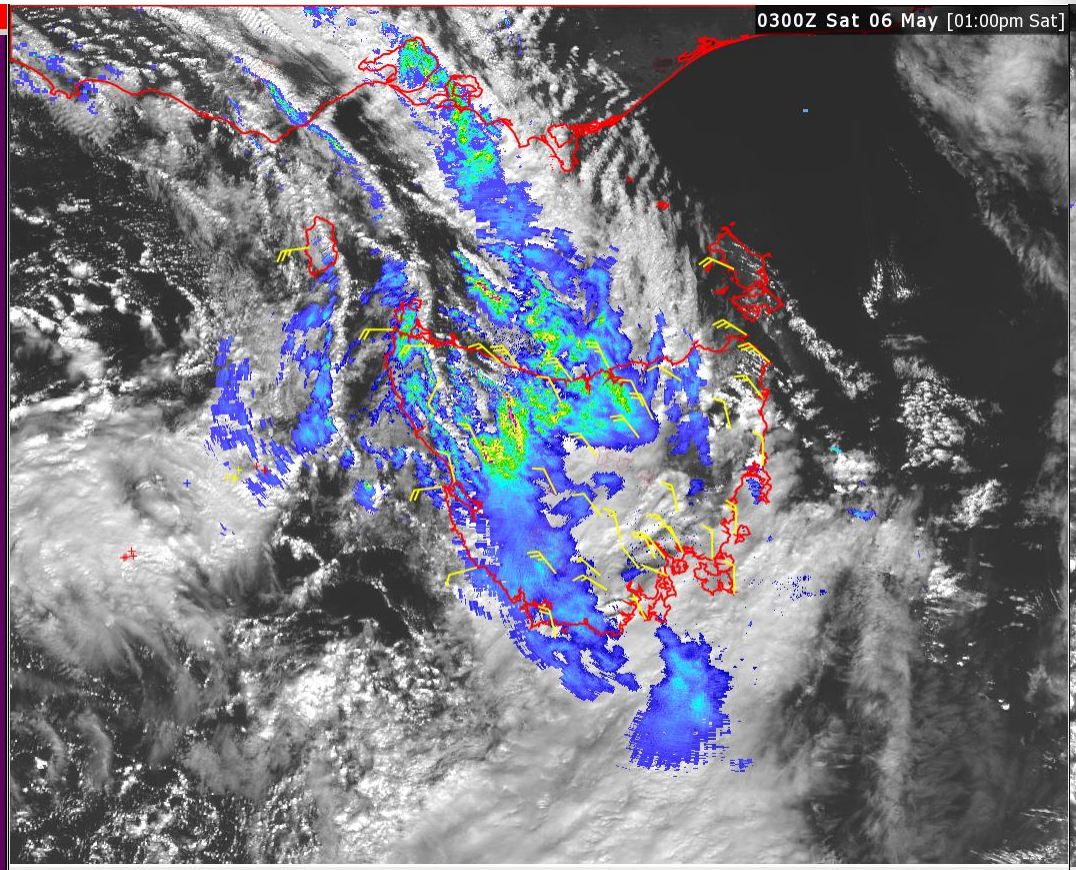
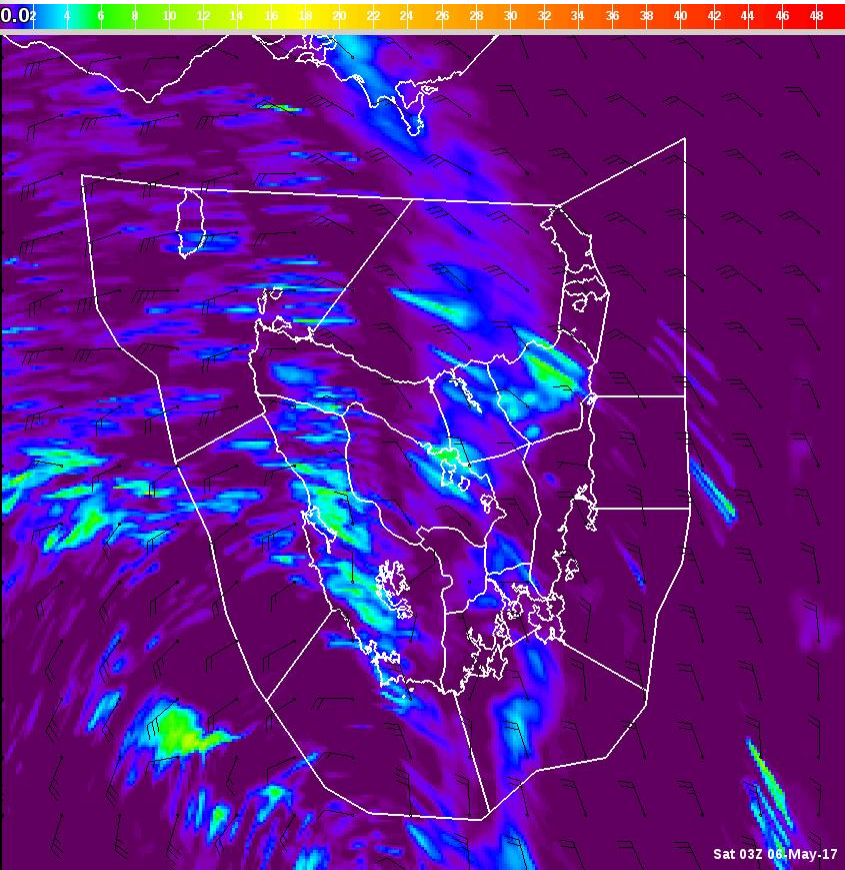
**Dr Mika Peace** – Bushfire and Natural Hazards CRC, Bureau of Meteorology

**Dr Alex Filkov** – Bushfire and Natural Hazards CRC, University of Melbourne

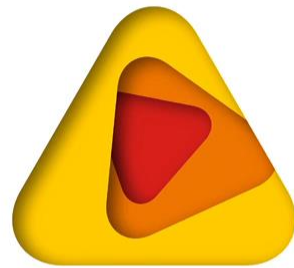
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# **JOHN BALLY, BUREAU OF METEOROLOGY, LEAD END-USER**



**VIDEO WITH DR SIMON HEEMSTRA, NSW  
RURAL FIRE SERVICE, LEAD END-USER**



bushfire&natural  
**HAZARDS**CRC

## Building bushfire predictive services capability

**DR ADAM LEAVESLEY, ACT PARKS AND  
CONSERVATION SERVICE, END-USER**

# BNHCRC RESEARCH SHOWCASE IN PRESCRIBED BURNING



**ACT**  
Government









DIRECTION  
247 deg(T)

55H FA 8179 4168

ACCURACY 5 m  
DATUM WGS84



Paul SE  
IOS

Brandy

6/04/2016  
12:53:30

DIRECTION  
256 deg(T)

55H FA 8213 4135

ACCURACY 5 m  
DATUM WGS84



Paul SE  
IOS

Brandy

6/04/2016  
12:59:30

DIRECTION  
161 deg(T)

55H FA 8131 4178

ACCURACY 5 m  
DATUM WGS84



Paul SE  
IOS

Brandy

6/04/2016  
13:00:08

DIRECTION  
43 deg(T)

55H FA 8105 4006

ACCURACY 10 m  
DATUM WGS84



Paul SE  
IOS

Brandy

6/04/2016  
13:01:08

DIRECTION  
37 deg(T)

55H FA 8096 4066

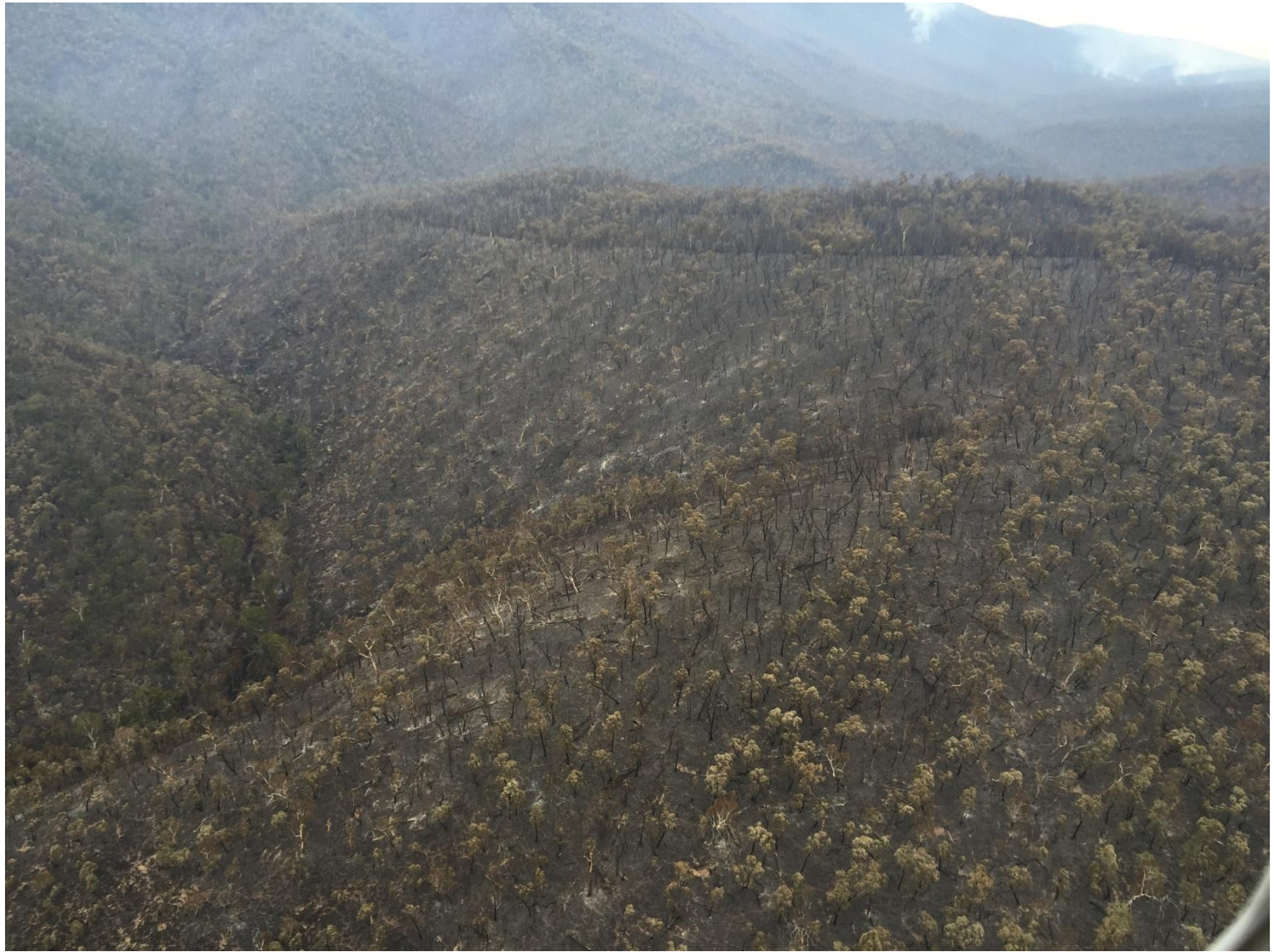
ACCURACY 30 m  
DATUM WGS84



Paul SE  
IOS

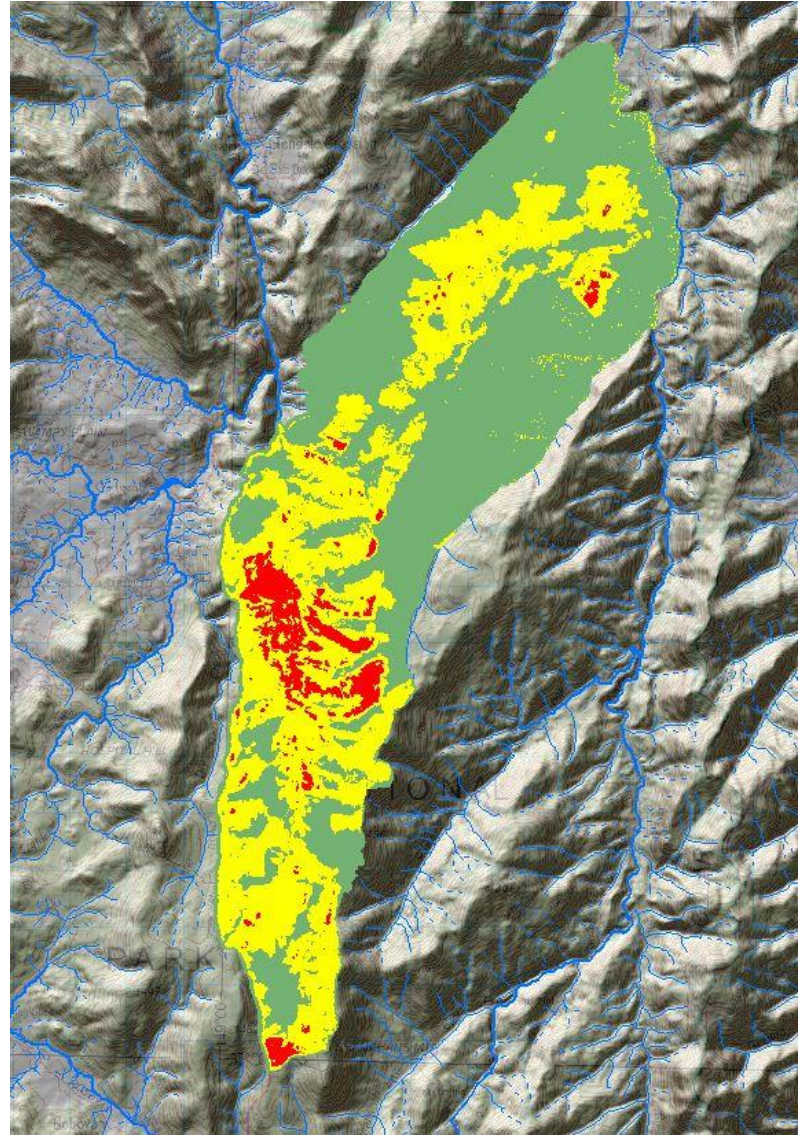
Brandy

6/04/2016  
13:05:51



# EVALUATION

Brandy Flat HRB fire  
severity assessment



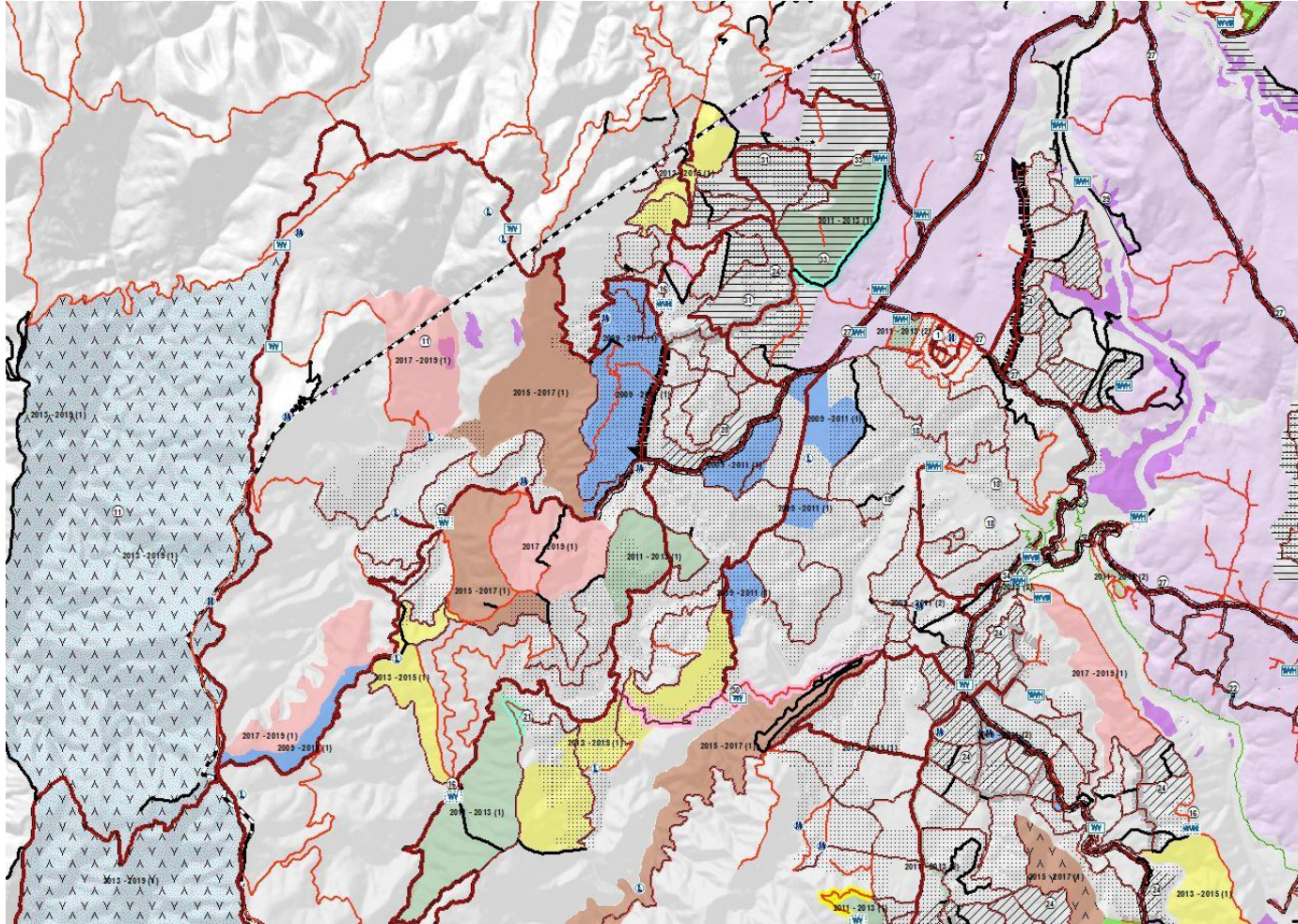


# RESEARCH SHOWCASE IN PRESCRIBED BURNING

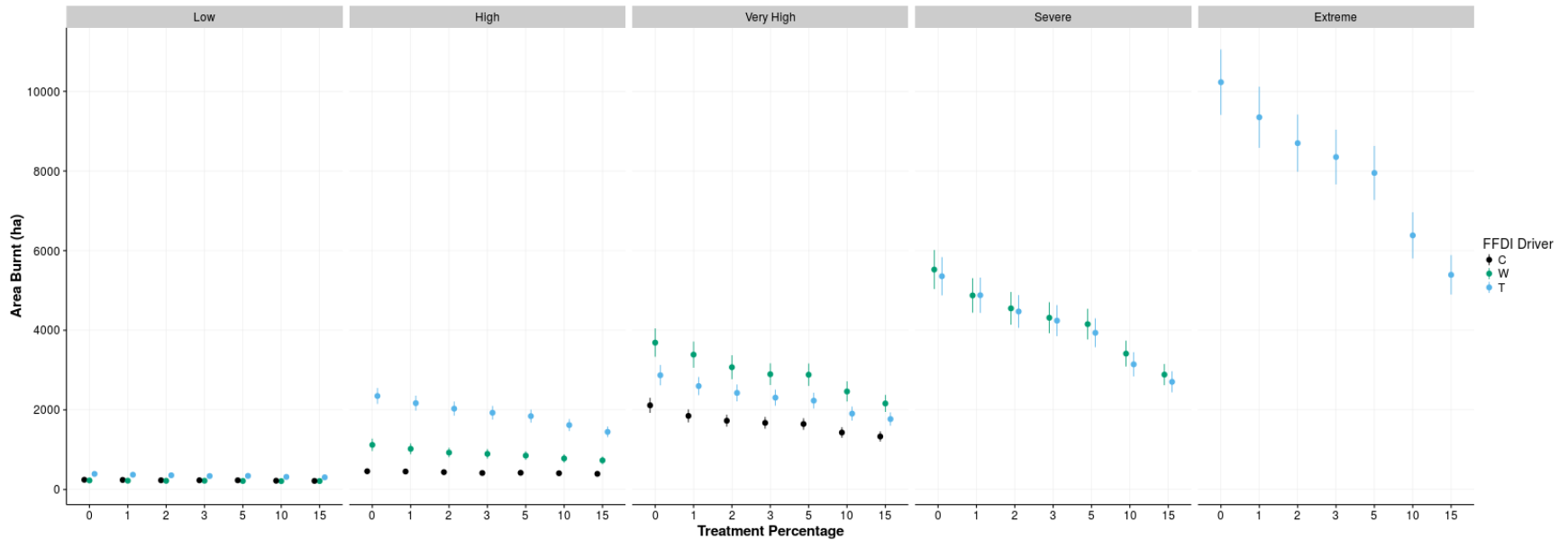
- 1) Planning: Bradstock group (UoW, UMelb)
- 1) Implementation: Van Dijk, Yebra and Cary (ANU)
- 1) Evaluation: Adams, Bell and Gharun (USyd)



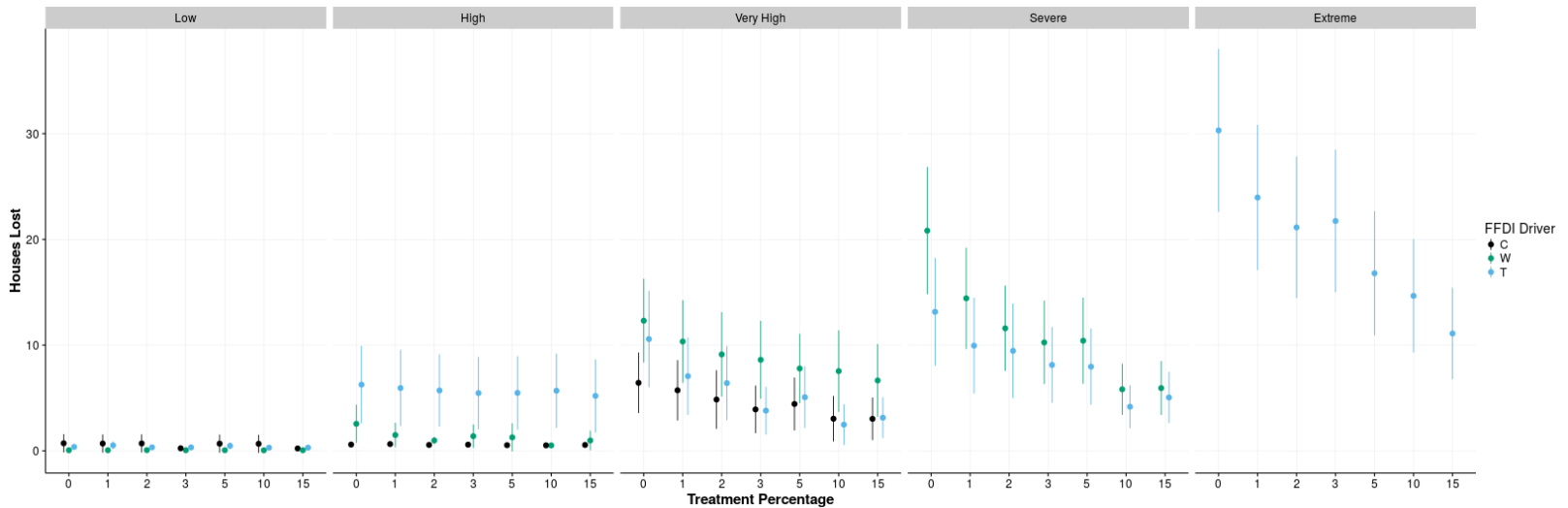
# PRESCRIBED BURNING - PLANNING



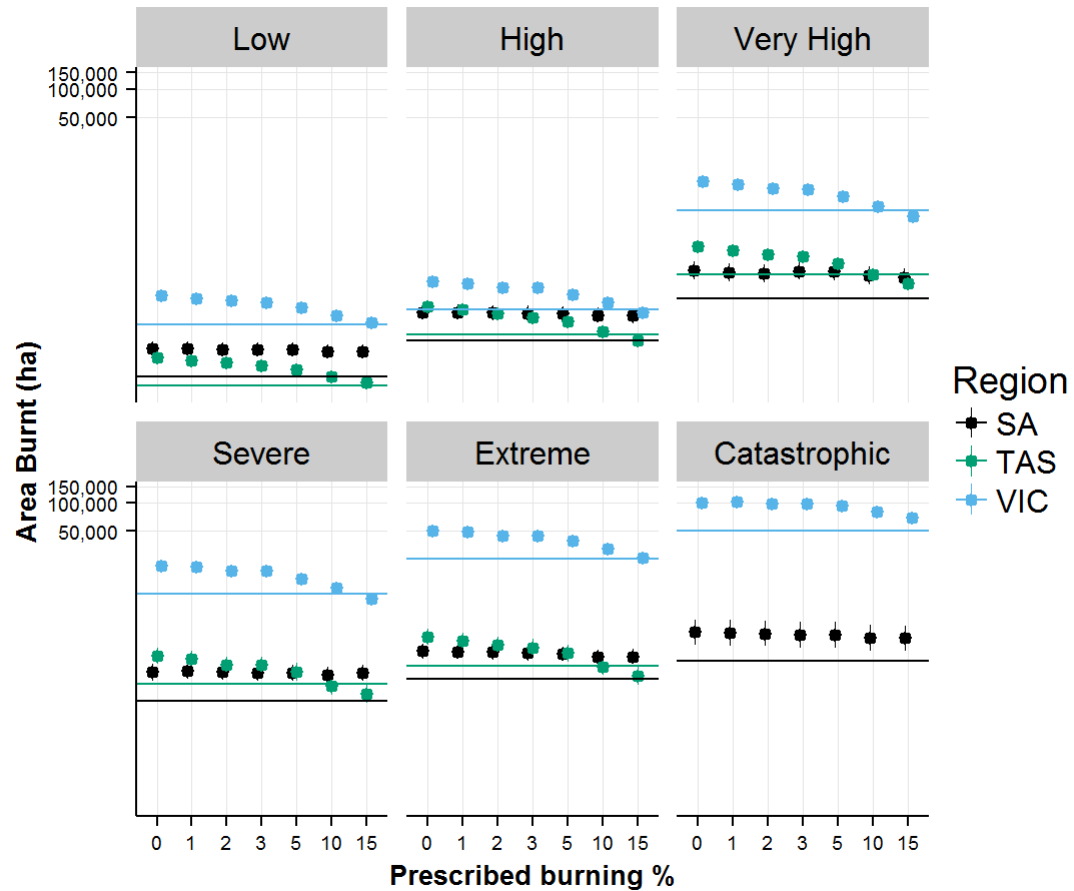
# PRESCRIBED BURNING - PLANNING



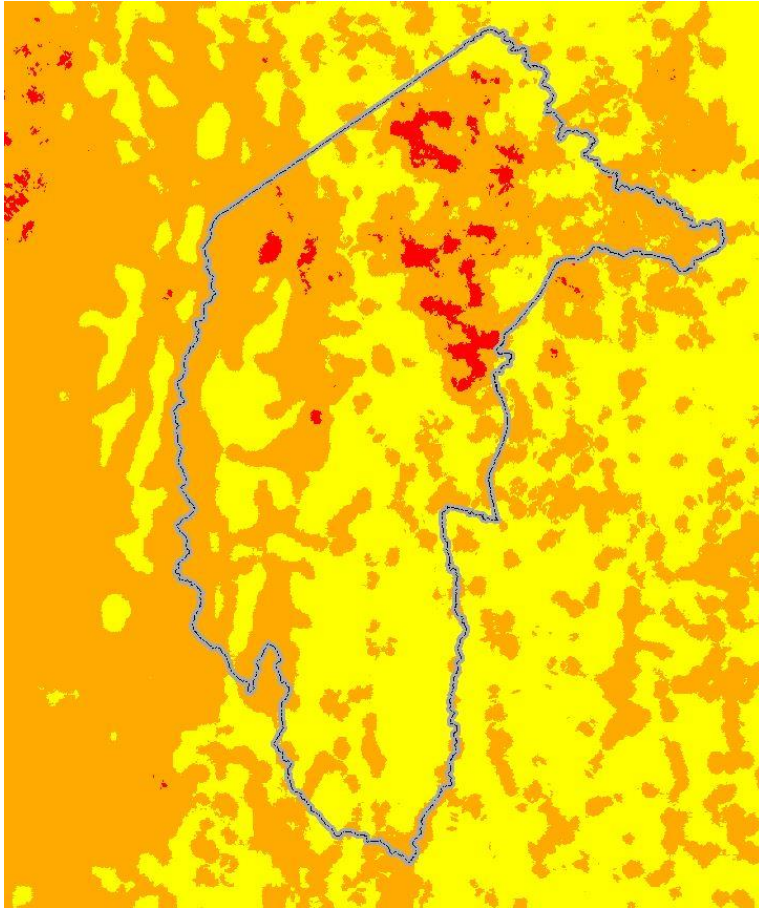
# PRESCRIBED BURNING - PLANNING



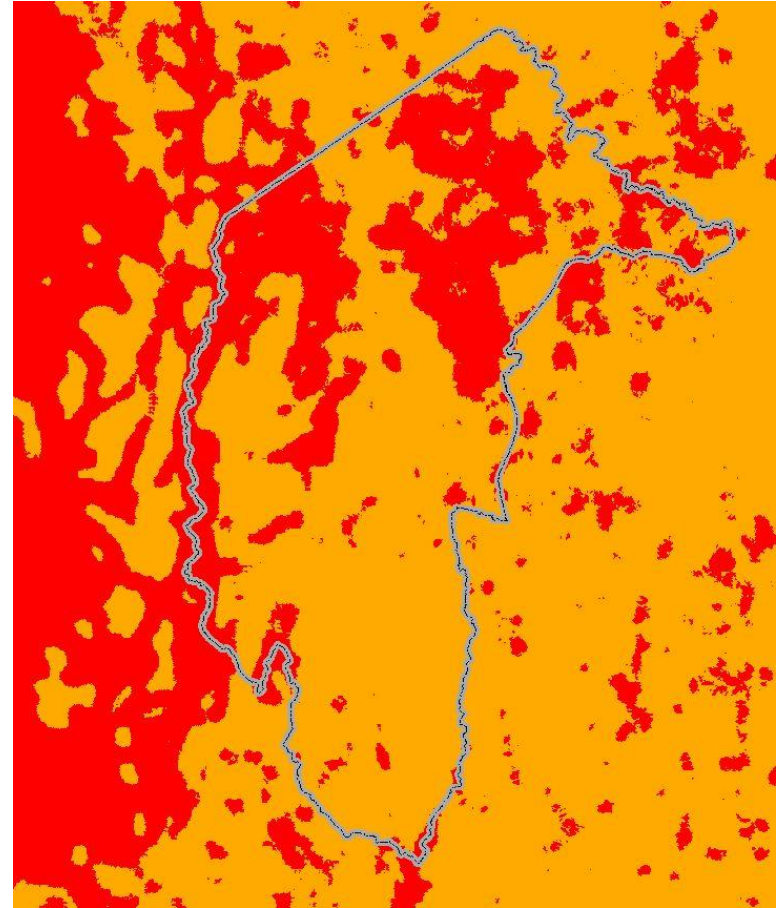
# PRESCRIBED BURNING - PLANNING



# PRESCRIBED BURNING - PLANNING



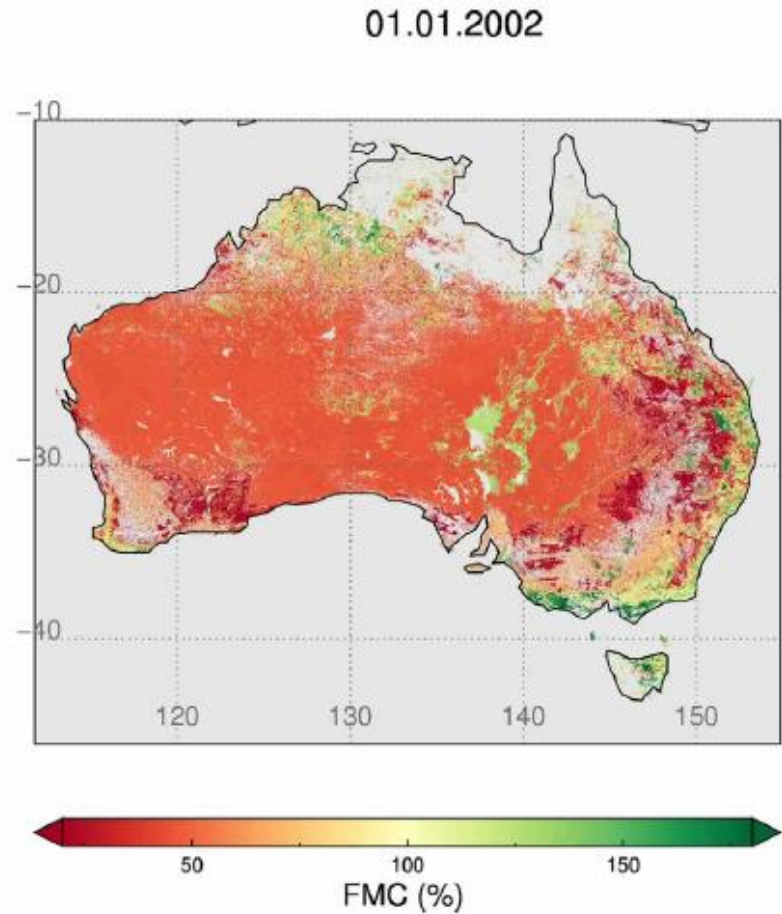
Ignition Probability – FFDI 25



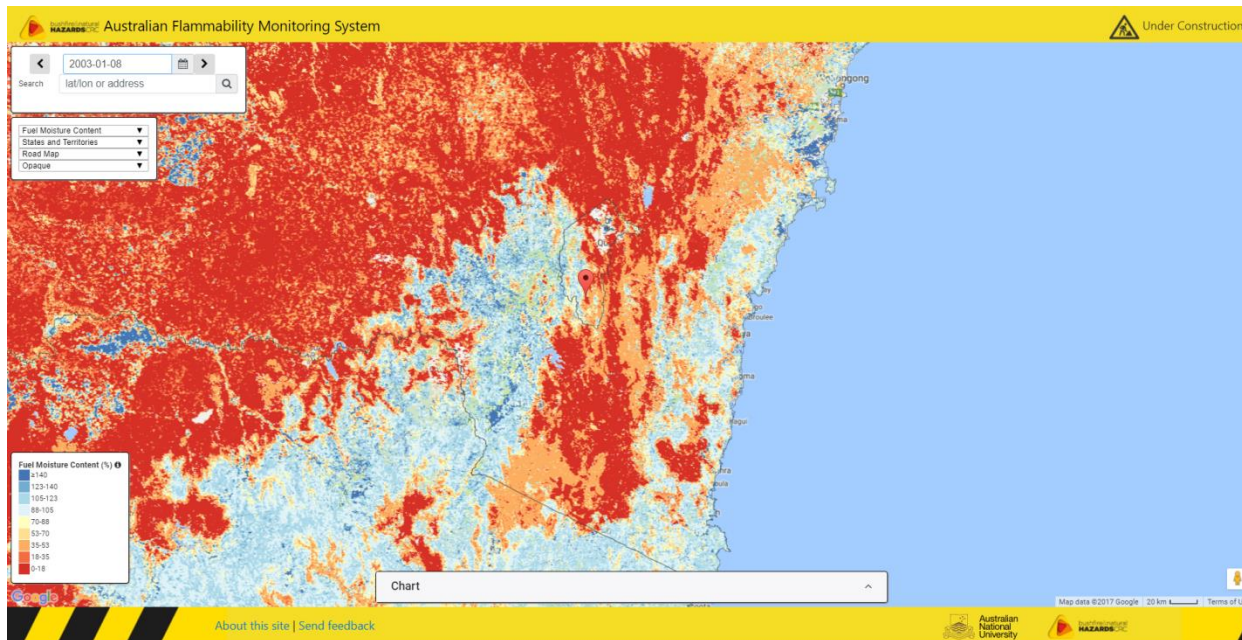
Ignition Probability – FFDI 135

# PRESCRIBED BURNING - IMPLEMENTATION

Satellite-based fuel moisture content and flammability



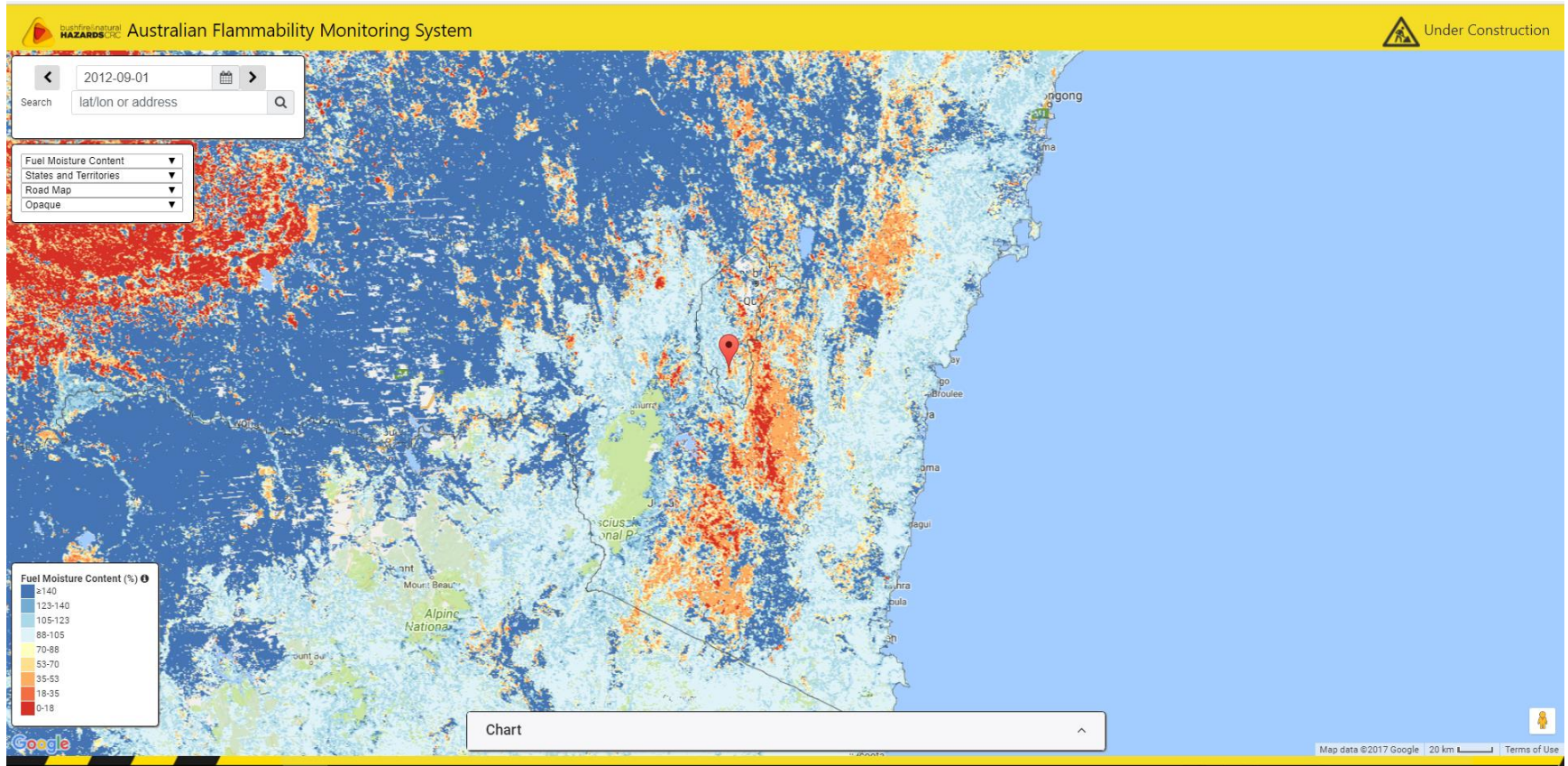
# PRESCRIBED BURNING - IMPLEMENTATION



January 2003

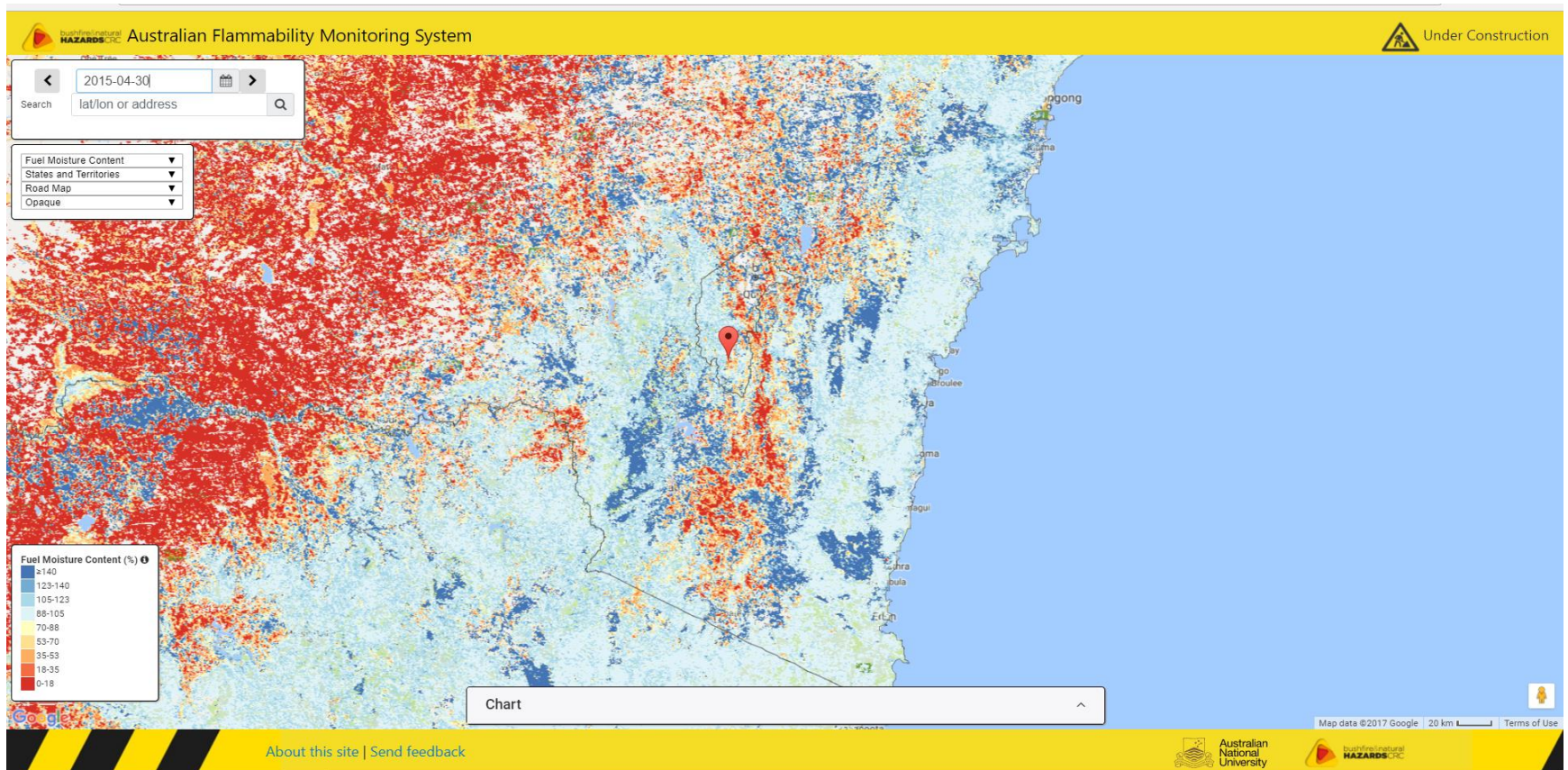


# PRESCRIBED BURNING - IMPLEMENTATION



October 2012

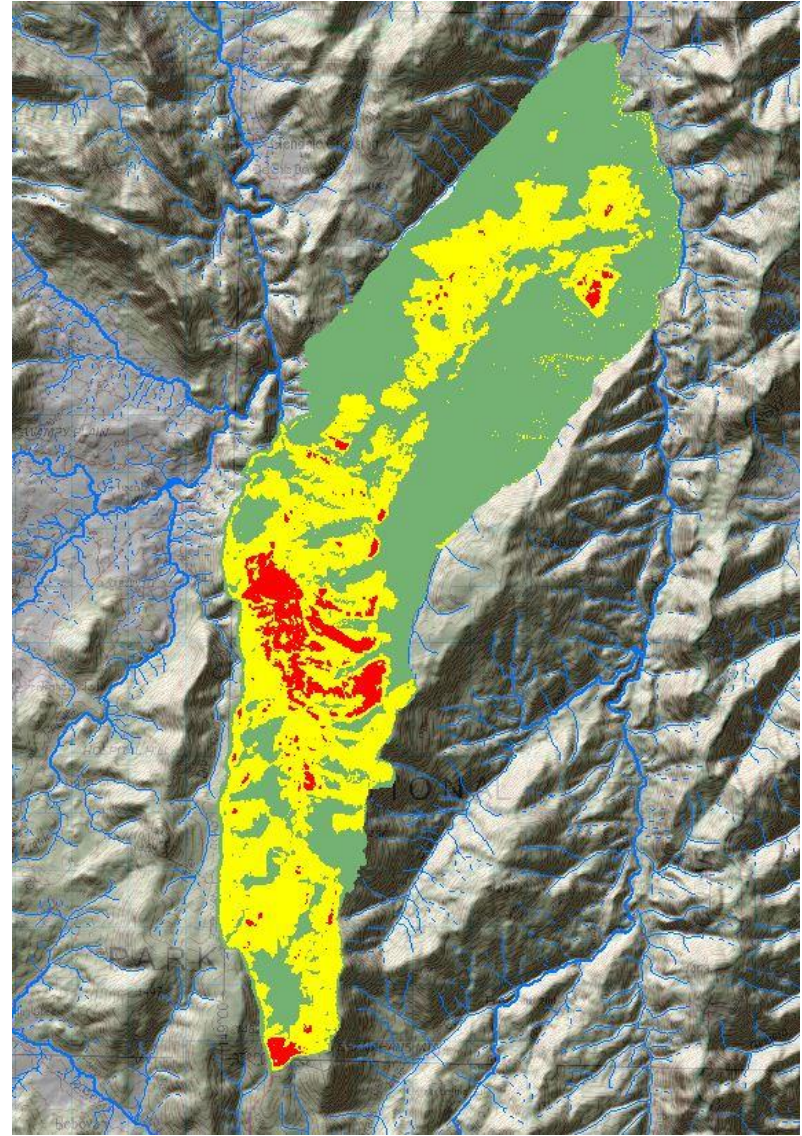
# PRESCRIBED BURNING - IMPLEMENTATION



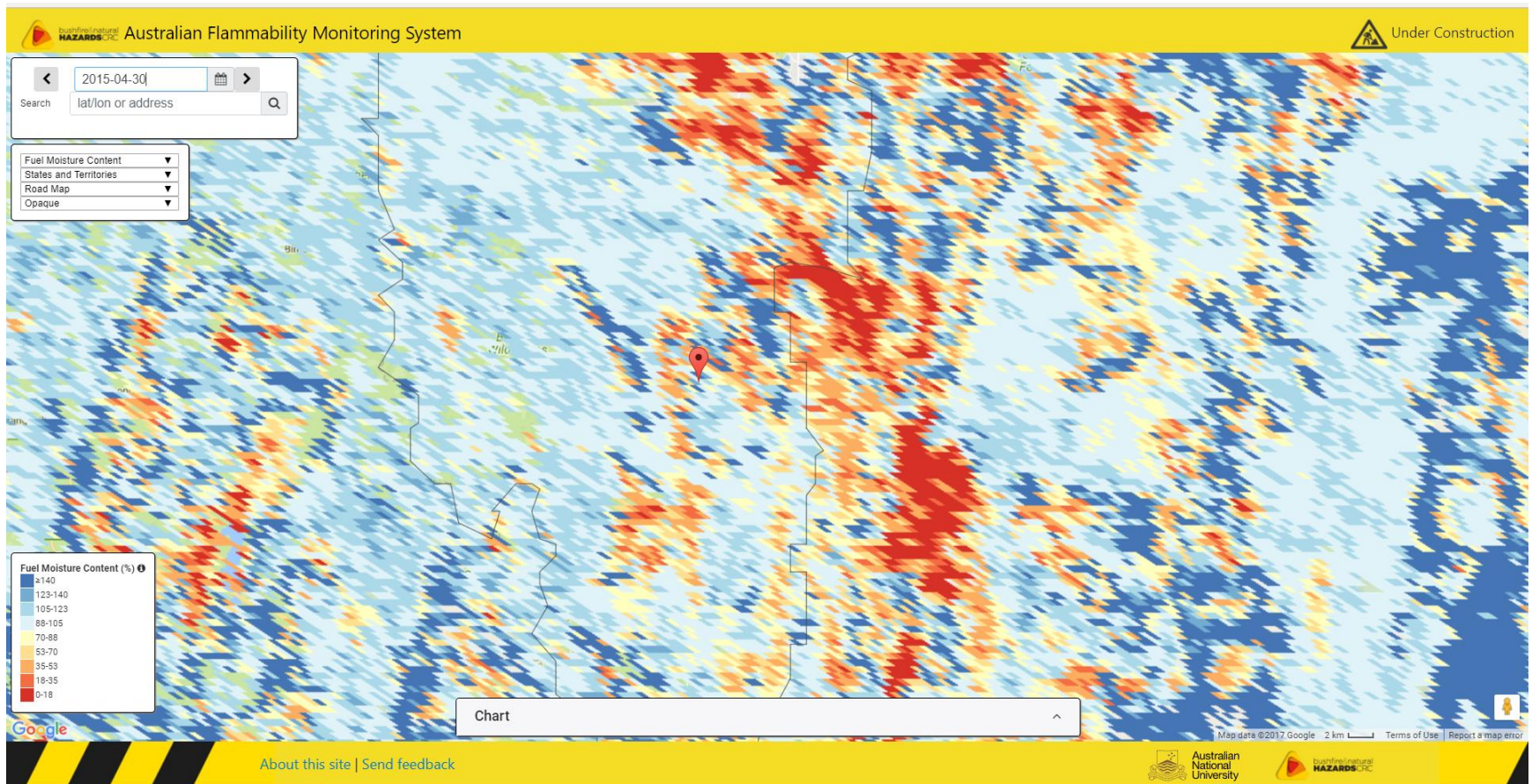
April 2015

# IMPLEMENTATION

Brandy Flat HRB fire  
severity assessment



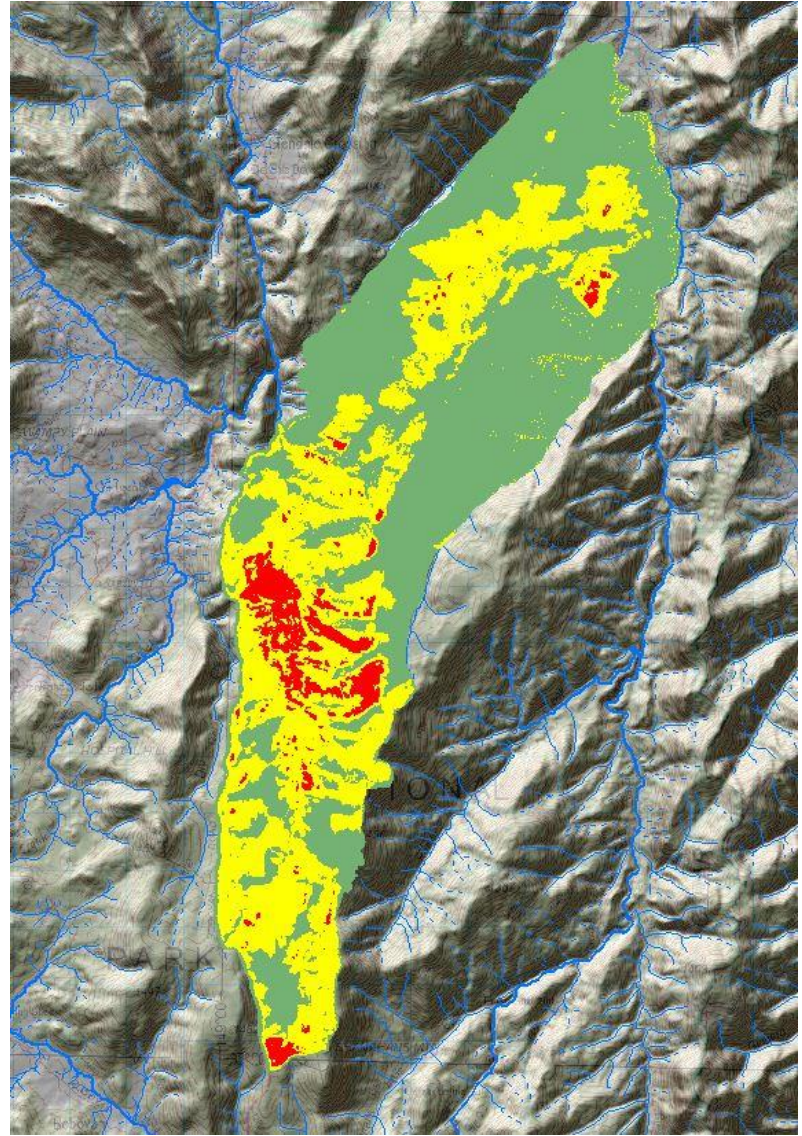
# PRESCRIBED BURNING - IMPLEMENTATION



April 2015 – Brandy Flat Burn

# EVALUATION

Brandy Flat HRB fire  
severity assessment

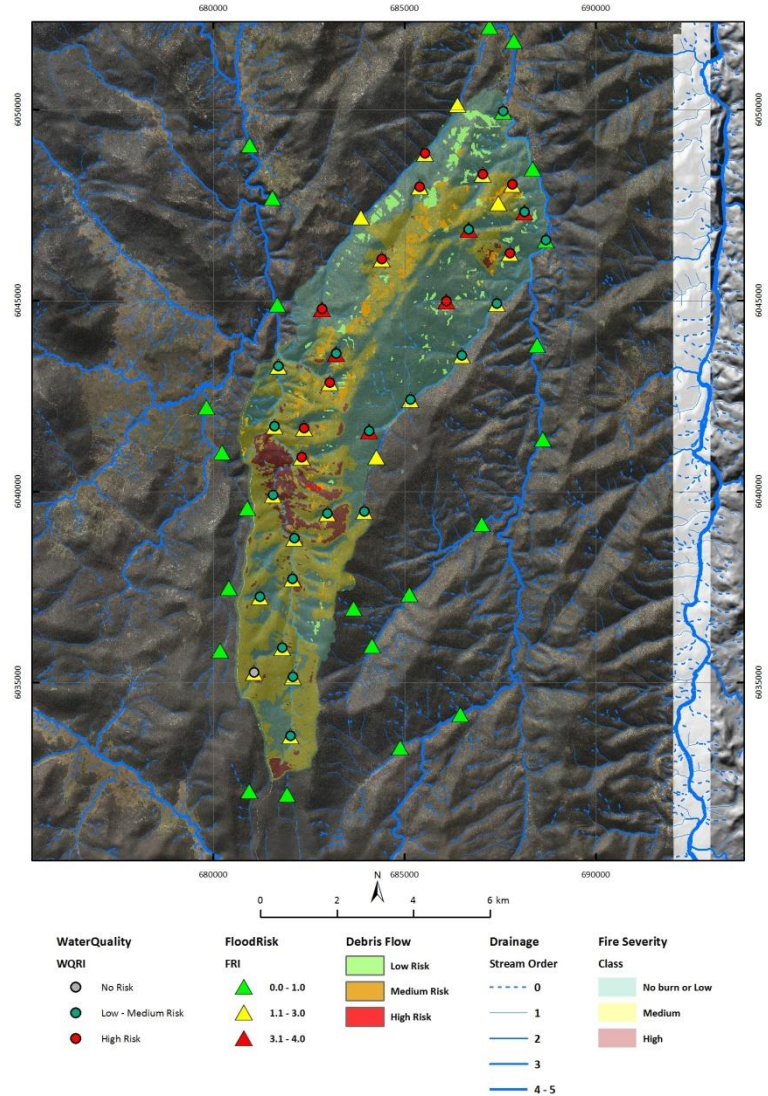


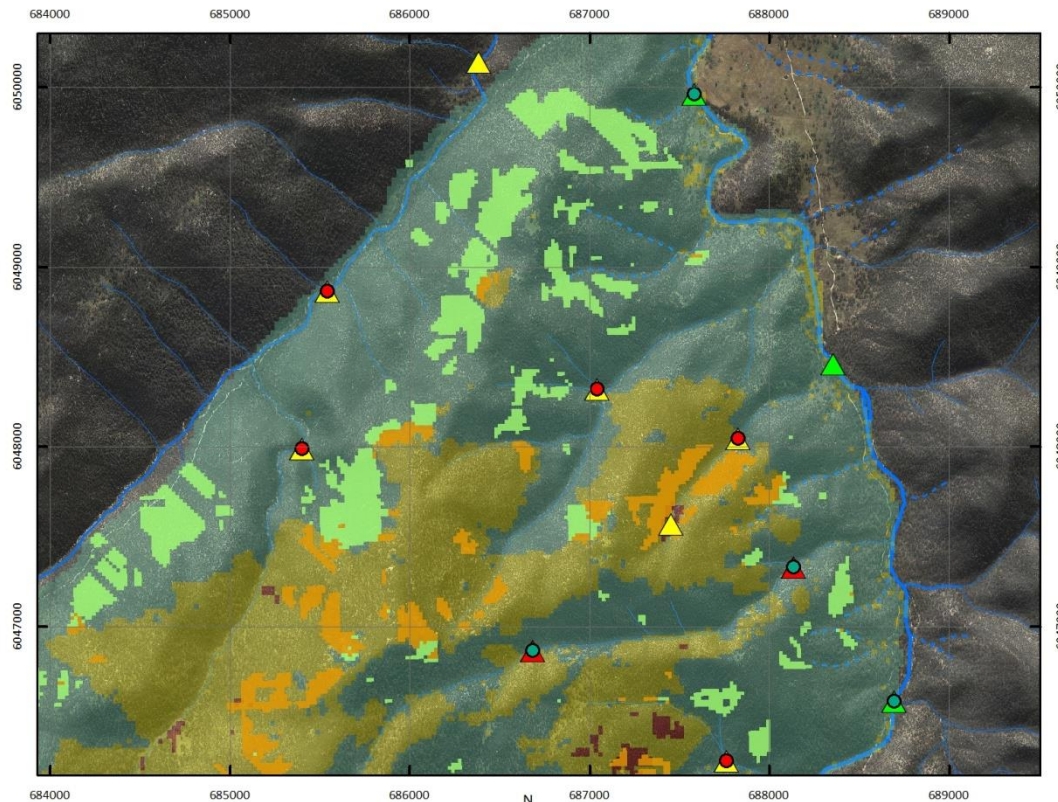
# PRESCRIBED BURNING - EVALUATION



# EVALUATION

## Post-burn hydrological risk – Brandy Flat HRB





**WaterQuality**

**WQRI**

- No Risk
- Low - Medium Risk
- High Risk

**FloodRisk**

**FRI**

- ▲ 0.0 - 1.0
- ▲ 1.1 - 3.0
- ▲ 3.1 - 4.0

**Debris Flow**

- Low Risk
- Medium Risk
- High Risk

**Drainage**

**Stream Order**

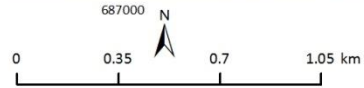
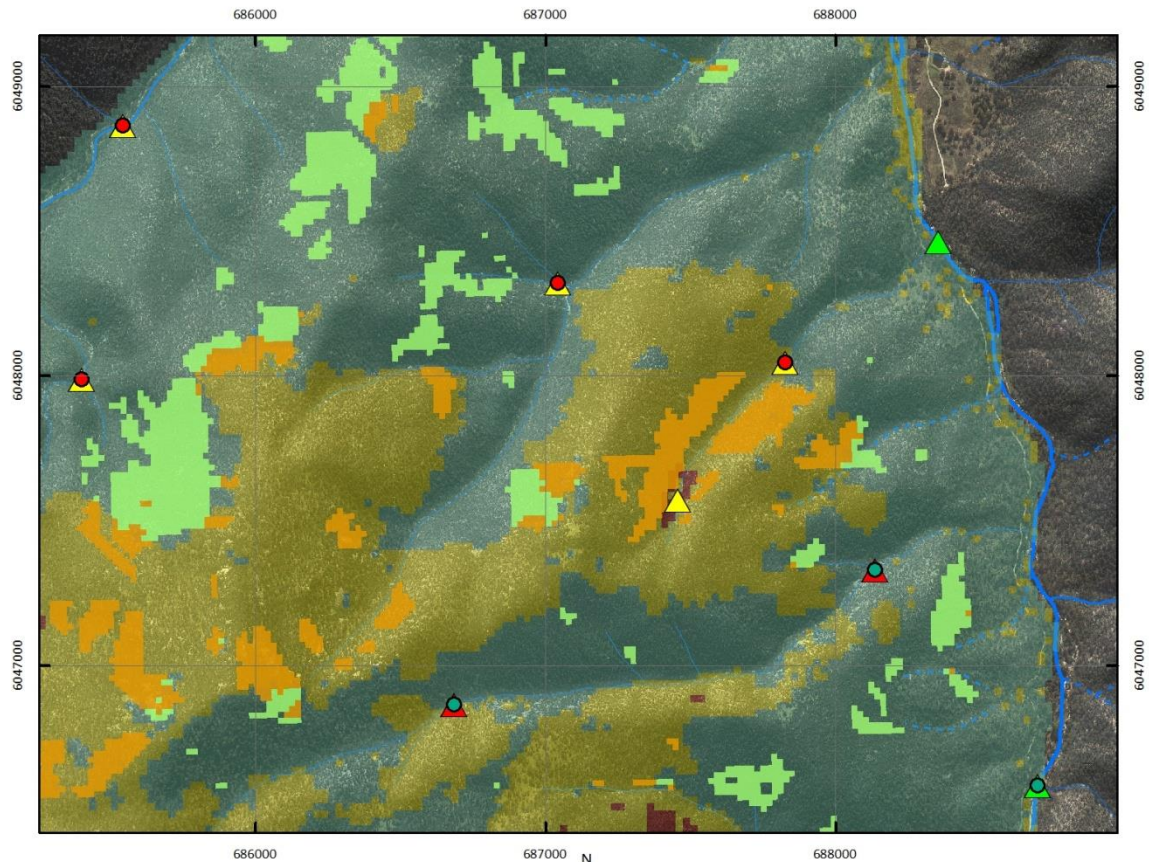
- 0
- 1
- 2
- 3
- 4 - 5

**Fire Severity**

**Class**

- No burn or Low
- Medium
- High





**WaterQuality**

**WQRI**

- No Risk
- Low - Medium Risk
- High Risk

**FloodRisk**

**FRI**

- 0.0 - 1.0
- 1.1 - 3.0
- 3.1 - 4.0

**Debris Flow**

- Low Risk
- Medium Risk
- High Risk

**Drainage**

- Stream Order**
- 0
  - 1
  - 2
  - 3
  - 4 - 5

**Fire Severity**

- Class**
- No burn or Low
  - Medium
  - High



**DAVID PEARCE, COUNTRY FIRE SERVICE SOUTH  
AUSTRALIA, END-USER**

**AND**

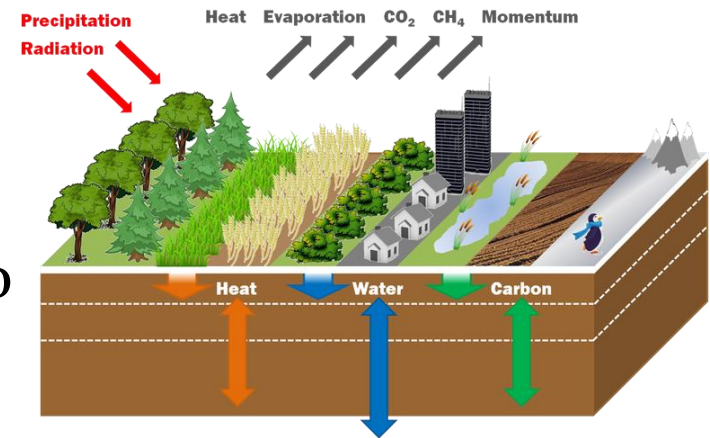
**JOHN BALLY, BUREAU OF METEOROLOGY**

# HISTORY

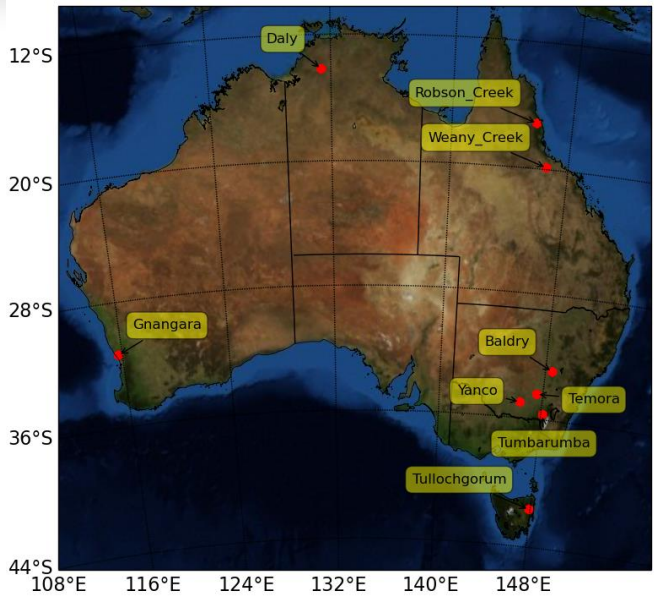
- *"From the standpoint of fire control, the significant moisture relationships are those which exists in an upper layer of soil and a covering layer of duff. ..."* (Keetch & Byram, 1968, pp 24.)
- KBDI / MSDI
  - >> single soil layer (~1 m)
  - Simple (very simple!) bucket model
  - 60's science

# SOIL MOISTURE - 2016

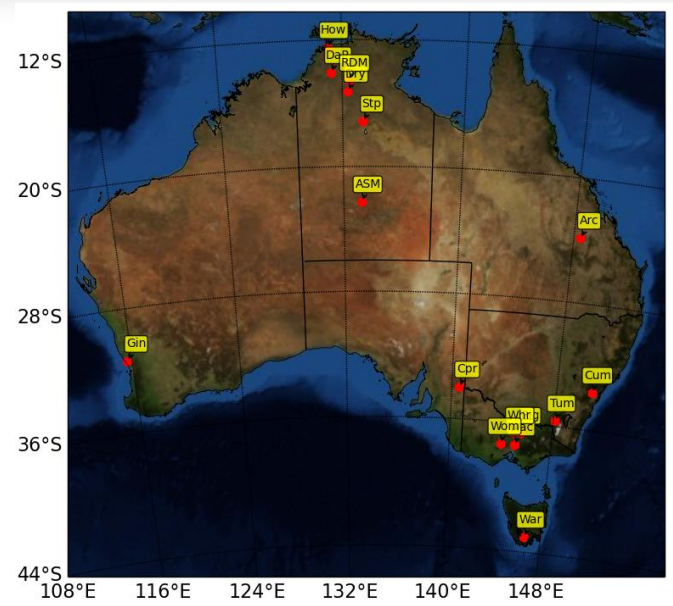
- Physics based land surface models.
  - Used in Numerical Weather Prediction & seasonal forecasting models.
  - JULES .... High resolution
  - Four soil layers, to 3 m deep.
  - 0~10; 10~35; 35~100; 100~300
  - Satellite remote sensing.



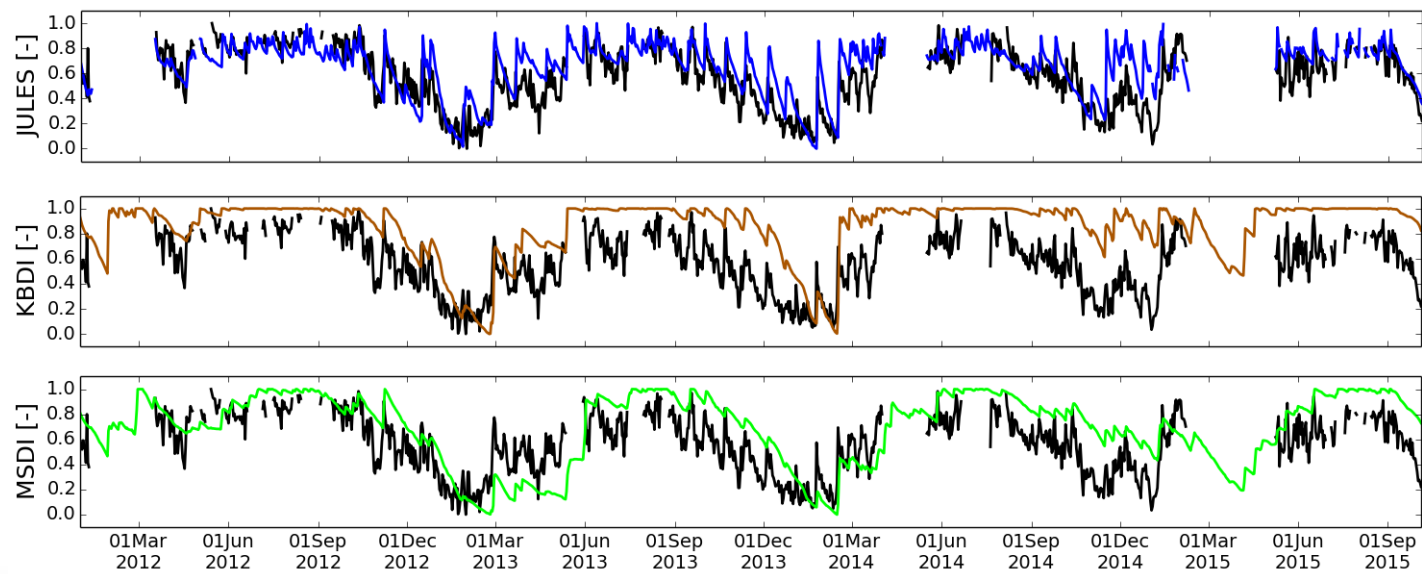
CosmOz



OzFlux



CosmOz Hydrological Network - Site: Tumbarumba



Comparison to In-situ Observations

# Website in preparation - SDI

## JASMIN rescaled to SDI

**About JASMIN**

The plots available here are generated as part of the project "Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts" funded by the Bushfire and Natural Hazards Cooperative Research Centre, Australia. The JASMIN outputs are at a 5 km resolution.

Select Date  
2 Jan 2010

Select Method  
Minimum-Maximum Matching

Select Layer  
0-35 cm layer

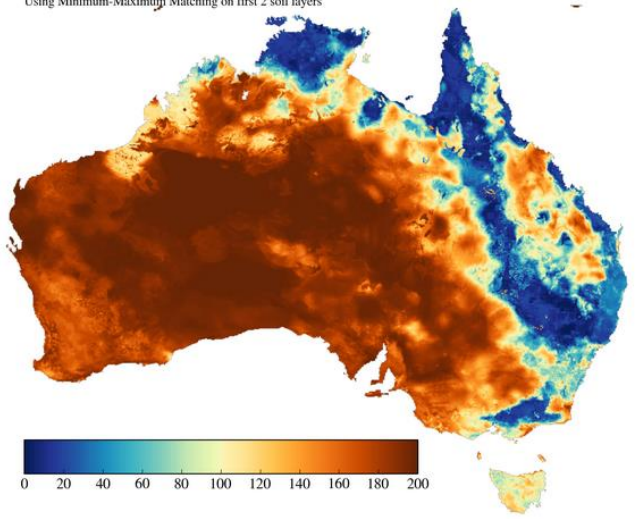
Select Region  
Australia

[Download Data](#)



[Contact](#)

[Home](#)

**JASMIN scaled to SDI for 02/Jan/2010**  
Using Minimum-Maximum Matching on first 2 soil layers



Partner Organizations



Disclaimer: These plots are experimental. The Bureau of Meteorology accepts no responsibility for actions taken on the basis of these plots.

# Website in preparation - KBDI

## JASMIN rescaled to KBDI

**About JASMIN**

The plots available here are generated as part of the project "Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts" funded by the Bushfire and Natural Hazards Cooperative Research Centre, Australia. The JASMIN outputs are at a 5 km resolution.

Select Date  
12 Feb 2017

Select Method  
Minimum-Maximum Matching

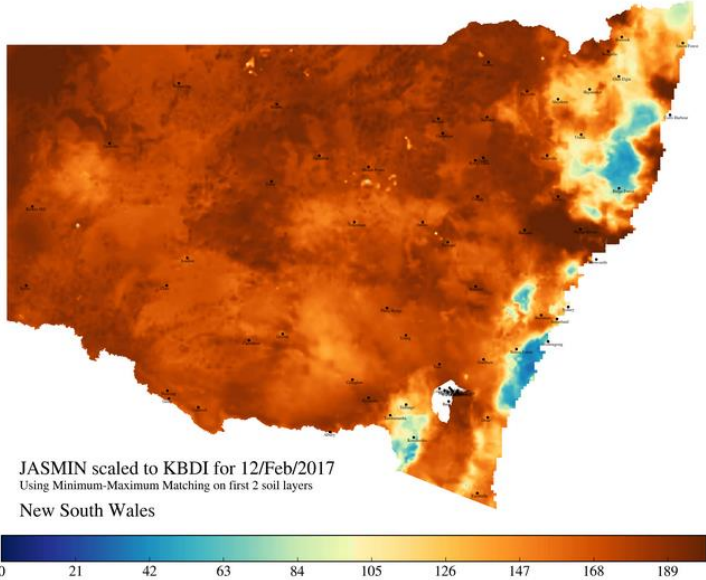
Select Layer  
0-35 cm layer

Select Region  
New South Wales

[Download Data](#)

[Contact](#)


[Home](#)



JASMIN scaled to KBDI for 12/Feb/2017  
Using Minimum-Maximum Matching on first 2 soil layers  
New South Wales

0 21 42 63 84 105 126 147 168 189

**Partner Organizations**



**Australian Government**  
Bureau of Meteorology

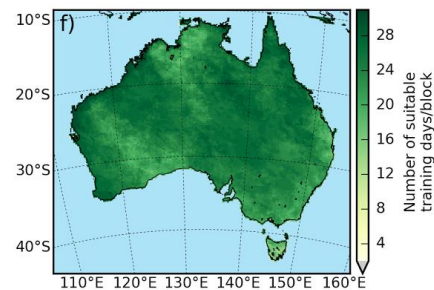
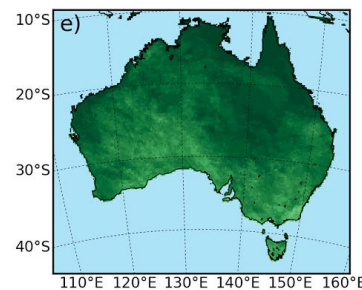
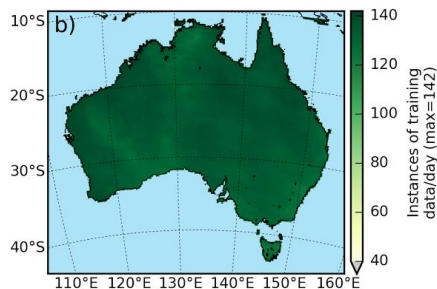
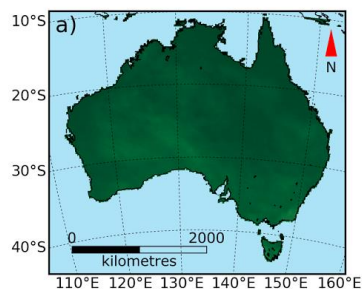
Disclaimer: These plots are experimental. The Bureau of Meteorology accepts no responsibility for actions taken on the basis of these plots.



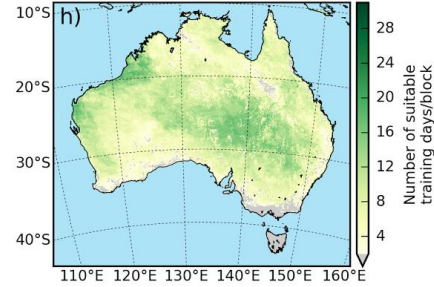
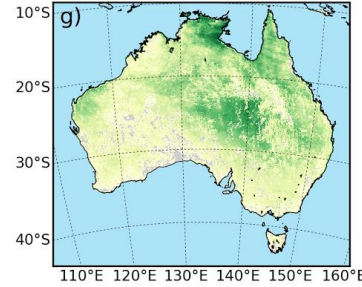
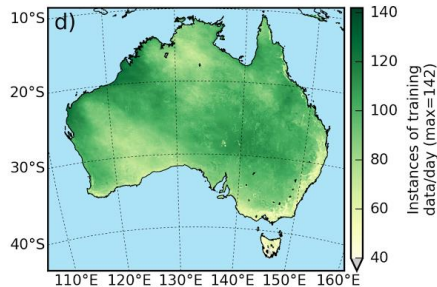
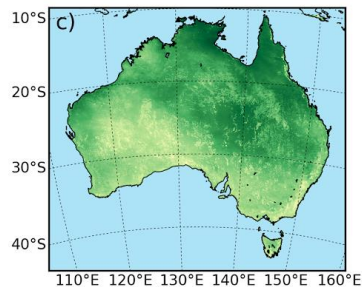
**SIMEON TELFER, DEPARTMENT OF ENVIRONMENT,  
WATER AND NATURAL RESOURCES SOUTH  
AUSTRALIA, END-USER**

# ACTIVE FIRE SURVEILLANCE - DETECTION

BA  
T



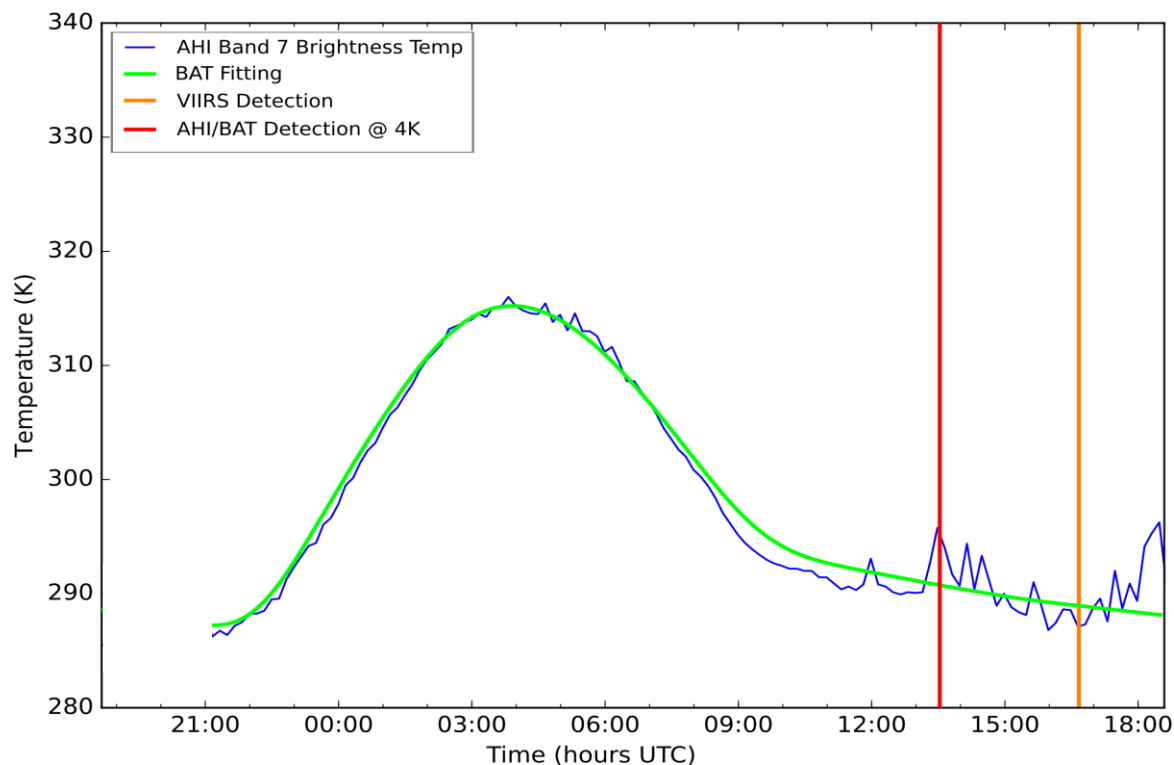
pix  
el



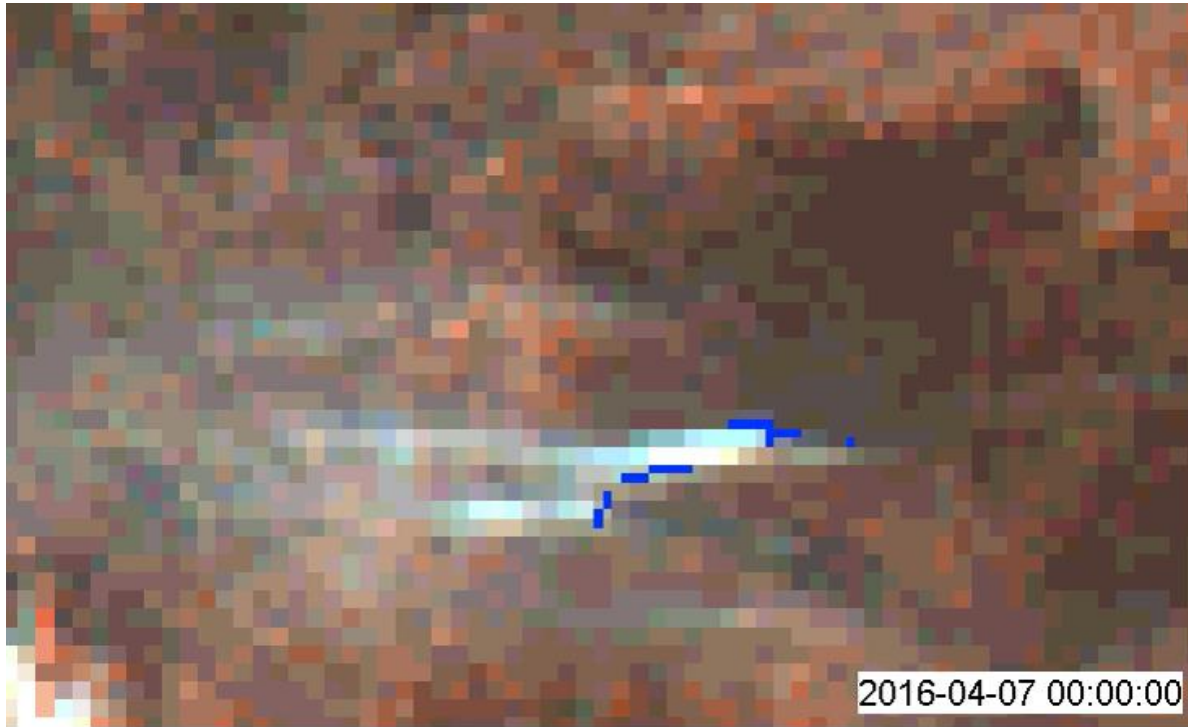
Advantages over pixel-based training data include increased availability of data for fitting, reduced error of fitting through periods of cloud and reduced processing load

# ACTIVE FIRE SURVEILLANCE - DETECTION

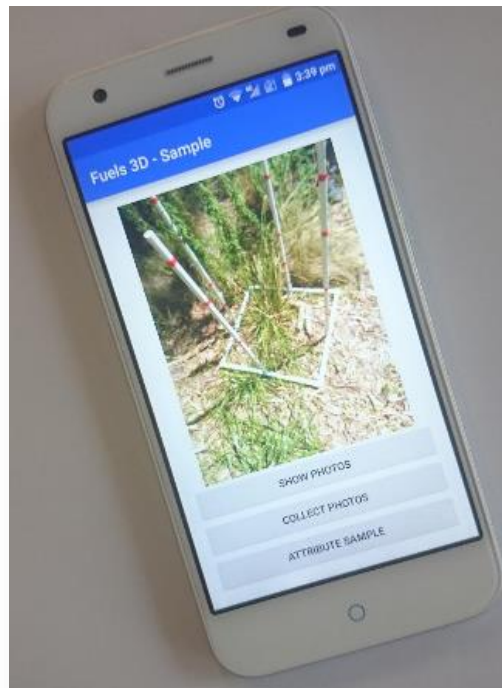
Example showing fire detected in band 7 AHI Himawari-8 at least 3 hours earlier than the first detection by LEO fire products



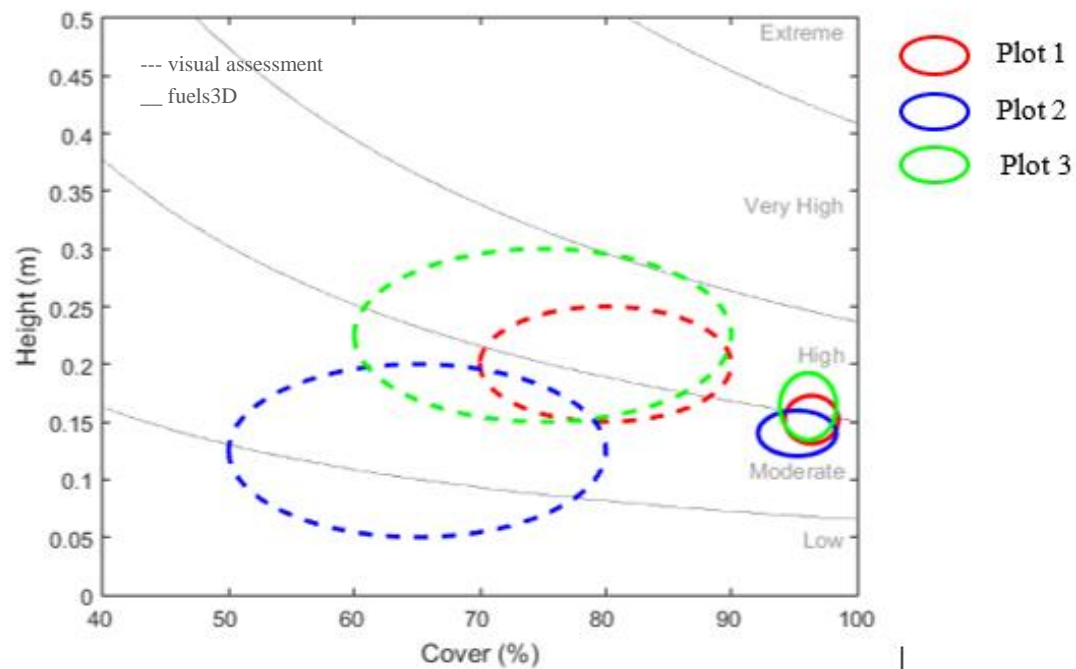
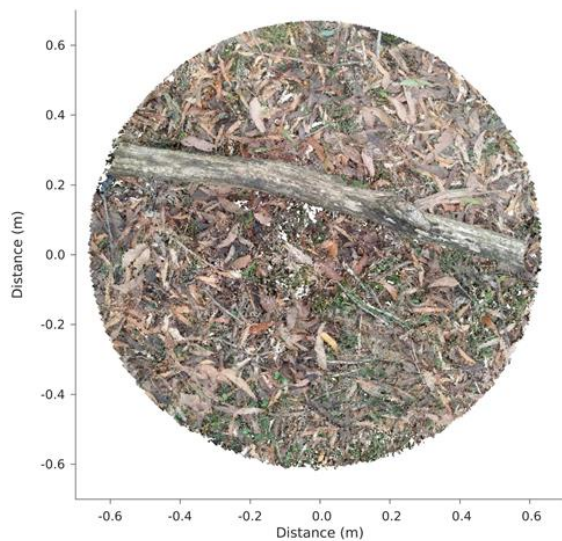
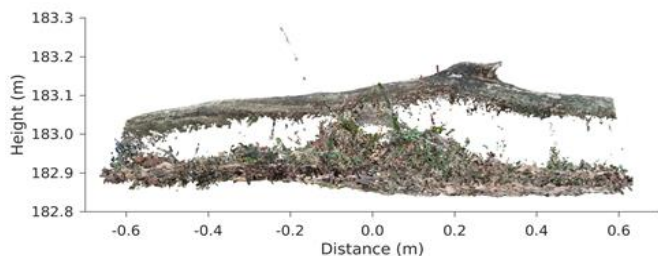
# ACTIVE FIRE SURVEILLANCE - MAPPING



# FUEL HAZARD FIELD ASSESSMENTS - FUELS3D

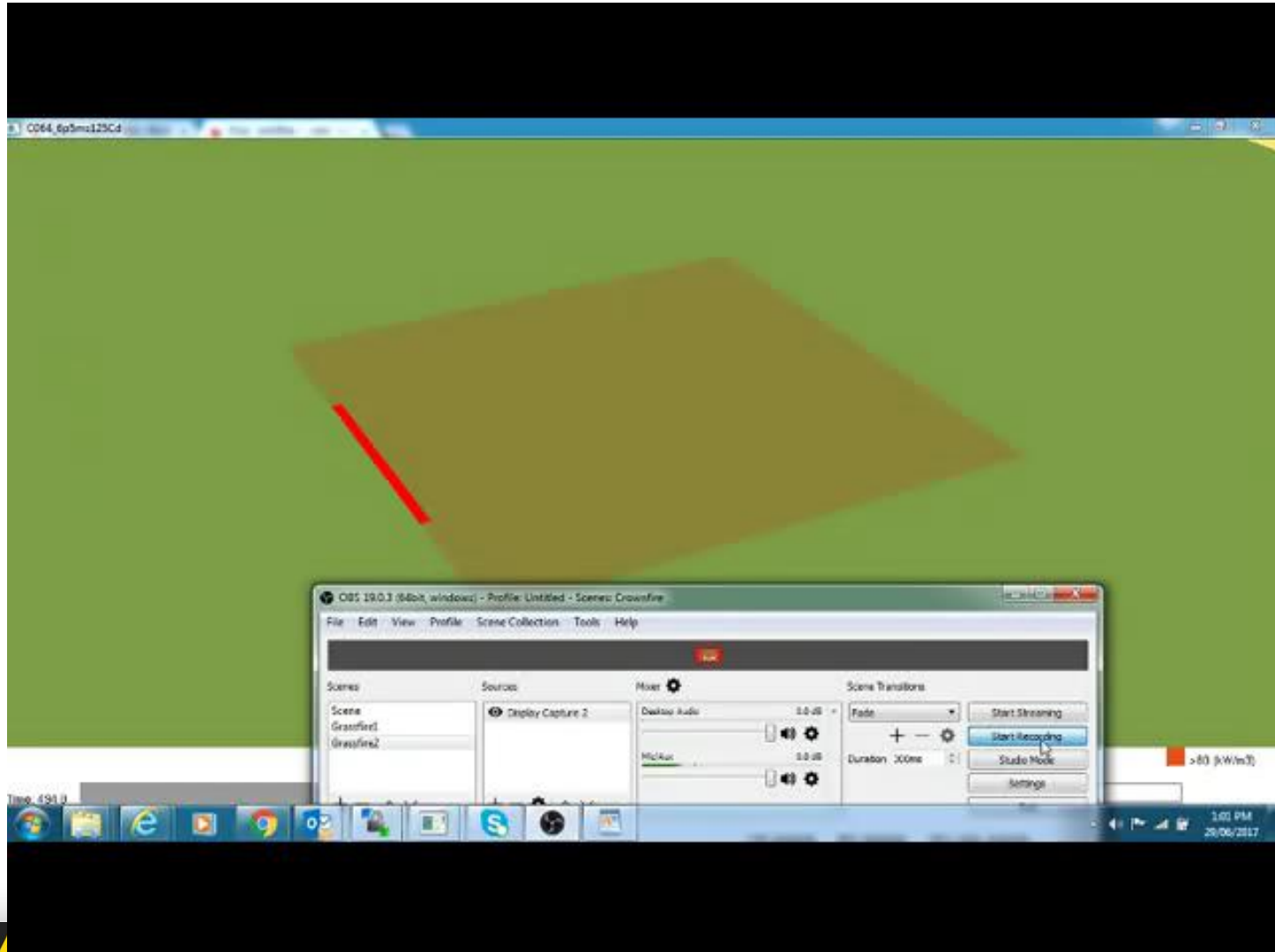


# FUEL HAZARD FIELD ASSESSMENTS - FUELS3D



**ASSOCIATE PROF KHALID  
MOINUDDIN, PROJECT LEADER,  
VICTORIA UNIVERSITY**

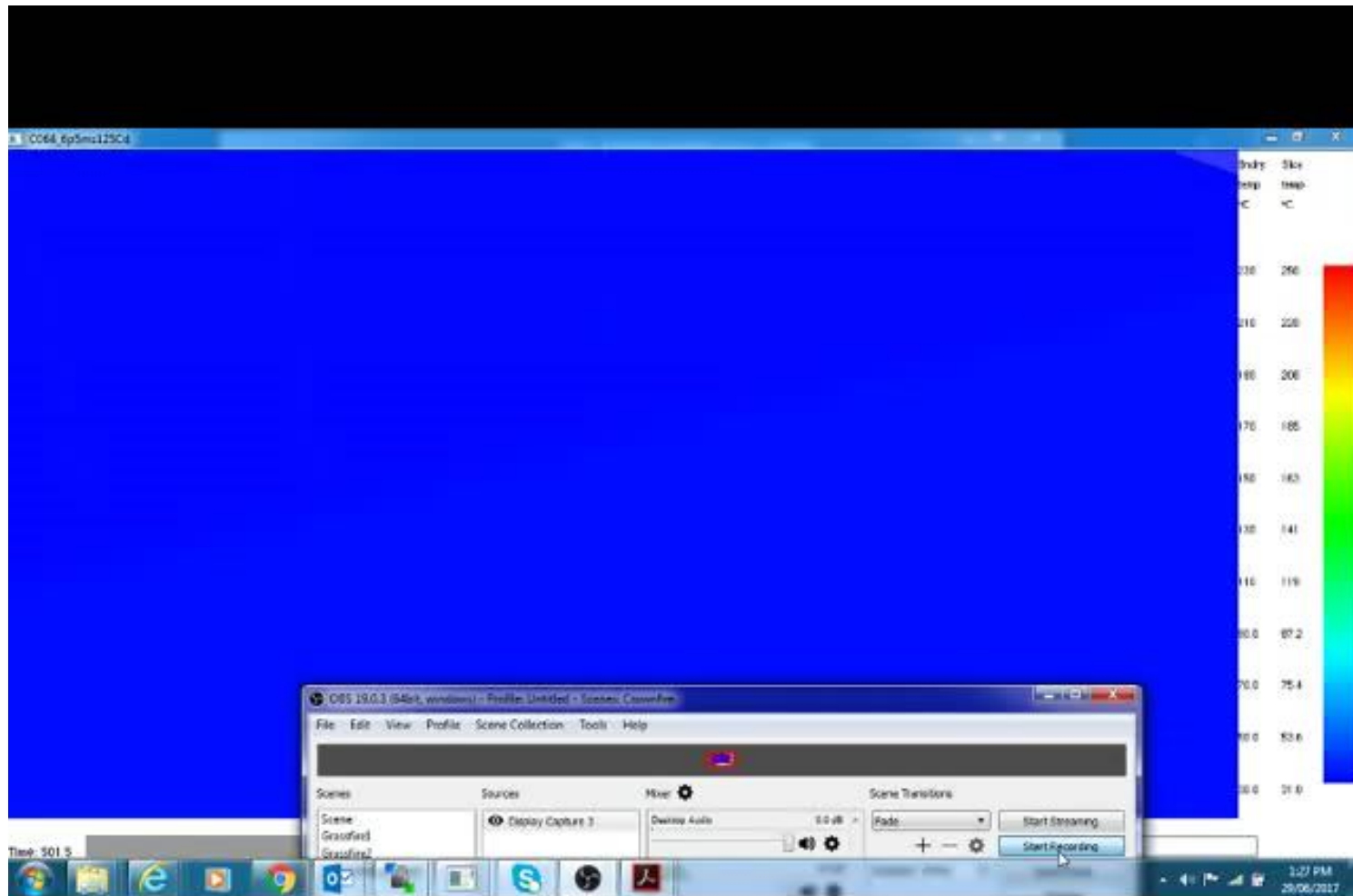
# CAPABILITY OF PHYSICS-BASED MODELLING GRASSFIRE AND SMOKE PROPAGATION



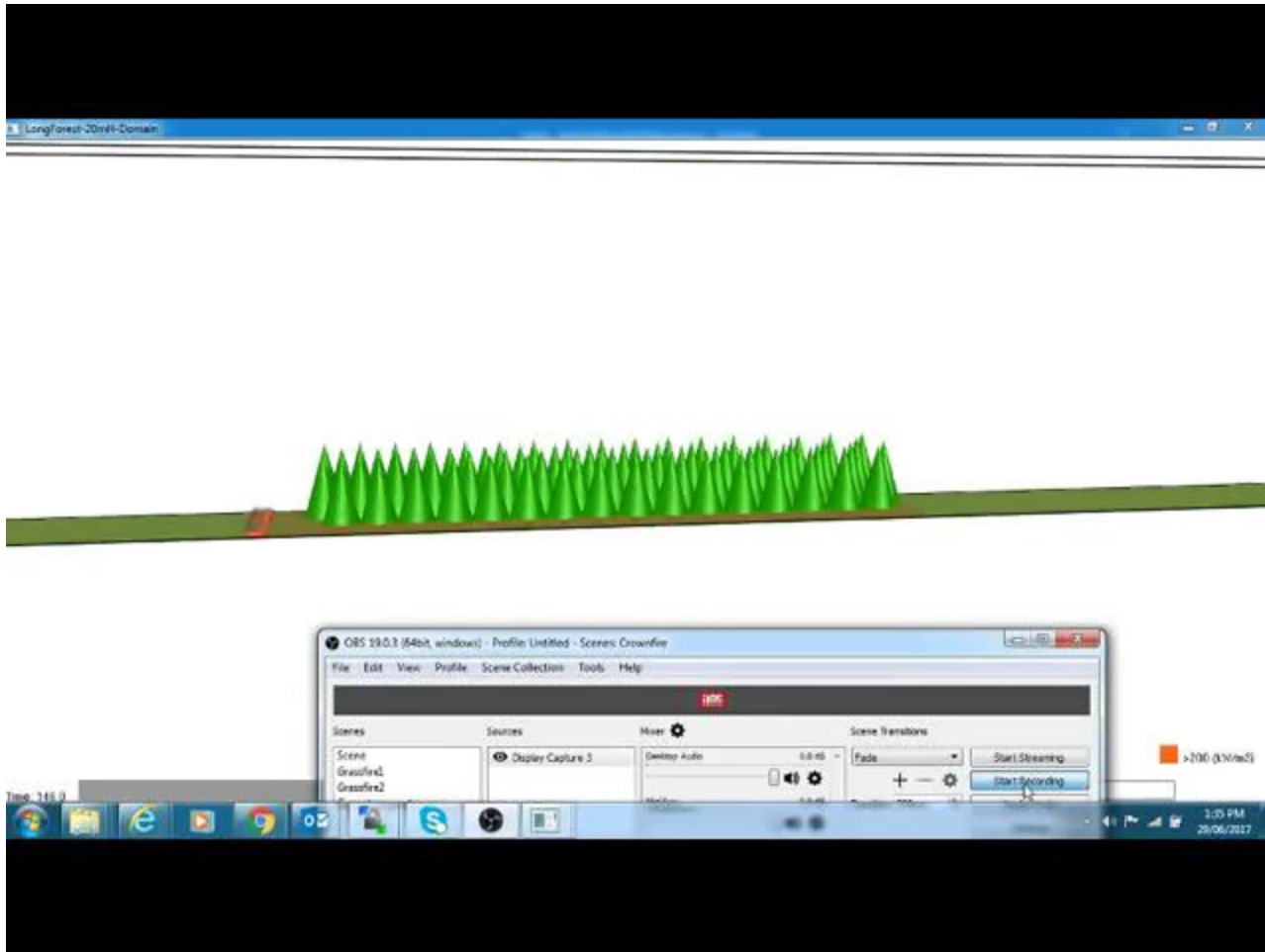


# CAPABILITY OF PHYSICS-BASED MODELLING

## GRASSFIRE – GAS & SURFACE TEMPERATURE



# CAPABILITY OF PHYSICS-BASED MODELLING CROWNFIRE AND SMOKE PROPAGATION



# Benefits

- Can develop improved operational model and provide insight into them
- Assessment of heat and ember loading on homes; appraisal of AS3959
- Facility siting (including power poles, bridges, shelters etc), estimation of fire breaks, planning prescribed burning etc

# DETERMINING THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR

Alex Filkov, Tom Duff, Trent Penman

The University of Melbourne

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Australian Government  
Department of Industry,  
Innovation and Science

**Business**

Cooperative Research  
Centres Programme



THE UNIVERSITY OF  
MELBOURNE

[bnhcrc.com.au](http://bnhcrc.com.au)

# EXTREME FIRE BEHAVIOURS



Spotting/fire storm



Fire tornado/whirls



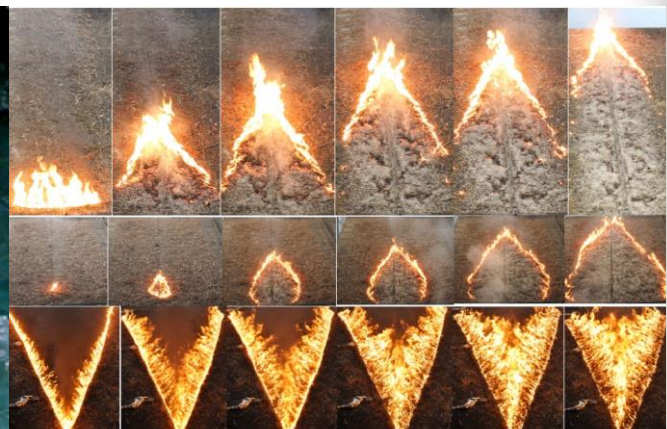
Pyro-convective events



Crown fires



Conflagrations



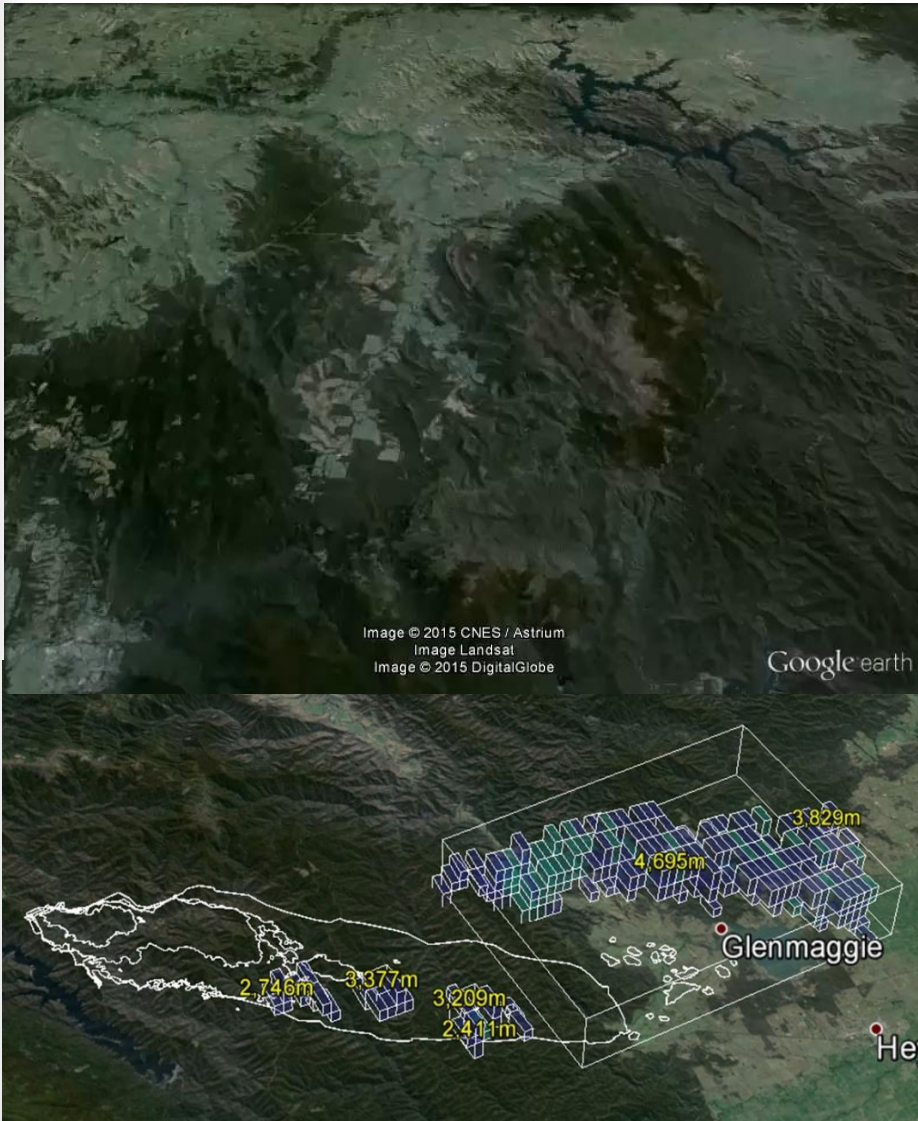
Junction zones/Eruptive fires

# STANDARDISING BUSHFIRE DATA

## INNOVATION IN DATA COLLECTION

There are a wide range of sources of information in relation to fires, however, as a starting point we recommend a focus on particular categories:

- Ground observations and operational information;
- Linescans;
- Forward Looking IR;
- Aerial observers;
- Satellites;
- Remote weather observations
- UAV observations;
- Vehicle/aircraft GPS tracks; and
- suppression strategies.



# FUTURE RESEARCH

- Analyse the frequency and importance of extreme fire behaviours (Dec 2017)
- Examine environmental contribution to landscape scale fire behaviour (2018 +)
- Evaluate influence of dynamic radiant heat on fire front propagation and structure ignition (2018 +)

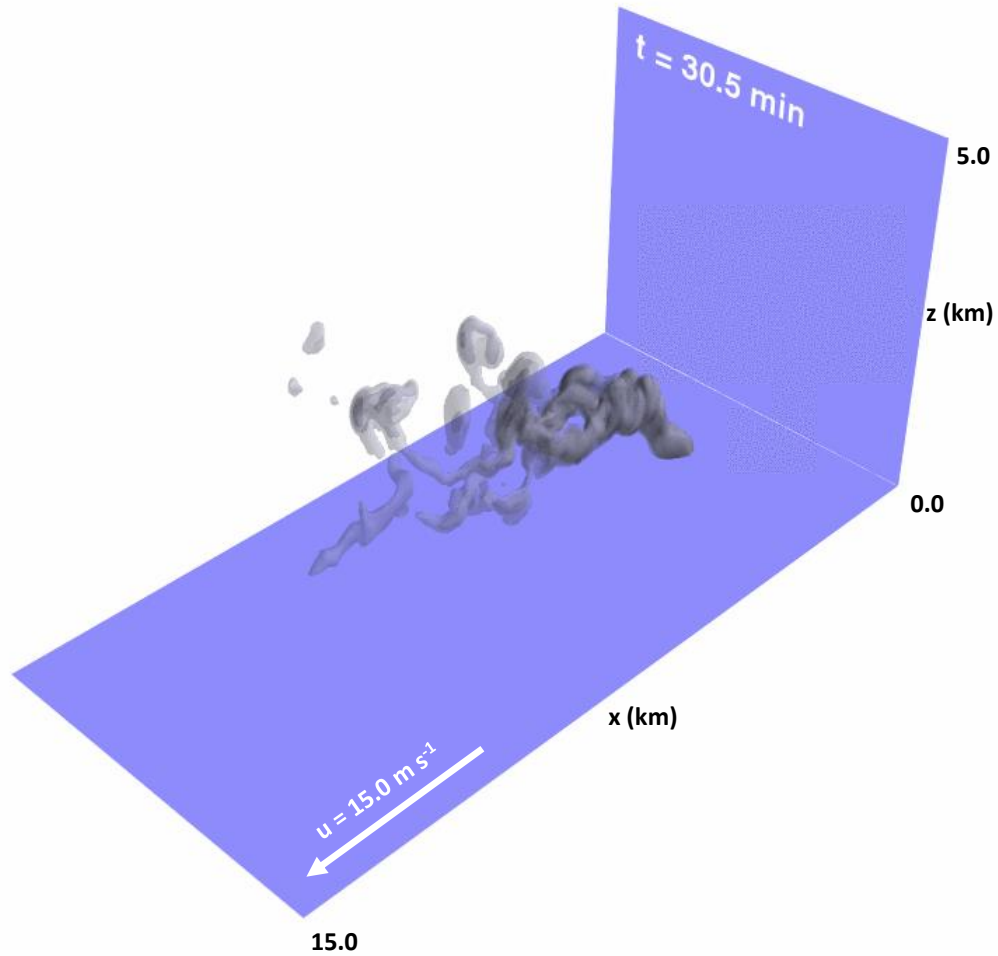
# THANK YOU!



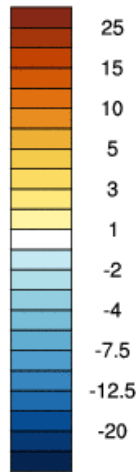
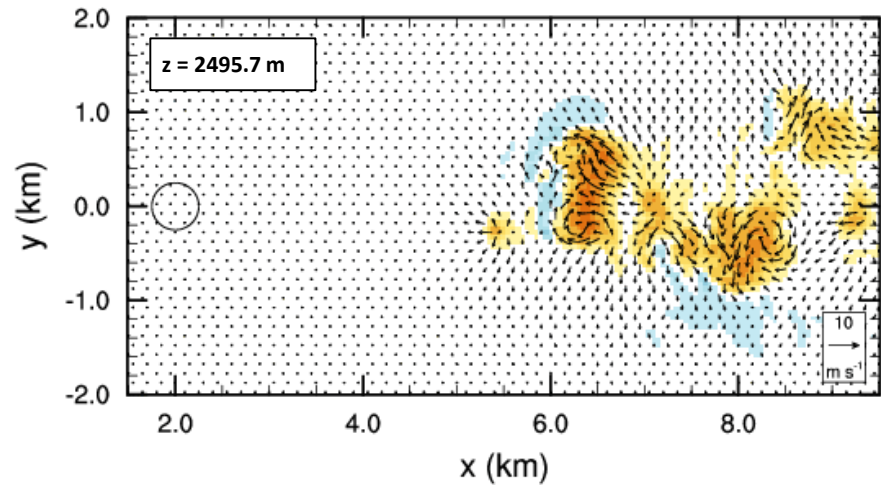
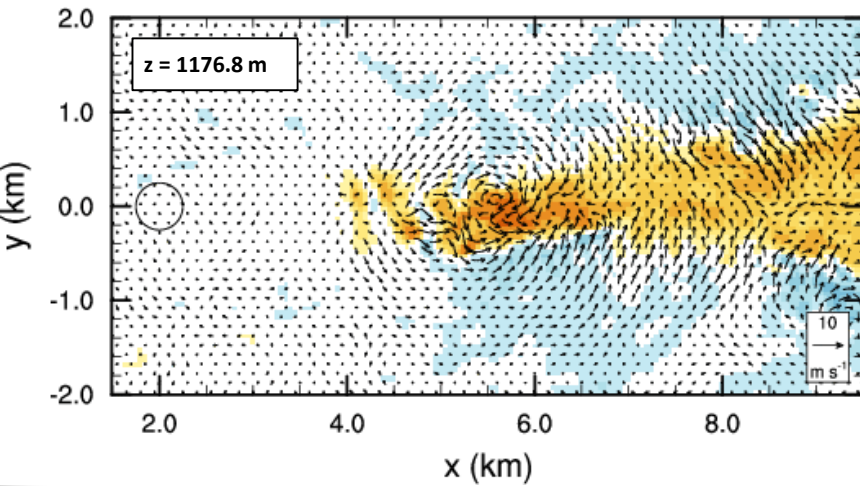
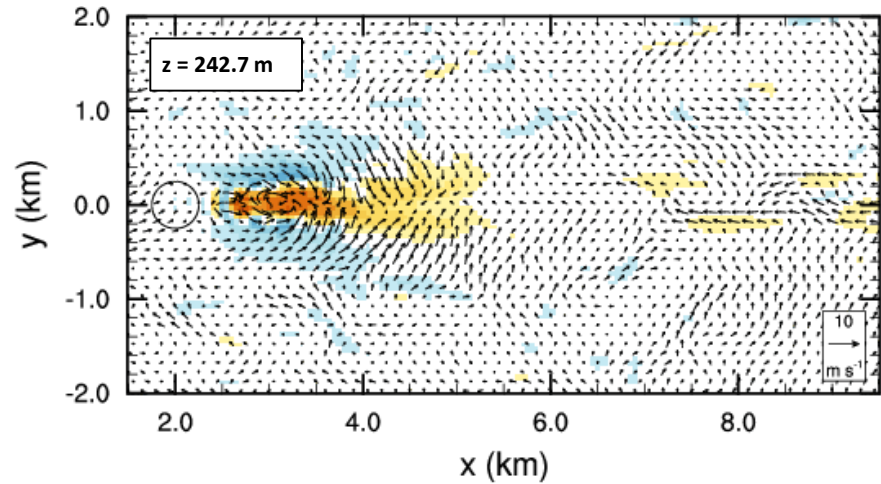
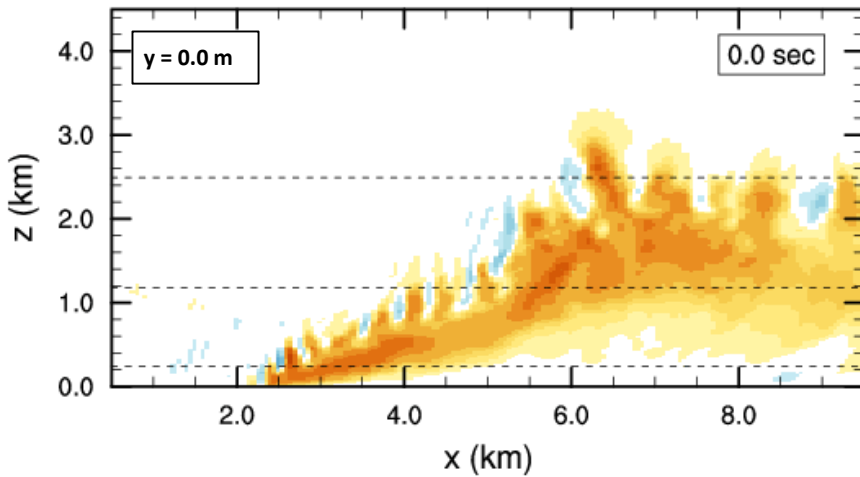
**DR JEFF KEPERT, CRC PROJECT LEADER,  
BUREAU OF METEOROLOGY**



# SIMULATED FIRE PLUME, 56 KM/HR WIND



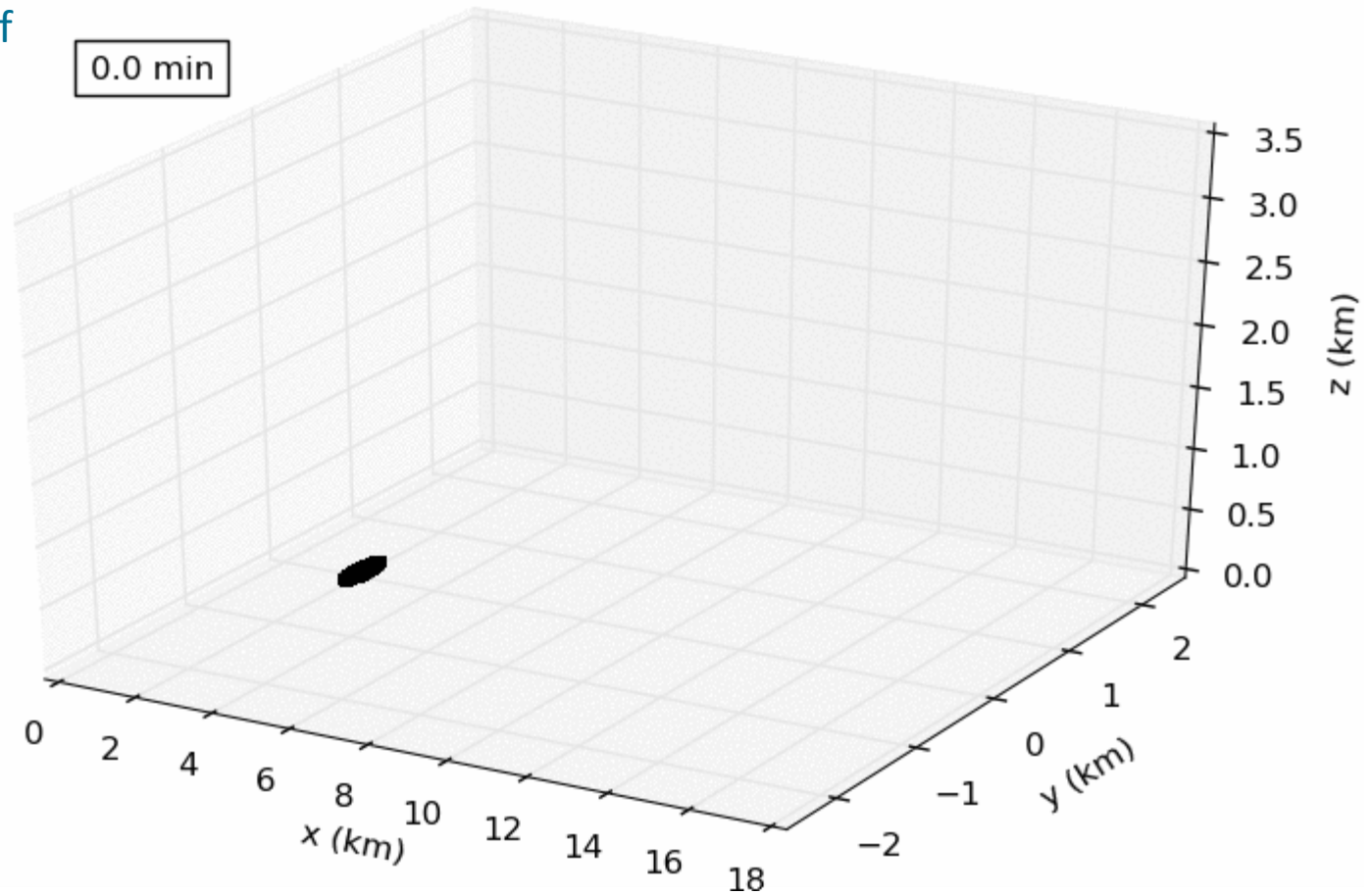
# WINDS IN AND NEAR THE SMOKE COLUMN



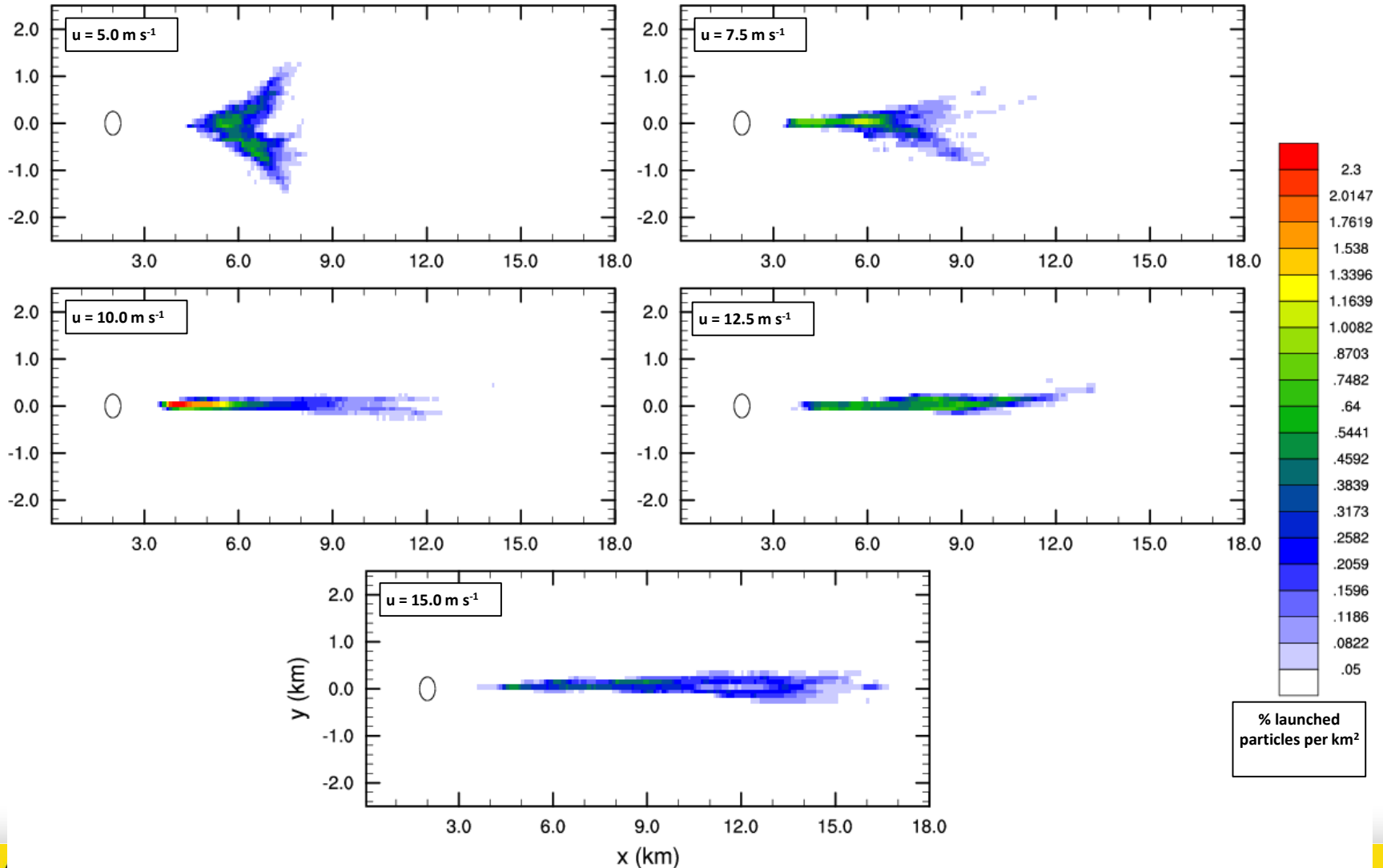
# FIREBRAND TRANSPORT – 56 KM/HR WIND

Studied the path of nearly 1.5 million embers (only 1% are shown here)

Almost 33% travel more than 1 km in this case



# WHERE DO THE EMBERS END UP?





# FIRE COALESCENCE AND MASS SPOT FIRE DYNAMICS

## Experimentation, modelling and simulation

Jason Sharples<sup>1</sup>, James Hilton<sup>2</sup>, Andrew Sullivan<sup>3</sup>

1. Computational Science Initiative,  
School of Physical, Environmental and Mathematical Sciences, UNSW Canberra
2. CSIRO Data 61
3. CSIRO Land and Water

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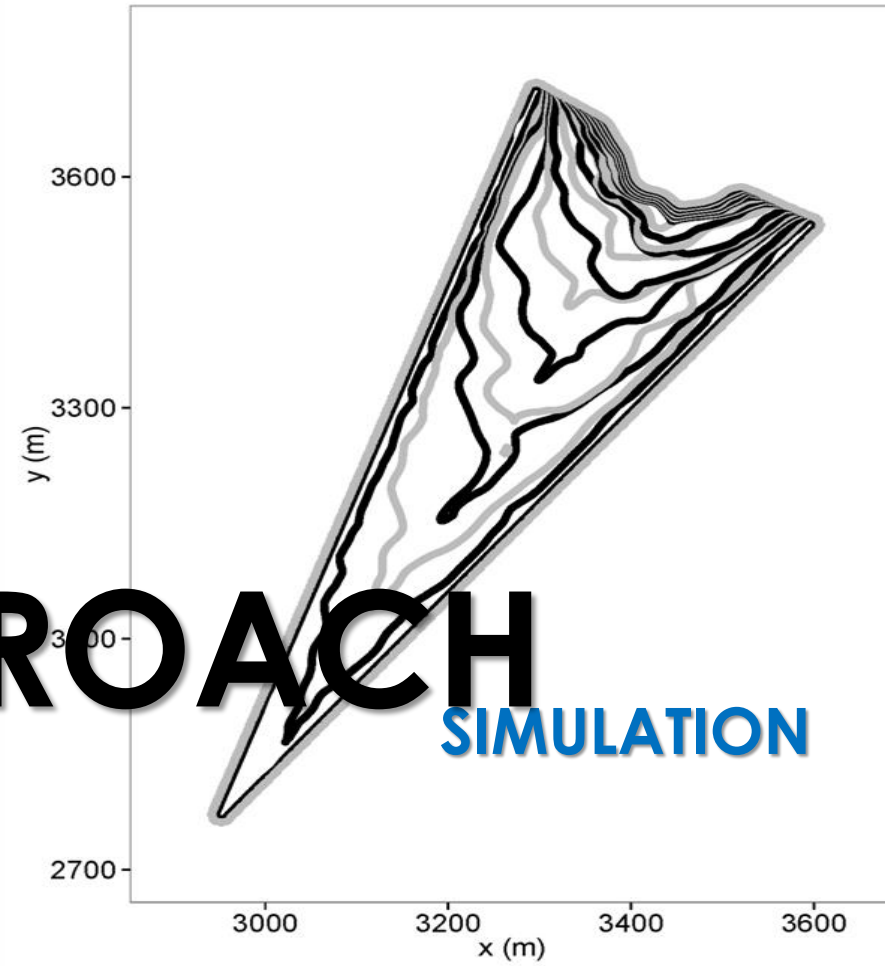


**'JUNCTION FIRES'**

**→ FIRE IS 'DRAWING IN' ON ITSELF ←**

**UNDERSTANDING SPOT FIRE DYNAMICS...**

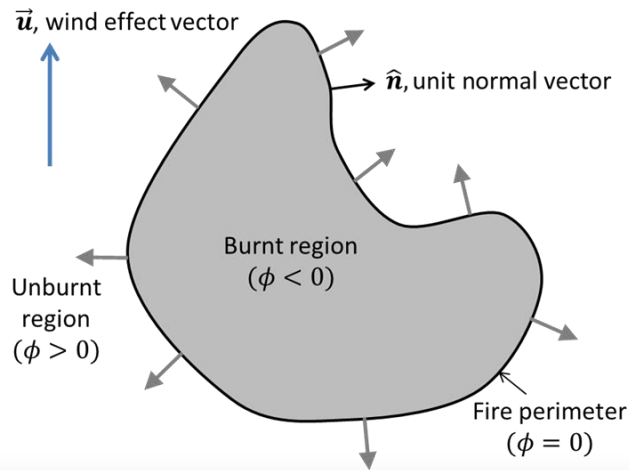
# EXPERIMENTATION



# OUR APPROACH

MATHEMATICAL MODELLING

SIMULATION



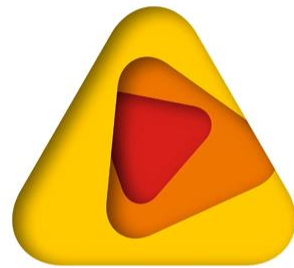
$$\frac{\partial \phi}{\partial t} + \beta \|\nabla \phi\| + (\mathbf{u}_a(\gamma) + \nabla \psi) \cdot \nabla \phi = 0$$

$$\nabla^2 \psi = \rho \int \delta(\mathbf{x} - \mathbf{x}_\Omega) d\mathbf{x} = \begin{cases} \rho & \mathbf{x} \in \Omega \\ 0 & \mathbf{x} \notin \Omega \end{cases}$$

# **AN END-TO-END FIRE SPREAD SIMULATOR INCORPORATING SPOTTING EFFECTS**

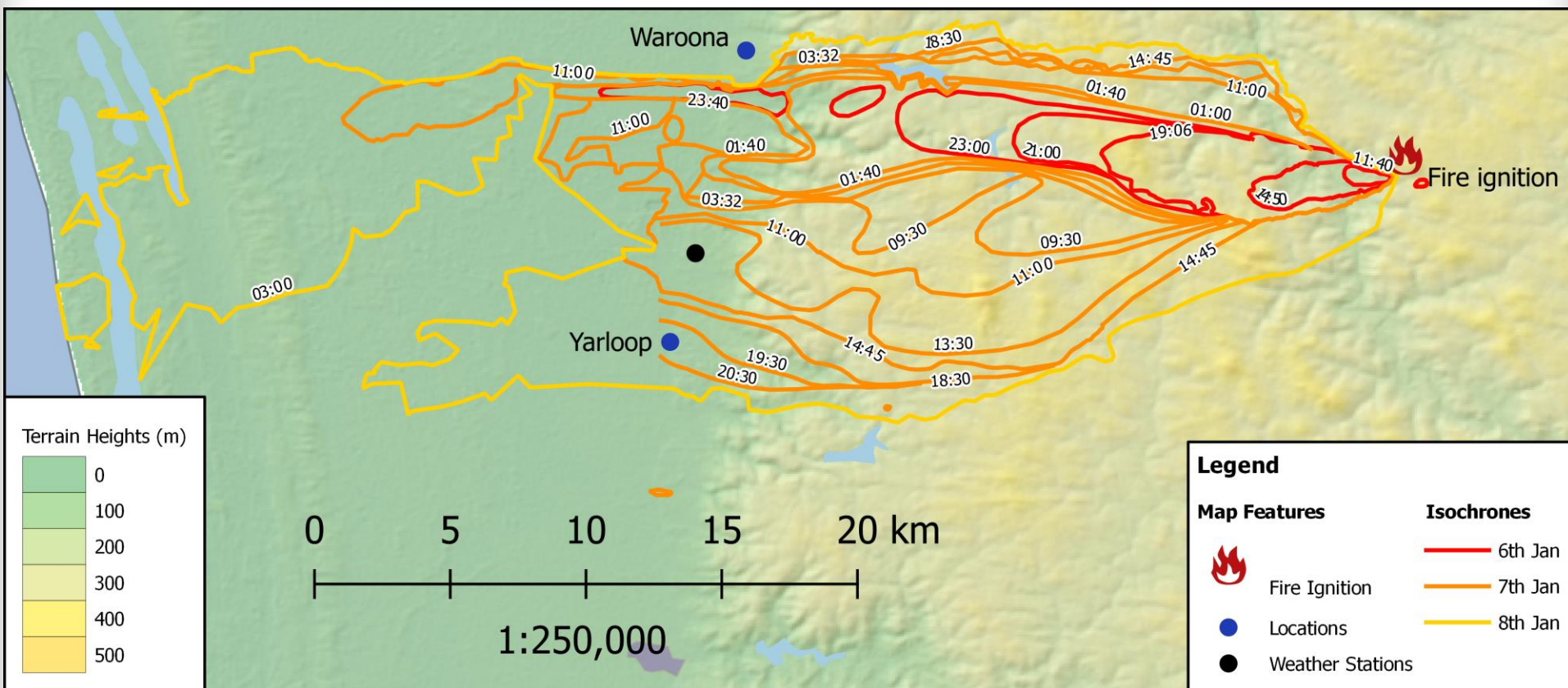
**DR MIKA PEACE, CRC RESEARCHER,  
BUREAU OF METEOROLOGY**

**VIDEO WITH DR LACHIE MCCAWE, DEPARTMENT  
OF PARKS AND WILDLIFE WA, END-USER**



bushfire&natural  
**HAZARDS**CRC

## Coupled fire-atmosphere modelling



Fire isochrones from reconstruction by  
Department of Parks and Wildlife, WA

# PYROCB EVENT 1, WEDNESDAY AFTERNOON



Still from video taken by Darren McCagh of Farmhouse Films



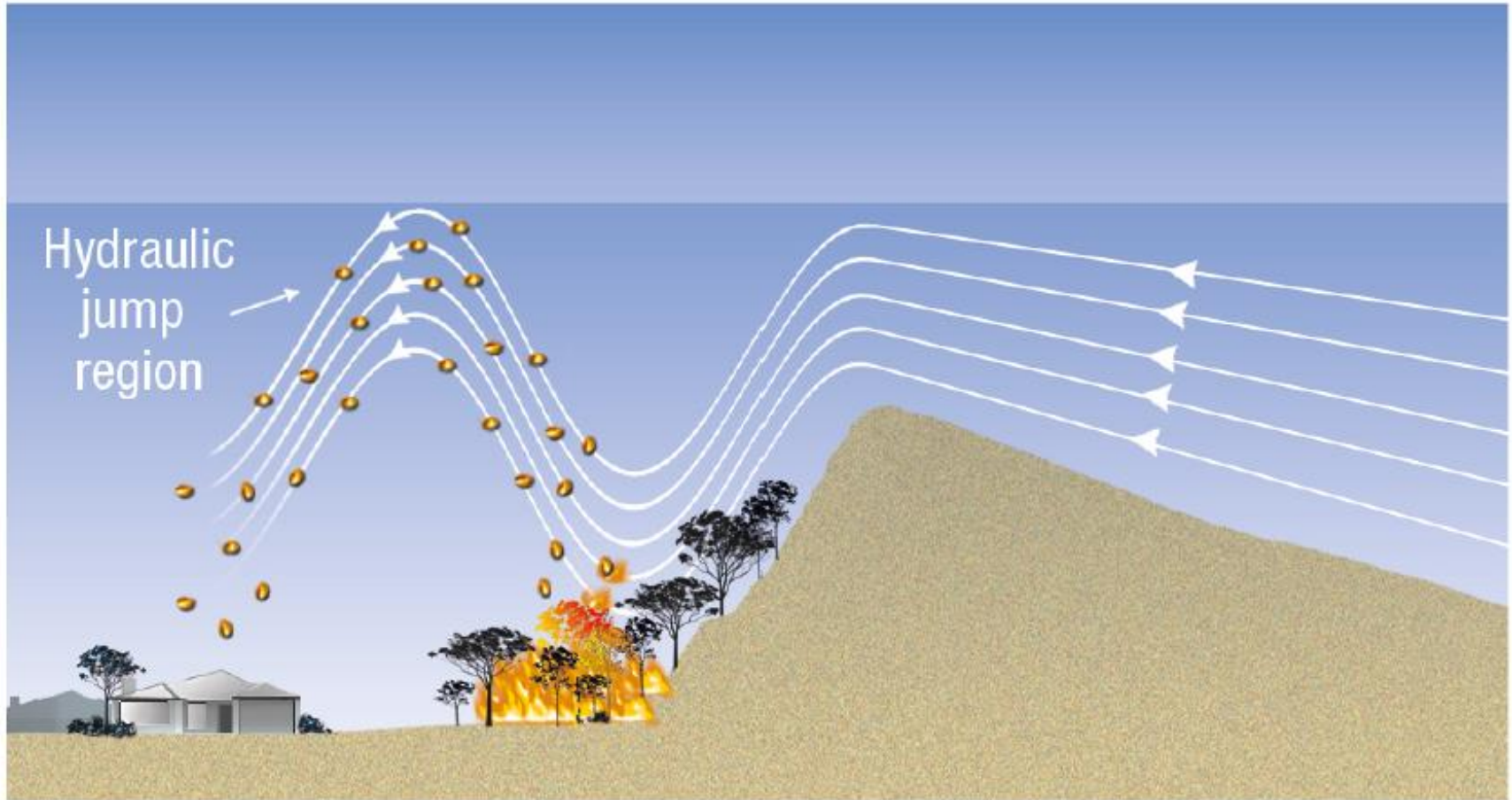
# PYROCB EVENT 2, THURSDAY MORNING



FFDI "Very High" from Dwellingup AWS observations

'...at one stage every single boundary was a head fire ...  
Like, the whole thing just exploded in a massive downdraft.'

(Operations manager quote from Ferguson report)



Fire



Embers



Temperature inversion

# SUPERCOMPUTER (NCI)

$$\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + \omega \left( \frac{\partial T}{\partial p} + \frac{RT}{pc_p} \right) = \frac{J}{c_p} \quad 0 = -\frac{\partial \rho}{\partial p} - \frac{RT}{p}$$

$$p = \rho R T$$

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + \omega \frac{\partial T}{\partial z}$$

$$0 = -\frac{\partial \rho}{\partial p} - \frac{RT}{p}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

$$p = \rho R T$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

$$\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + \omega \left( \frac{\partial T}{\partial p} + \frac{RT}{pc_p} \right) = \frac{J}{c_p}$$

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + \omega \frac{\partial T}{\partial z}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

**DR STUART MATTHEWS, NSW RURAL  
FIRE SERVICE**

**NATIONAL FIRE DANGER RATING  
SYSTEM**

# Q AND A