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PHOENIX RapidFire ENHANCEMENTS FOR FireDST

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AFAC13 – Bushfire CRC and AFAC annual conference, 2-5 September 2013, Melbourne

ENHANCEMENTS 2010-2013

Outline

1. Convection-driven spotting (strength)
2. Prediction Accuracy Evaluation tools
   a) Modified Procrustes method
   b) Travel Path method
   c) Area Difference Index (ADI)
3. Sensitivity analysis
4. Suppression navigator
5. Upper-wind driven ember transport
6. House-loss probability function (radiation, ember, convection)
7. Redefining WUI as WIZ (Wildfire Interface Zone)
8. Mid-flame height wind speed
9. Ensemble modelling (towards FireDST)

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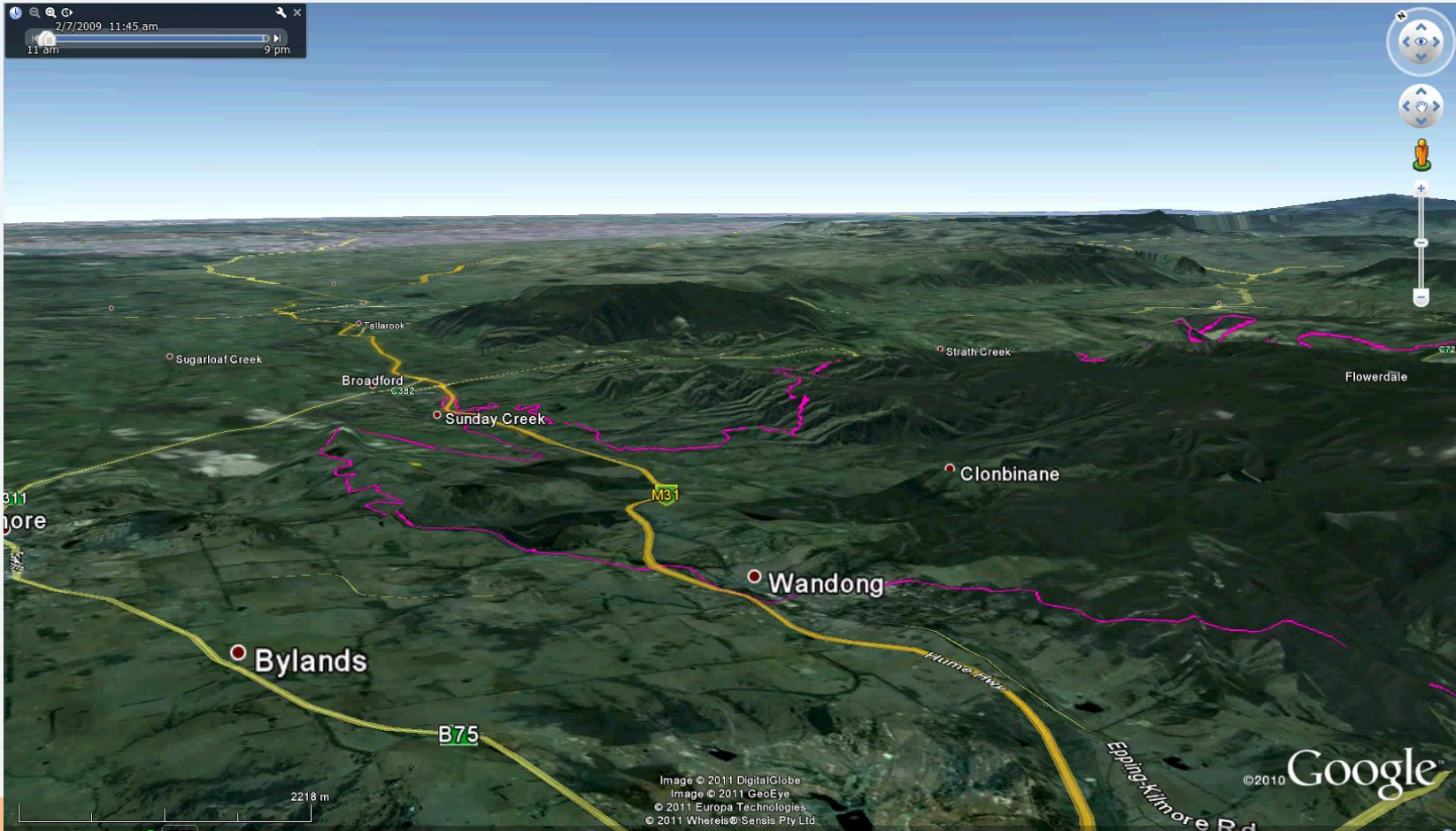
PHOENIX RapidFire

1. PHOENIX RapidFire is a:
   a) Mechanistic, Dynamic, Continuous, Empirical

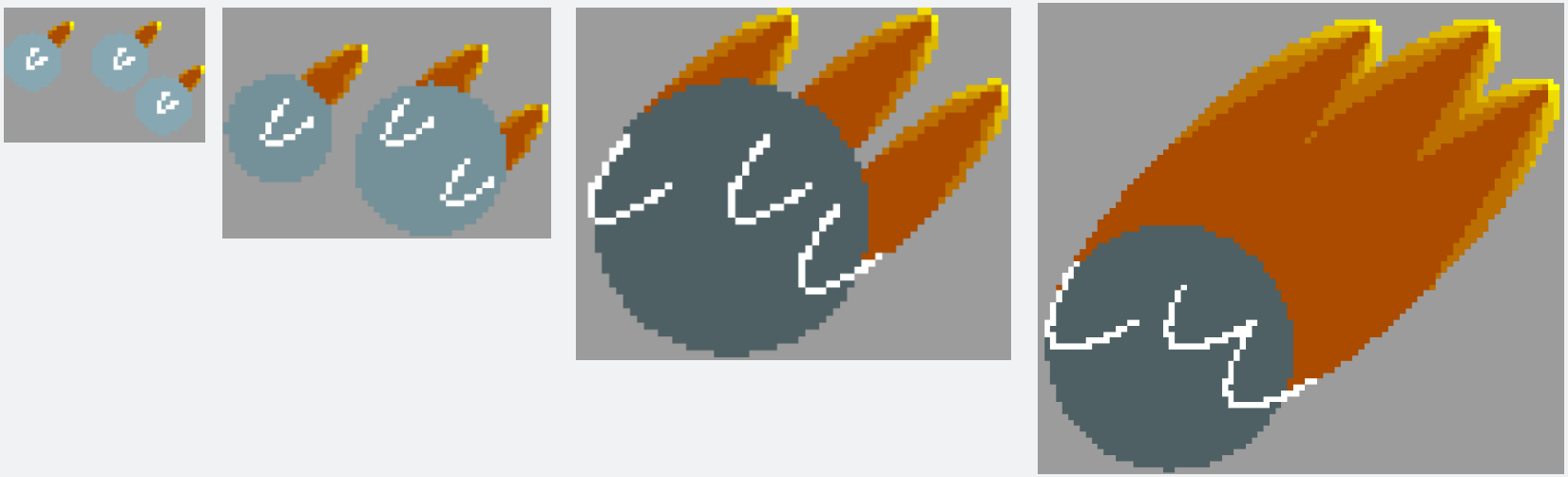
bushfire characterization model



1. CONVECTION-DRIVEN SPOTTING

Convective Centres

1. Identification of heat segments based on most intense 25% of perimeter points.
2. Aggregation of heat segments into convective centres based on combined heat output and distance to neighbour.



Chong, Tolhurst & Duff (2012) PHOENIX RapidFire 4.0 Convection and Ember Dispersal Model. Bushfire CRC – University of Melbourne Technical Report. 22pp.

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1. CONVECTION-DRIVEN SPOTTING

Ember number and hang time

1. Number of embers launched and “hang time”:

$$Available\ Embers = \frac{1}{1 + 108 * e^{(-1.2 \times Bark\ Load)}}$$

$$Ember\ Porportion\ Launched = 1.032 - e^{-.000045 \times \text{Convective Strength}}$$

$$Hang\ Time = 0.6 \times Convective\ Strength \div 10000$$

Chong, Tolhurst & Duff (2012) PHOENIX RapidFire 4.0 Convection and Ember Dispersal Model. Bushfire CRC – University of Melbourne Technical Report. 22pp.

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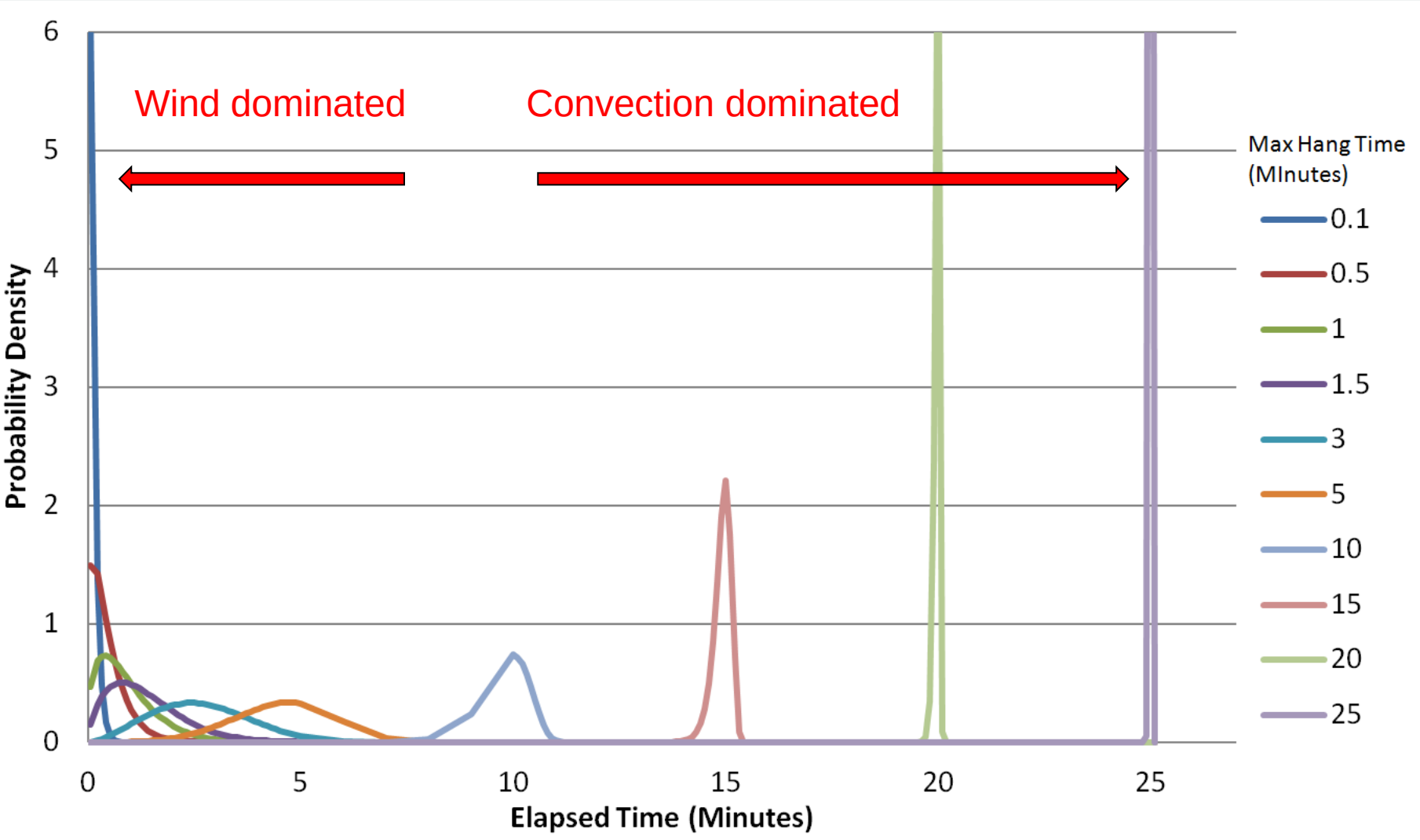
1. CONVECTION-DRIVEN SPOTTING

Ember distribution (bimodal)



Chong, Tolhurst & Duff (2012) PHOENIX RapidFire 4.0 Convection and Ember Dispersal Model. Bushfire CRC – University of Melbourne Technical Report. 22pp.

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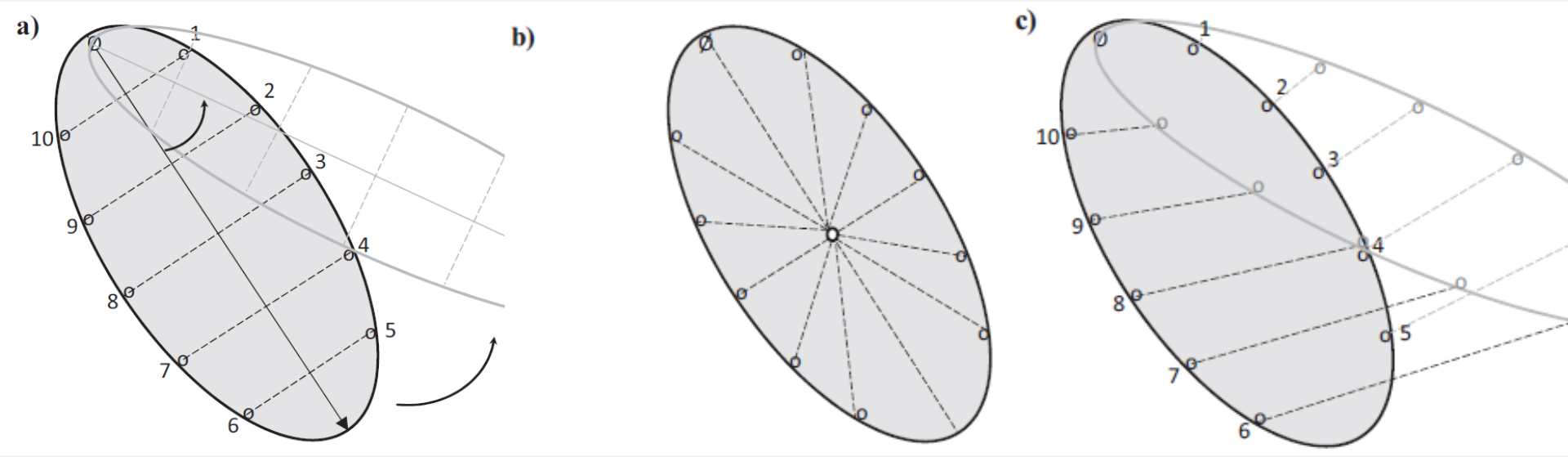
2. PREDICTION EVALUATION

Procrustes

1. Procrustes method needs “landmarks”, but fires only have one - the origin *(points of reference over time)*
2. Developed an unbiased pseudo-landmark methodology
3. Orientation, Size, Shape



Duff, Chong, Taylor & Tolhurst (2012) Procrustes based metrics for spatial validations and calibration of two-dimensional perimeter spread models – A case study considering fire. *Agricultural and Forest Meteorology*, **160** (2012) 110-117.

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Procrustes - Orientation Bias

-6.7° Wind Direction Change

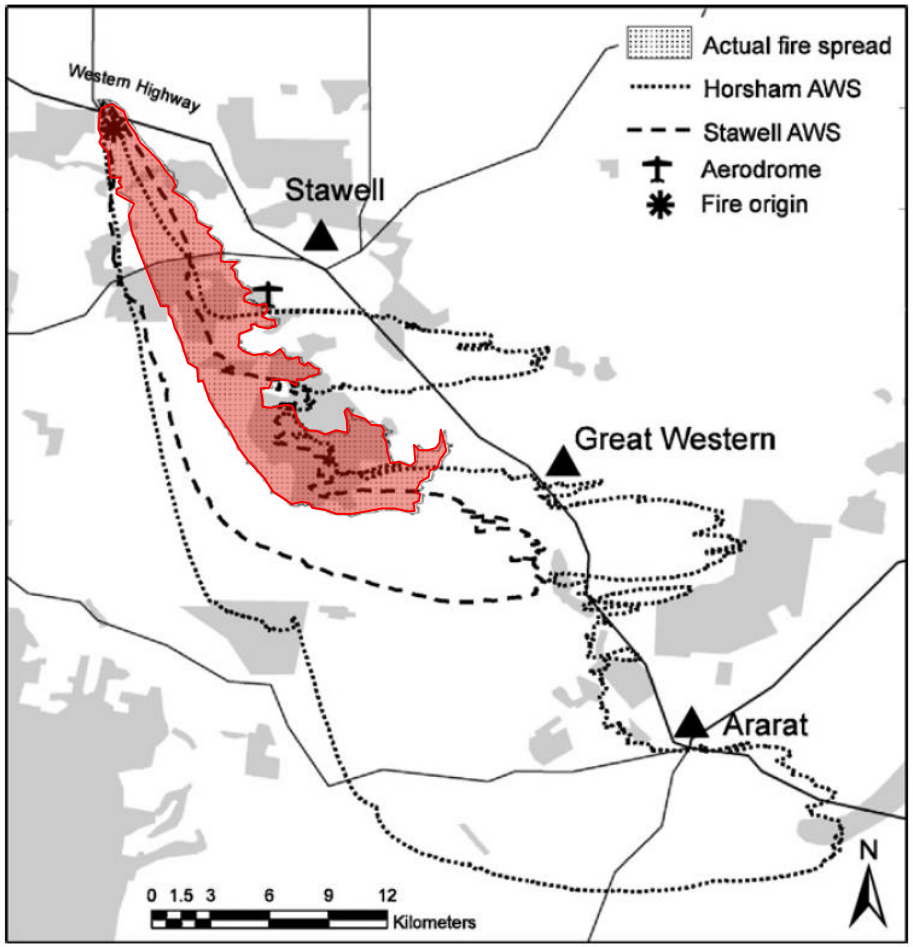

Fig. 4. Map of study area showing actual fire spread and simulated affected areas based on data from the Horsham and Stawell automatic weather stations. Heavily vegetated areas are indicated in grey.

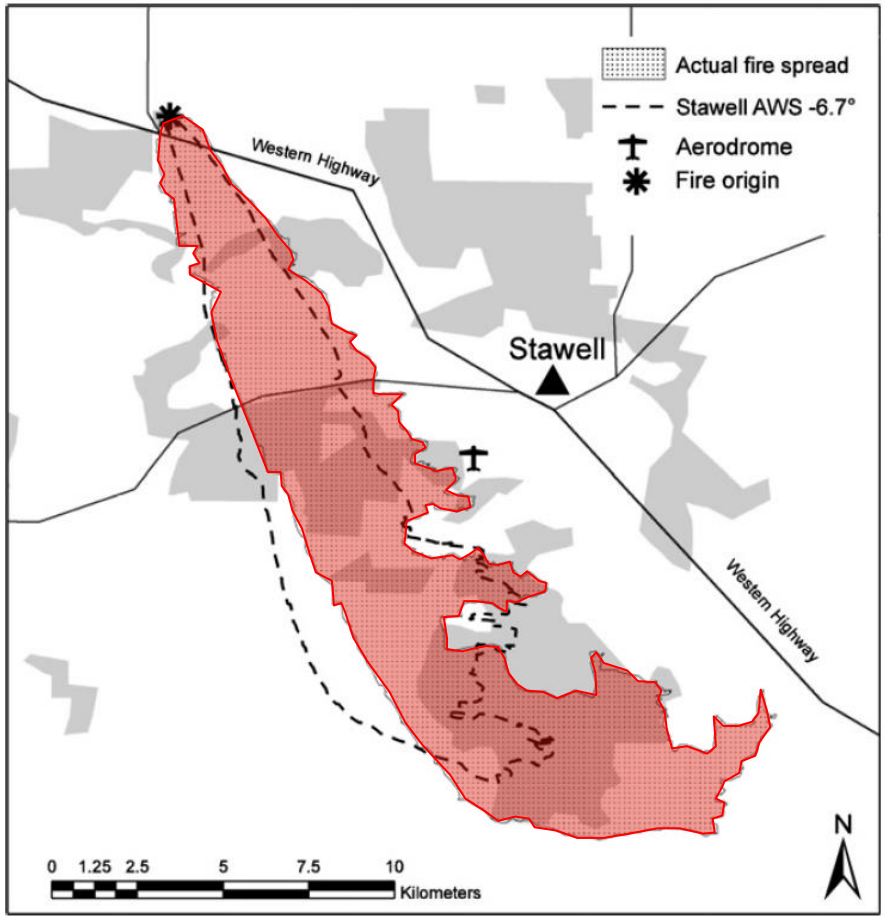

Fig. 5. Map of study area showing actual fire spread and simulated affected areas based on data from the Stawell automatic weather station with wind direction before the major wind change corrected by 6.7°. Heavily vegetated areas are indicated in grey.

Duff, Chong, Taylor & Tolhurst (2012) Procrustes based metrics for spatial validations and calibration of two-dimensional perimeter spread models – A case study considering fire. *Agricultural and Forest Meteorology*, **160** (2012) 110-117.

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2. PREDICTION EVALUATION

Minimum Travel Path Method

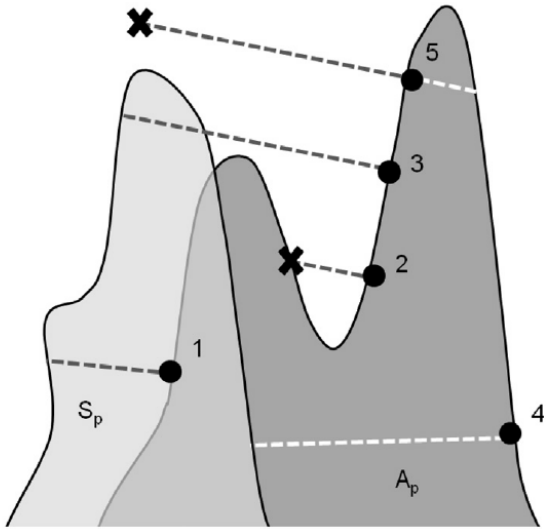
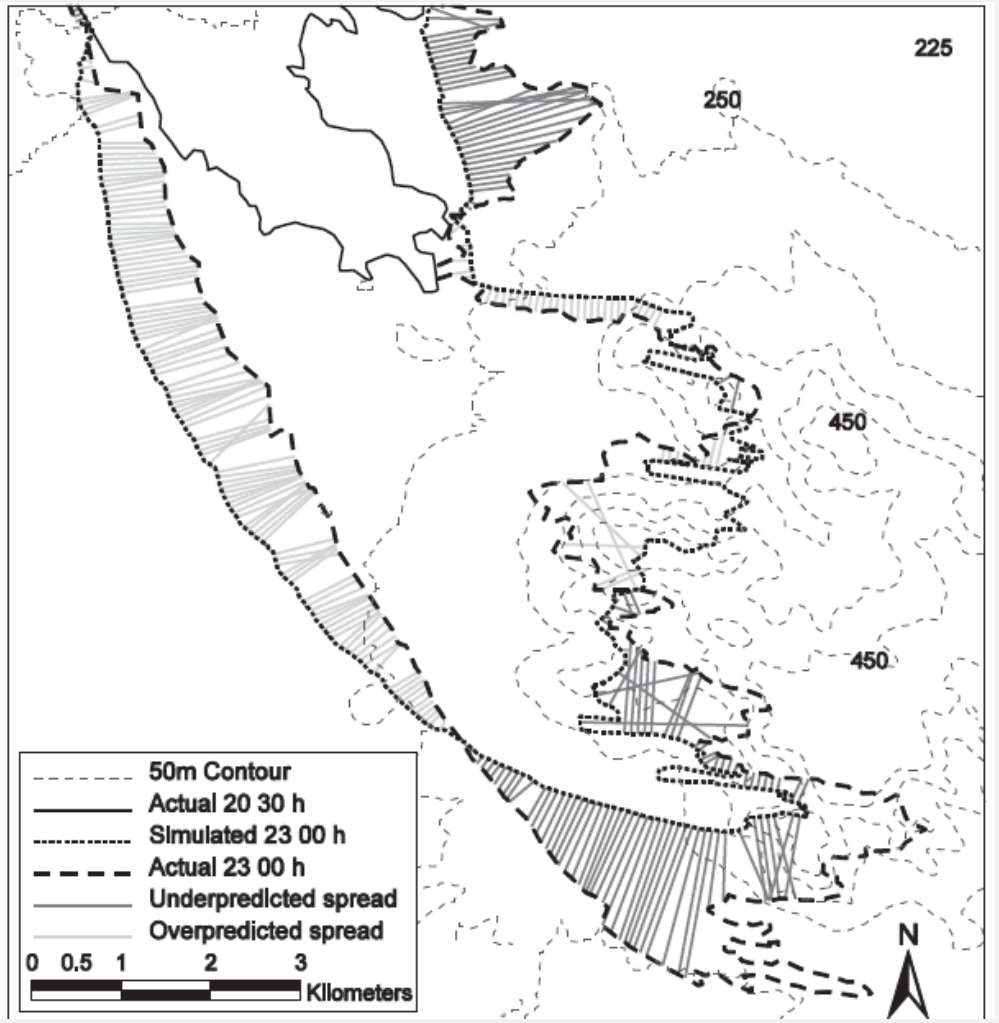


Fig. 3. Schema of travel path distance sampling approach. Where there were an odd number of intersections on a line outwards from the sample point (Pt) with the S_p (1), the distance to the first intersection was returned. Where the first intersection outwards from the Pt was with the A_p perimeter (2), no distance was returned. Where the number of intersections outwards from the Pt with the S_p was even (3), the distance to the second intersection was returned. Where there was an even number of intersections inwards from the Pt with the S_p (4), distance was returned to the first intersection. If there were no intersections with S_p (5) no distance was returned.



Duff, Chong, Tolhurst (2013) Quantifying spatio-temporal differences between fire shapes: Estimating fire travel paths for the improvement of dynamic spread models. *Environmental Modelling & Software* **46** (2013) 33-43.

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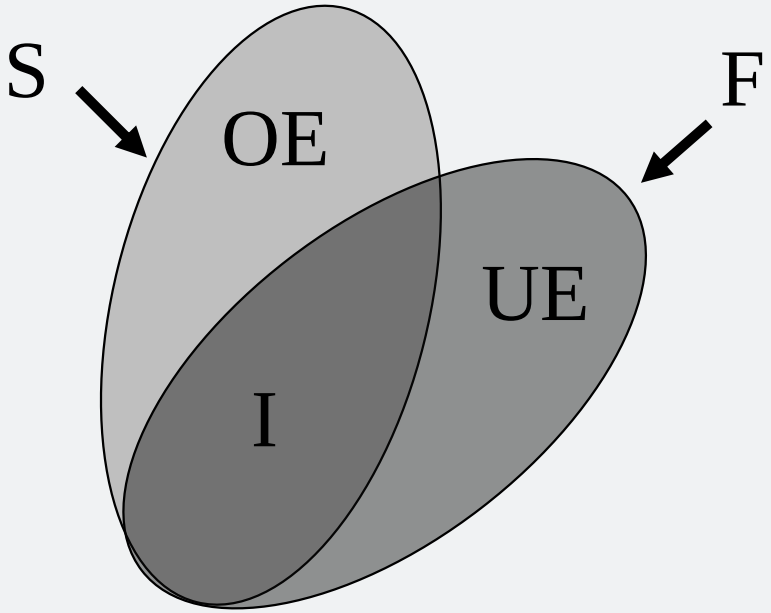
2. PREDICTION EVALUATION

Area Difference Index (ADI)

$$ADI\ (t) = \frac{OE(t) + UE(t)}{I(t)}$$



Duff, Chong & Tolhurst (2013) The Area Difference Index (ADI), an improved index for the comparison of patterns of fire spread. (in prep)

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3. SENSITIVITY ANALYSIS

Forest Fuel

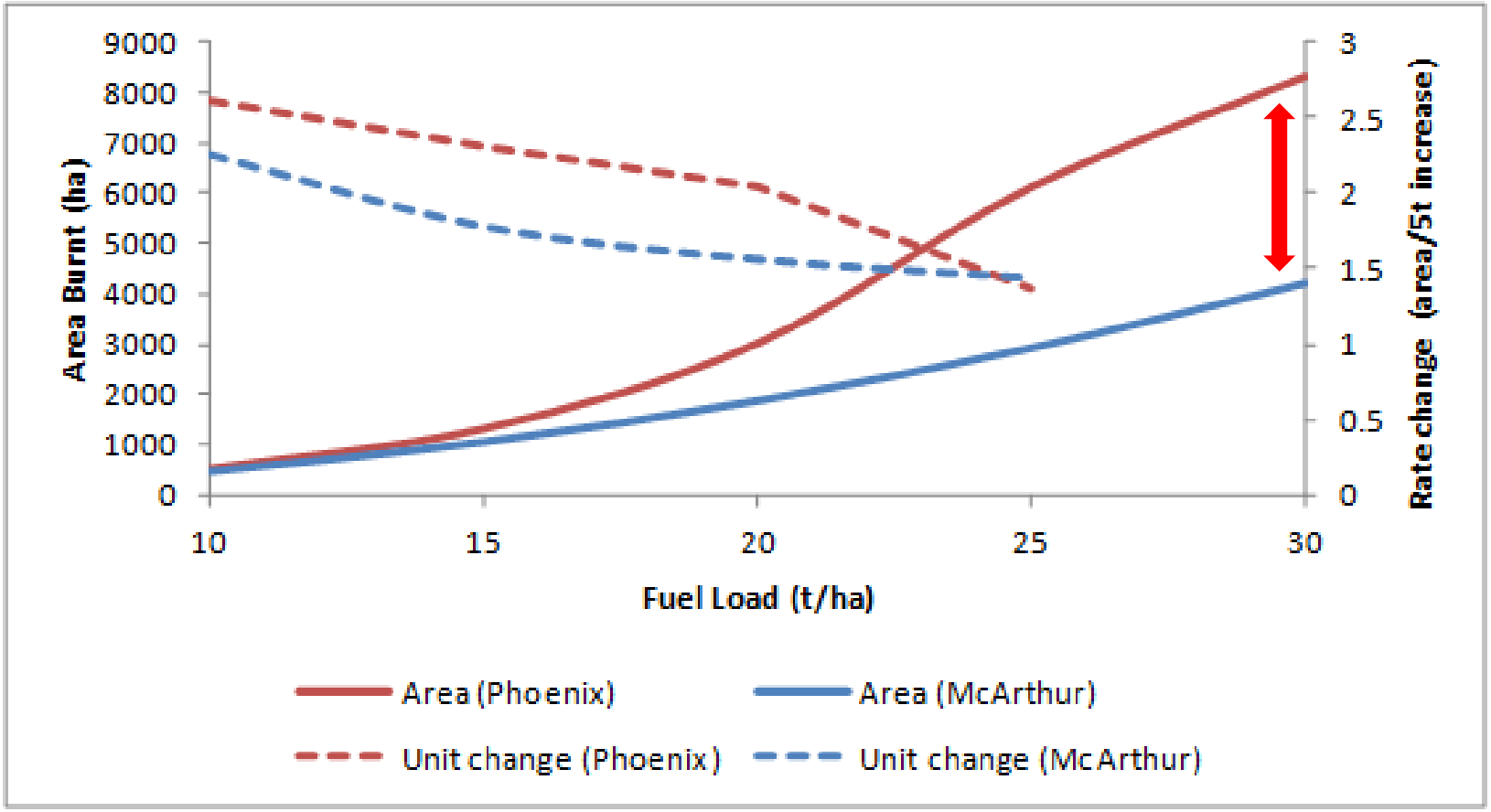

Figure 14: Forest fuel type area burnt in response to systematically changing fuel load.

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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3. SENSITIVITY ANALYSIS

Ignition Time - Wangary

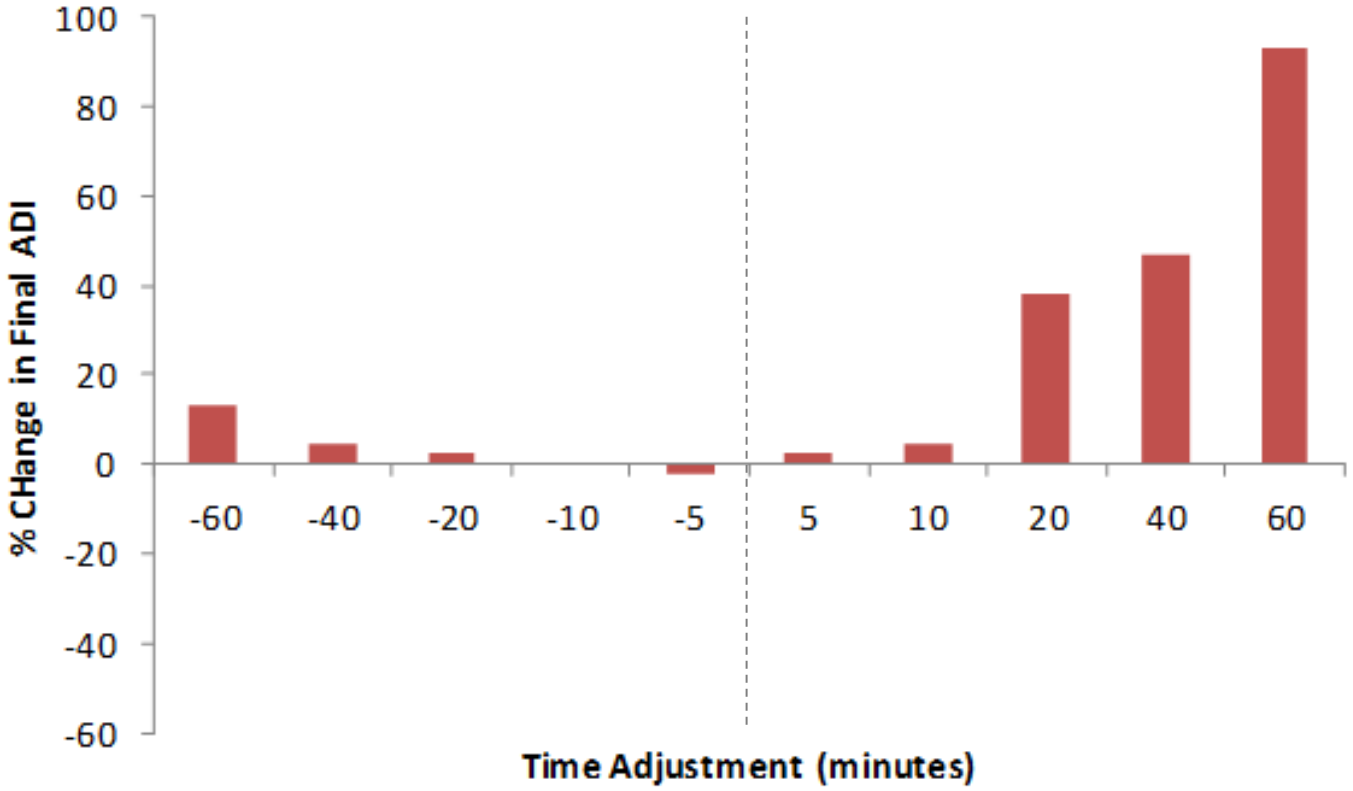

Figure 21: Wangary fire complex percentage change in ADI due to start time alteration (Baseline ADI =0.45).

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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3. SENSITIVITY ANALYSIS

Ignition Time – Kilmore East

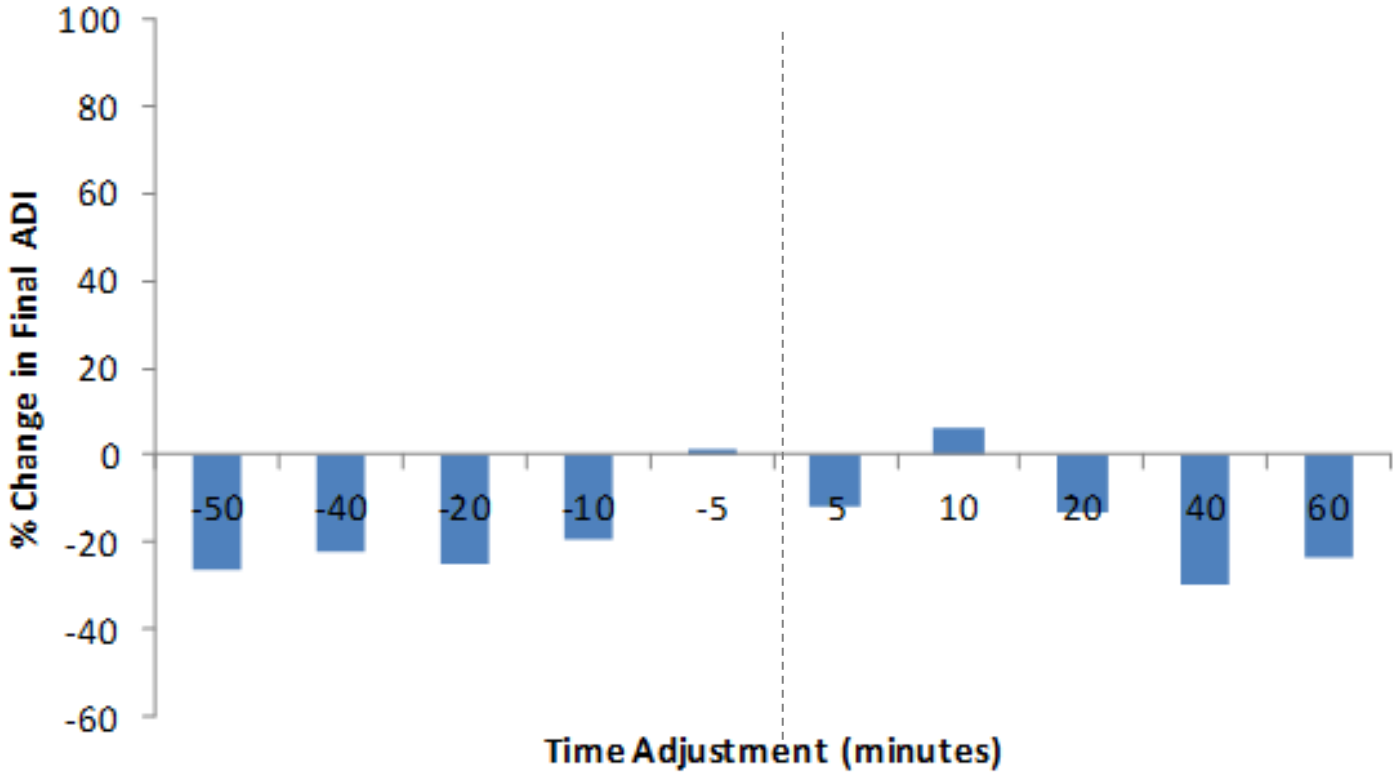

Figure 2: Kilmore fire complex percentage change in ADI due to start time alteration (Baseline ADI =0.77).

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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3. SENSITIVITY ANALYSIS

Ignition Location – Kilmore East

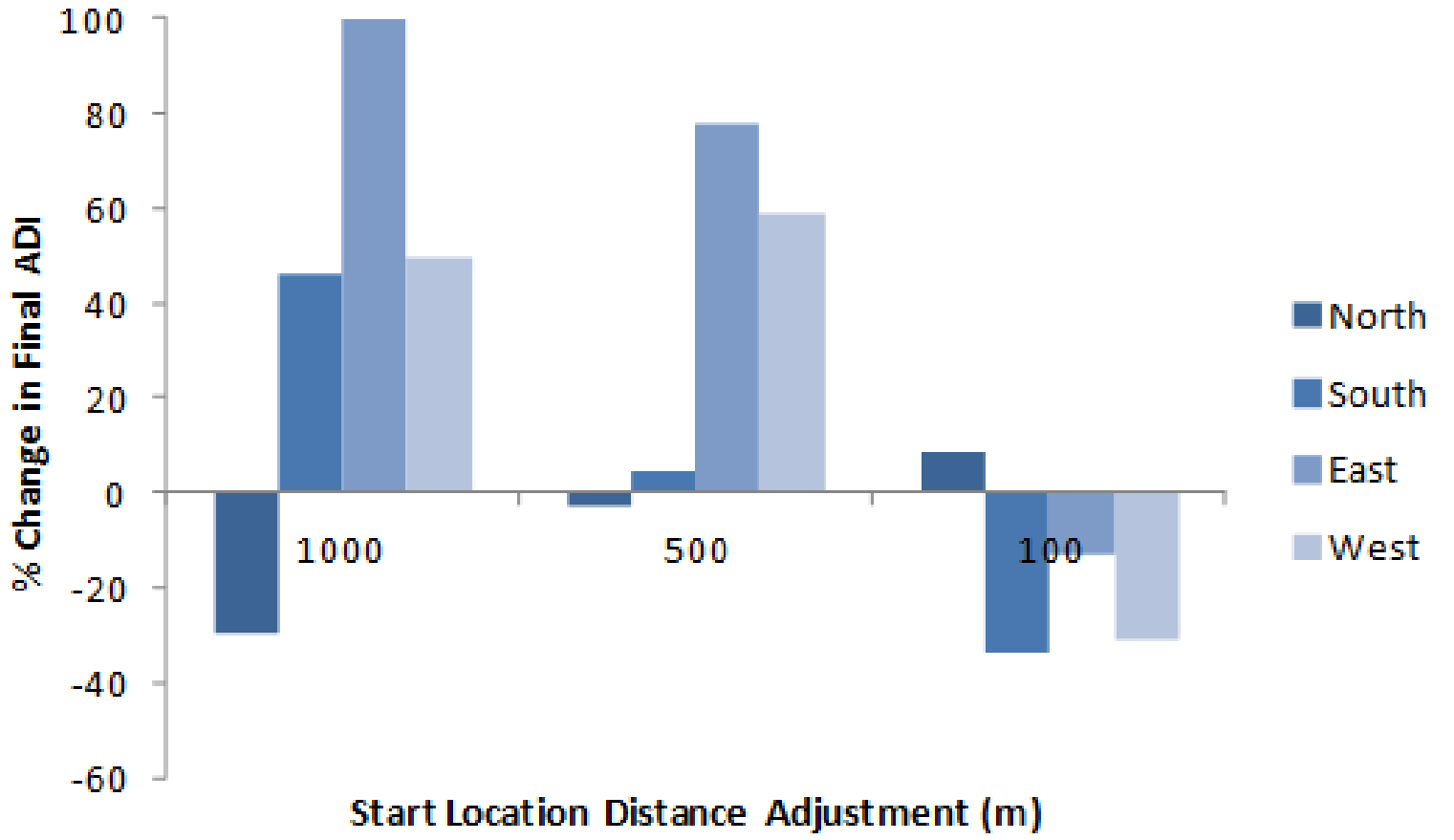

Figure 22: Kilmore change in predictive performance due to variation in ignition location

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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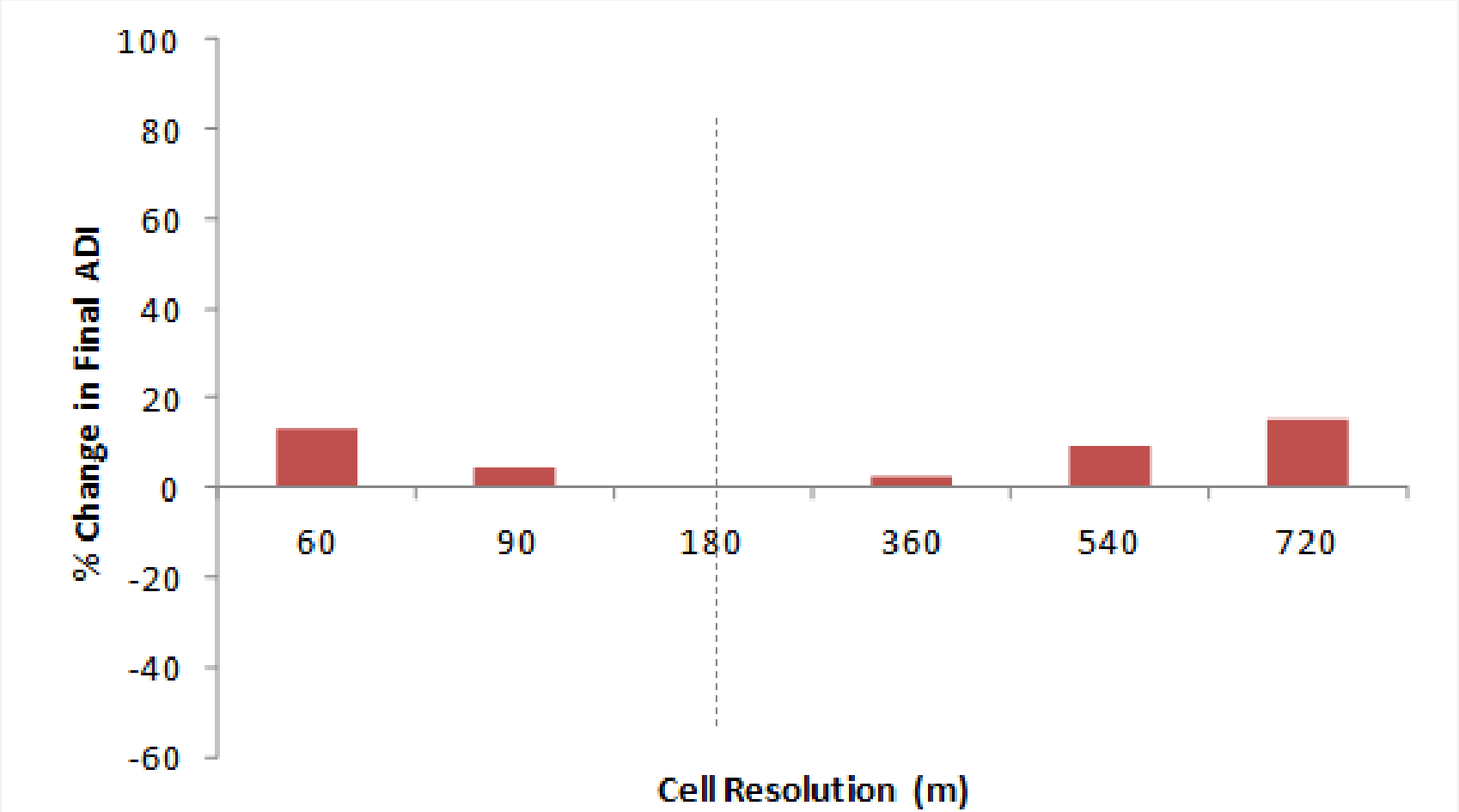
3. SENSITIVITY ANALYSIS

Cell Size – Wangary



ıre 3: Wangary complex change in predictive performance due to variation in analysis cell

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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3. SENSITIVITY ANALYSIS

Cell Size – Kilmore East

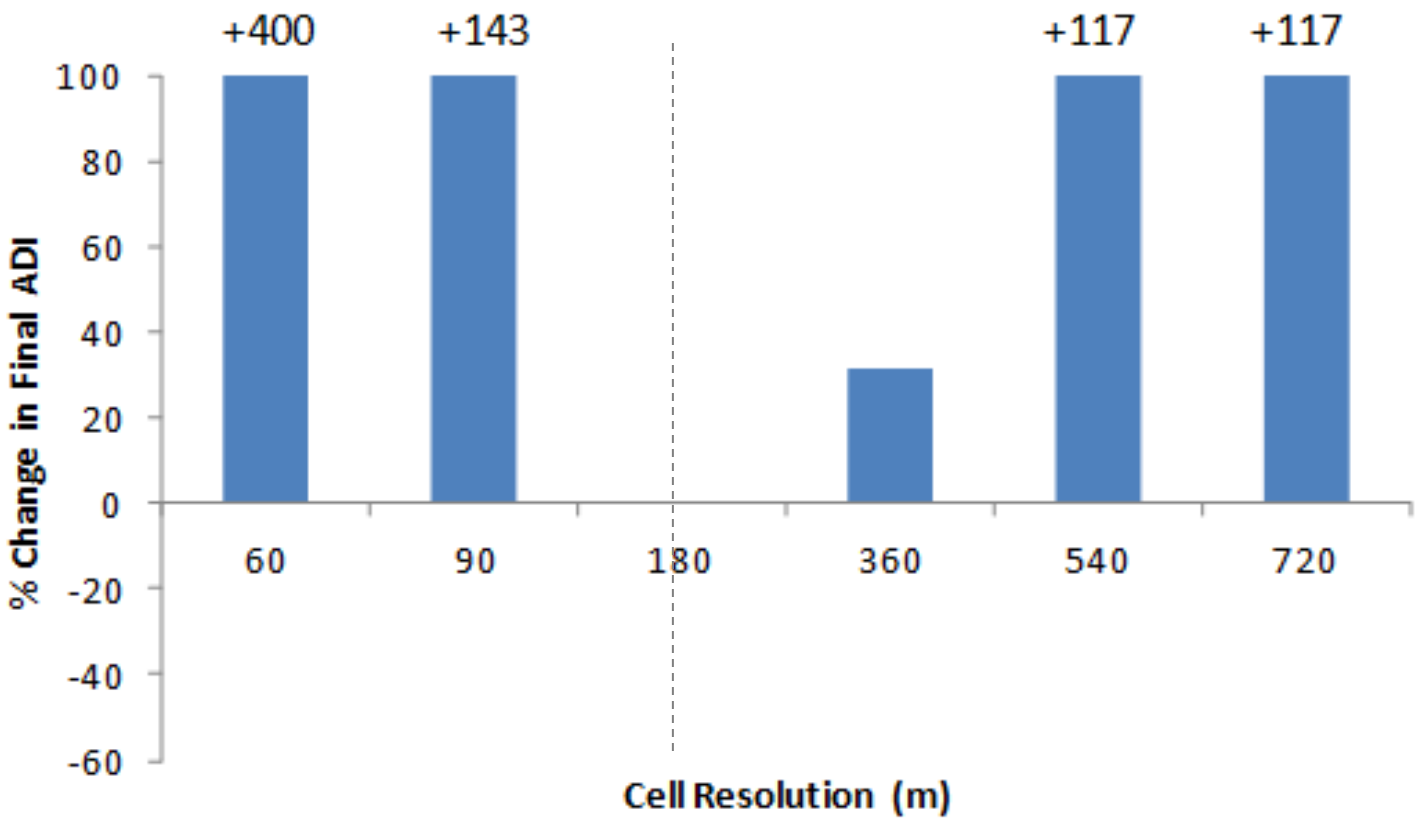

Figure 24: Kilmore complex change in predictive performance due to variation in analysis cell size

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp.

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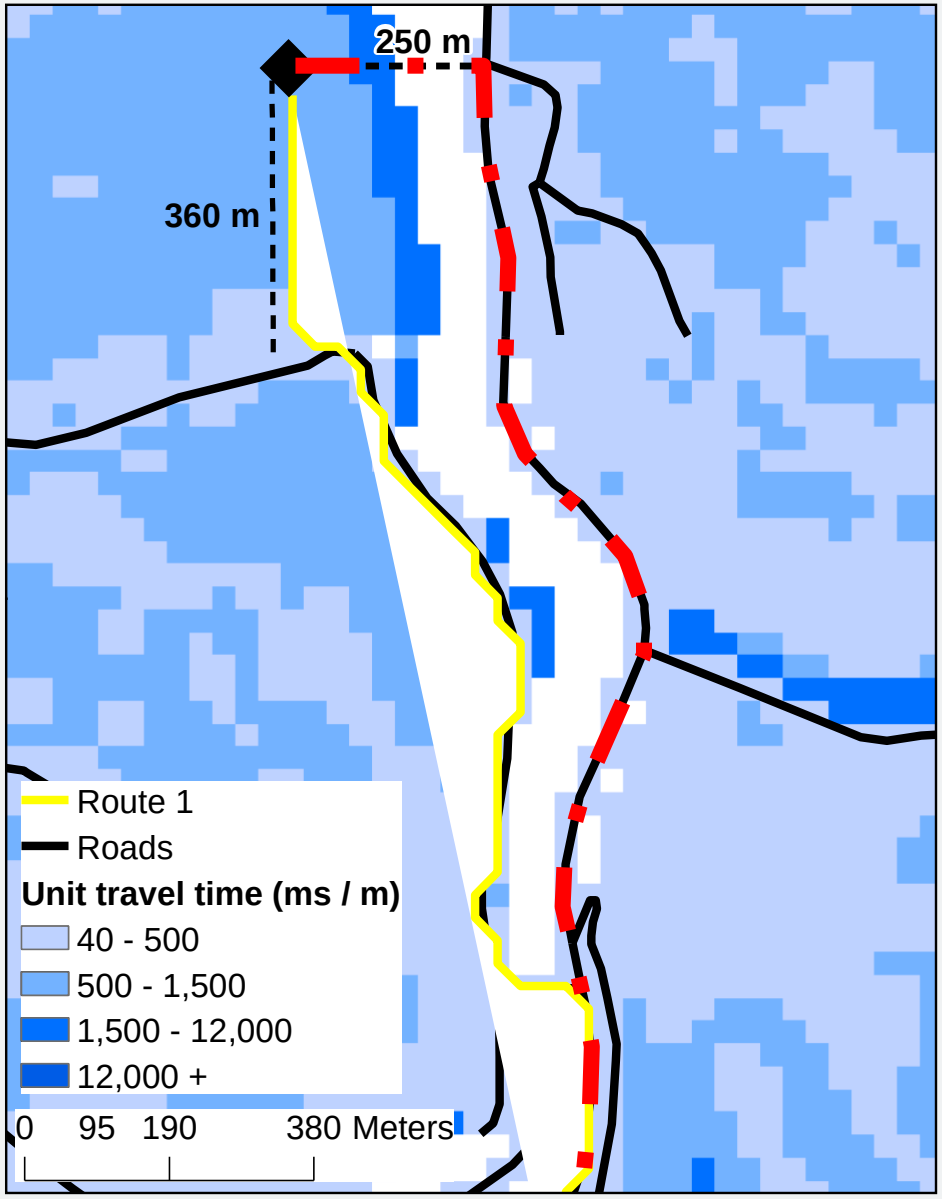
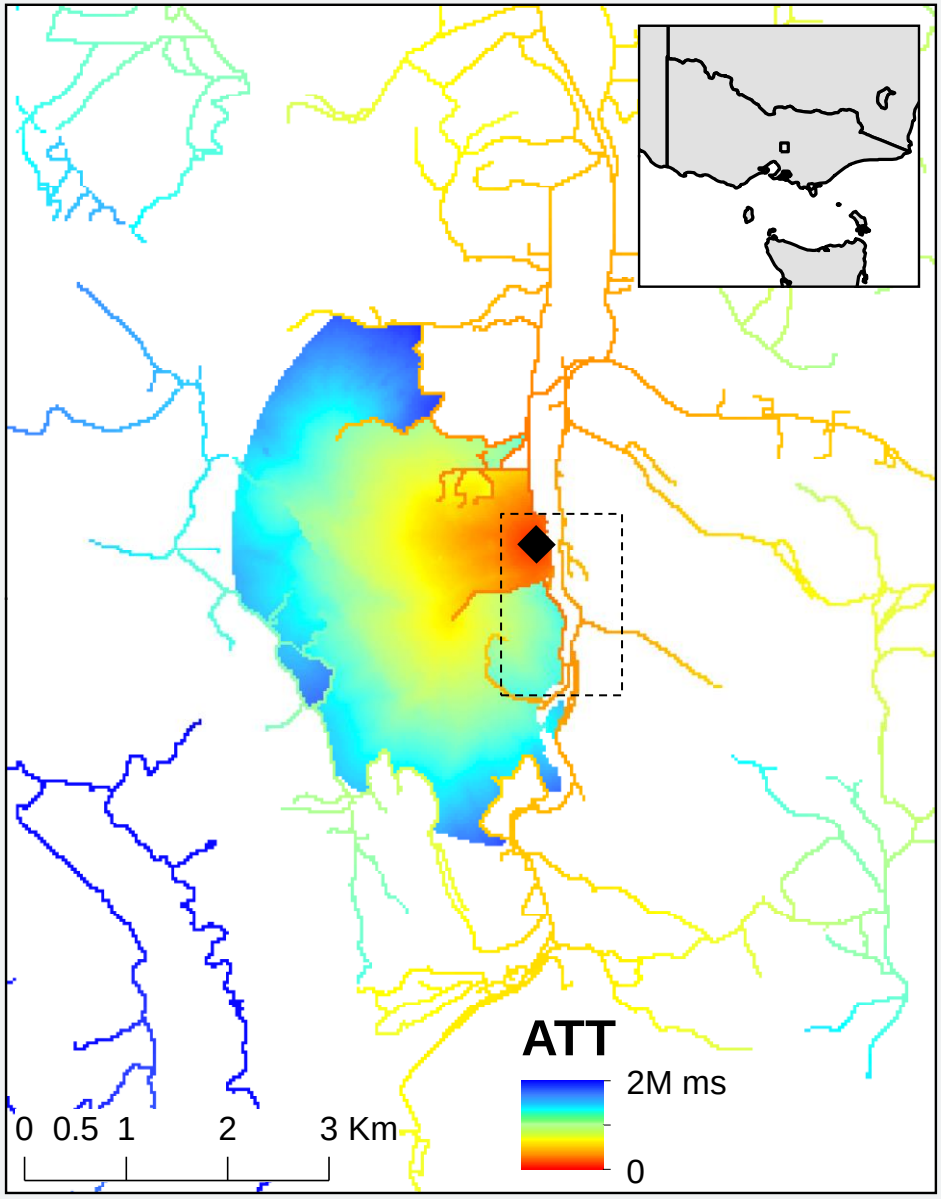
4. SUPPRESSION NAVIGATOR

Travel Cost method – Cellular Automata





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6. HOUSE LOSS PROBABILITY

Prediction using PHOENIX RapidFire

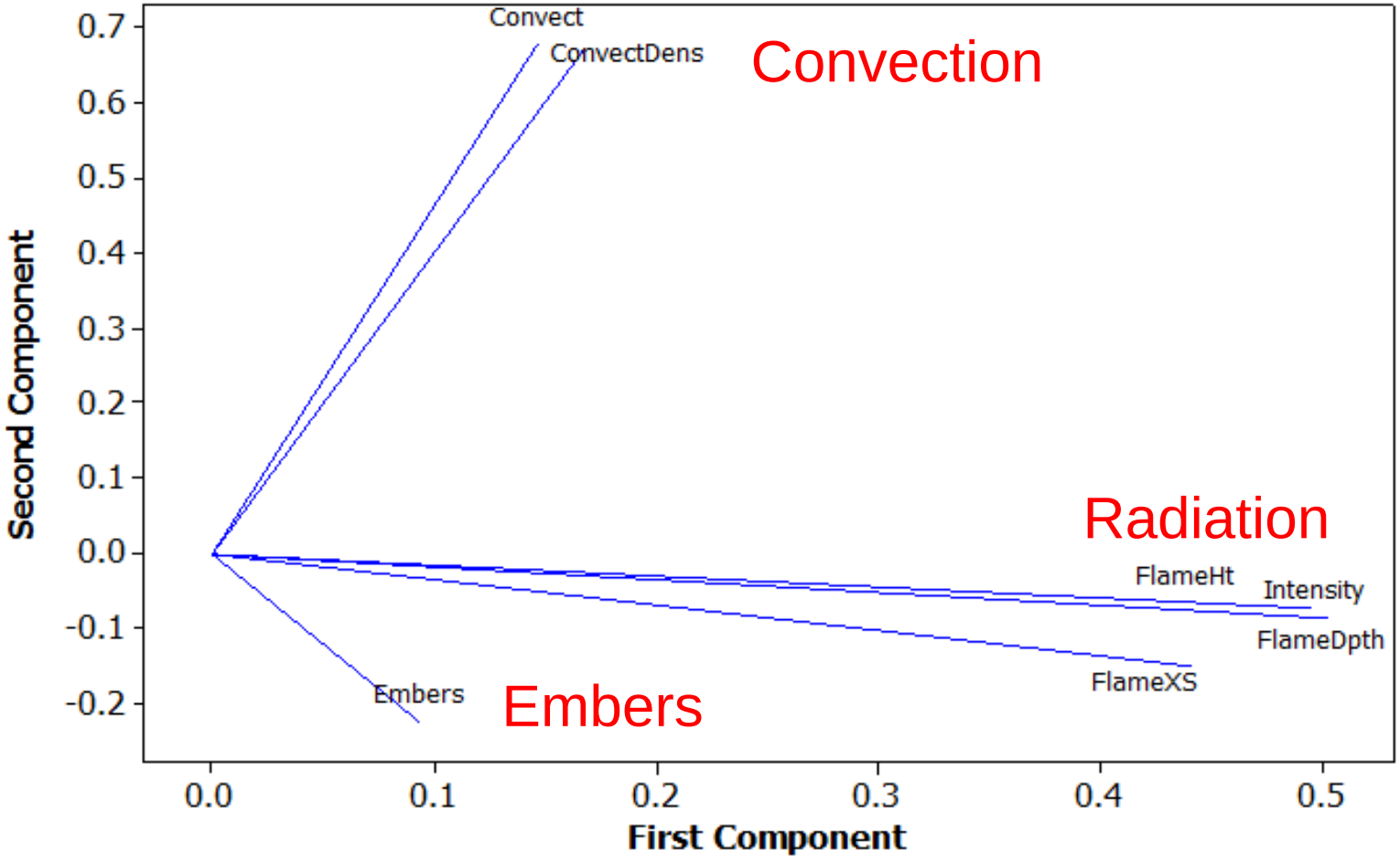

Figure 1. **Principal Component Analysis of predicted fire variables for houses destroyed in the Kilmore East, Murrindindi and Churchill fires on Black Saturday 2009.**

Tolhurst & Chong (2011) Assessing potential house losses using PHOENIX RapidFire. R.P.Thornton (ed.) Proc. Bushfire CRC & AFAC 2011 Conference Science Day, 1 Sept 2011, Sydney Aust. Pp. 74-86.

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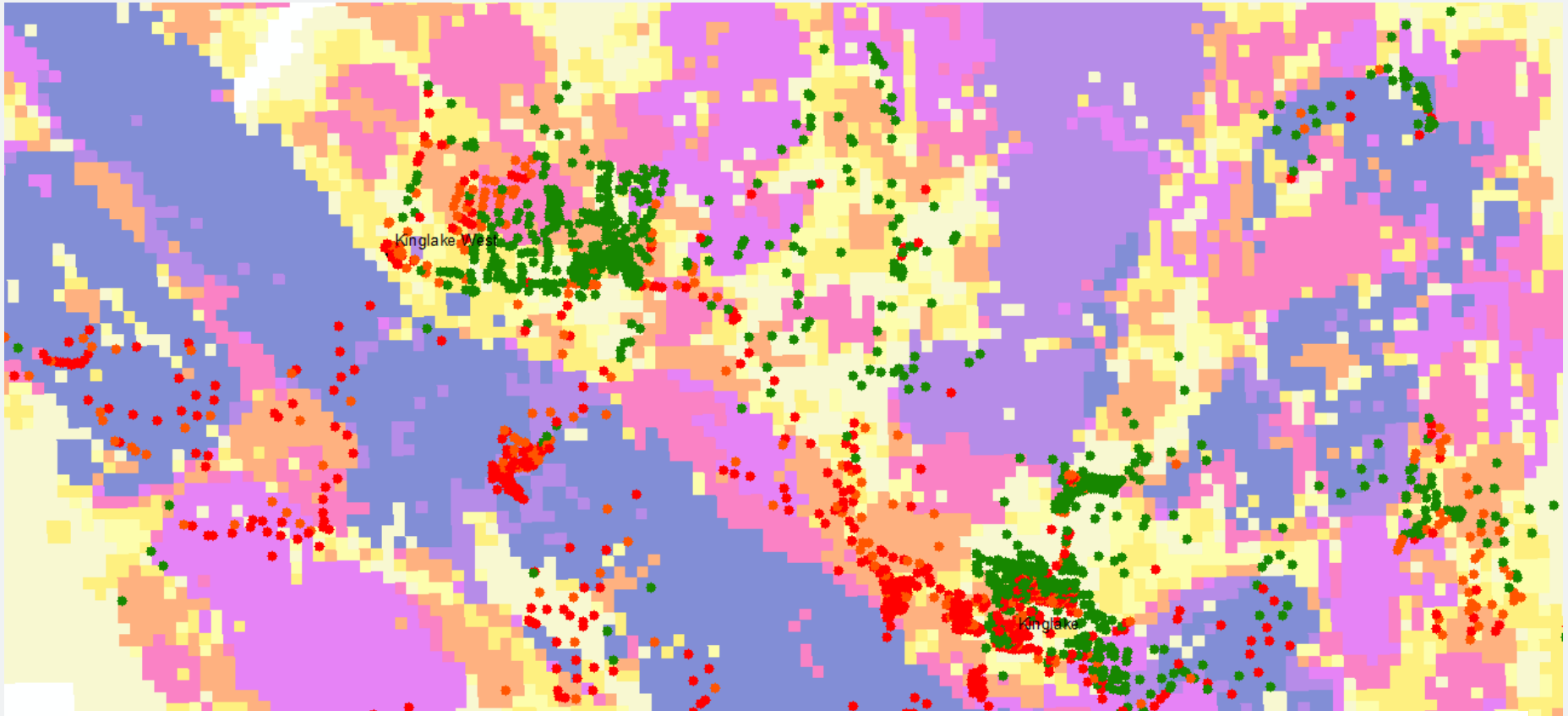
6. HOUSE LOSS PROBABILITY

Prediction using PHOENIX RapidFire



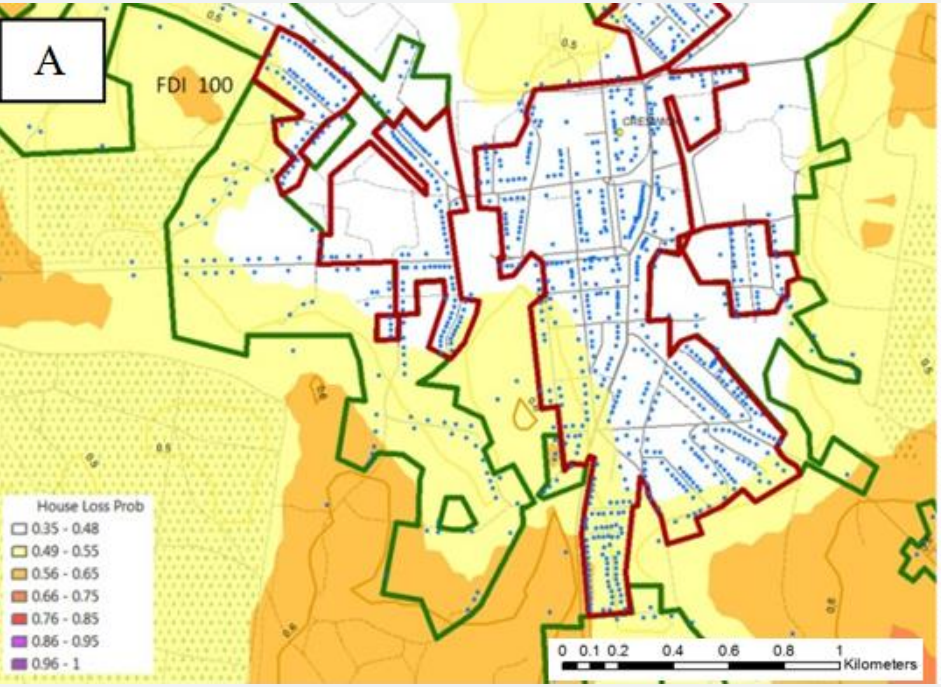
Logistic equation 1.

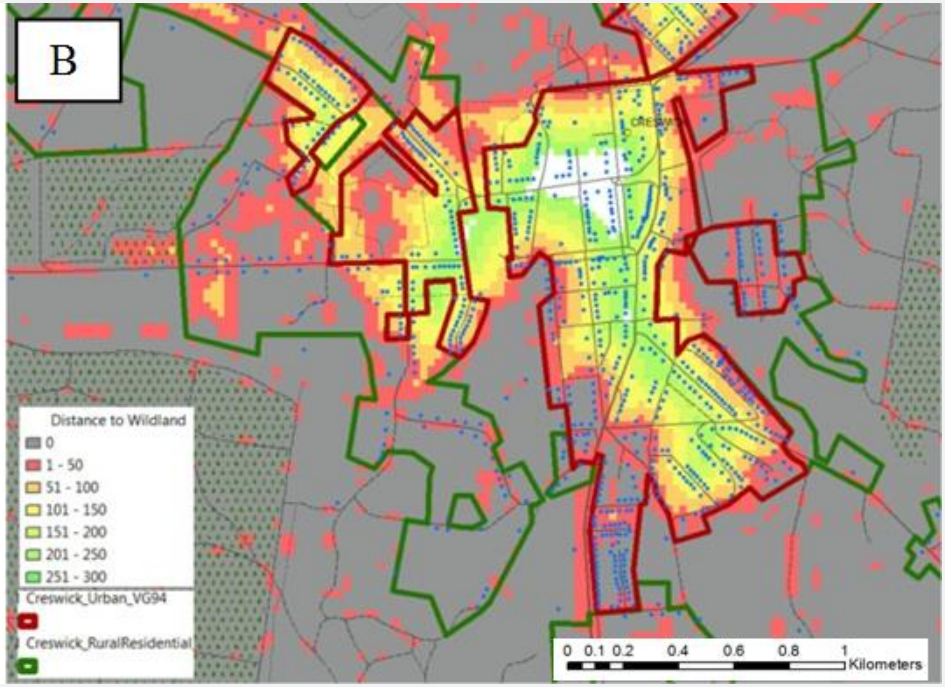
Pr(Loss)=1-EXP(0.63076-0.0000021*ConvectDens-0.0002662*FlameXS-0.01832*Embers)/(1+EXP(0.63076-0.0000021*ConvectDens-0.0002662*FlameXS-0.01832*Embers))

Somers' D = 0.51

7. DEFINING THE WILDFIRE INTERFACE ZONE

Using PHOENIX RapidFire and dynamic programming





Based on dynamic modelling (PHOENIX RapidFire)

Based on fixed distance mapping (GIS analysis)

Tolhurst, Duff & Chong (2013) From “Wildland-Urban Interface” to “Wildfire Interface Zone” using dynamic fire modelling. Paper prepared for MODSIM 2013, Adelaide, December 2013. (Under review)

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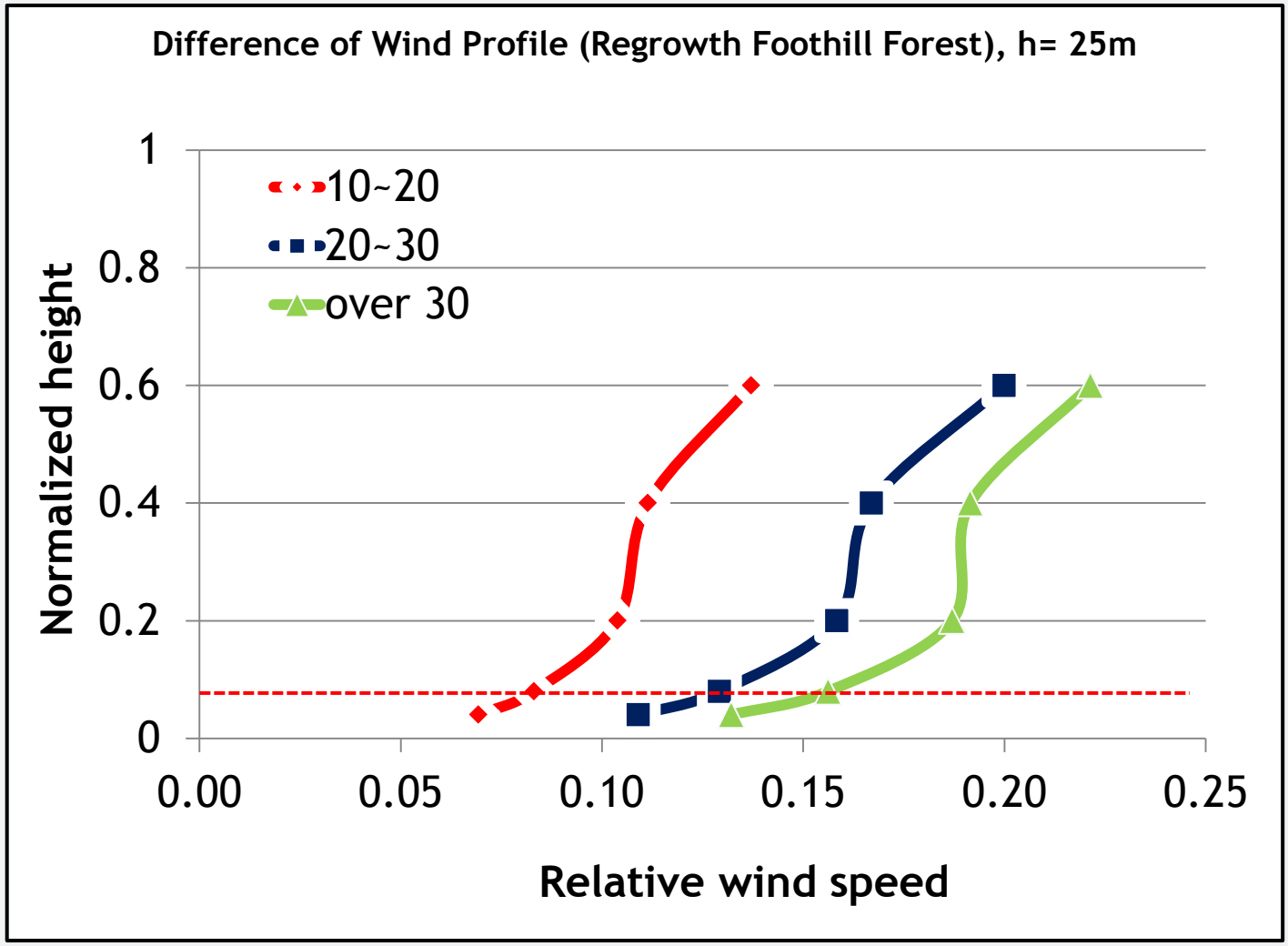
8. MID-FLAME HEIGHT WIND SPEED

Vary with vegetation structure and wind strength



Kangmin Moon, PhD student (2013)

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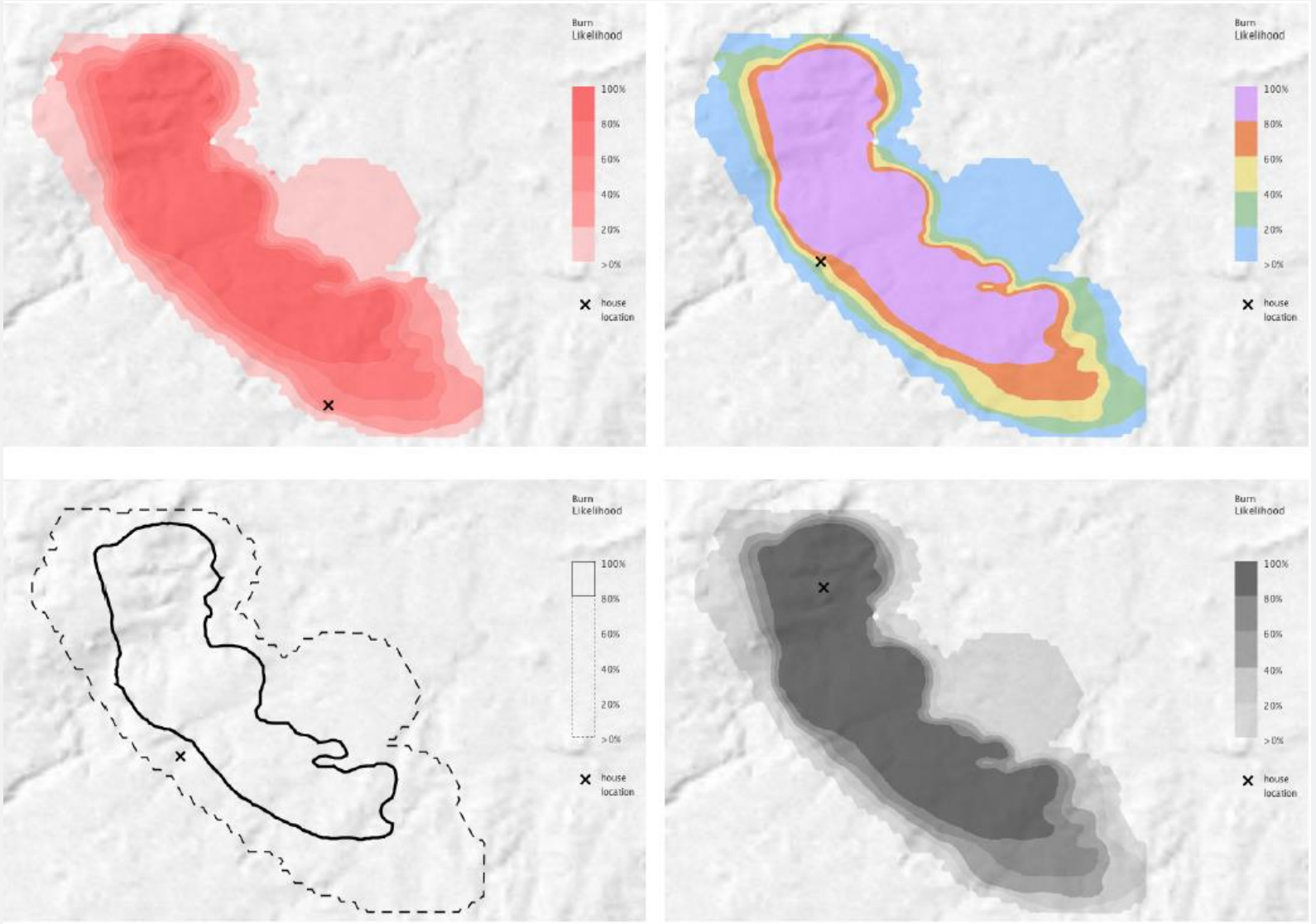
9. ENSEMBLE MODELLING

Fire probability



Lisa Cheong, PhD student (2013)

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SUMMARY

- PHOENIX was first developed in June 2007
- PHOENIX has identified fire behaviour related research needs and priorities
- It has operational and planning applications
- The need to deal with uncertainty and risk has required the use of ensemble simulations, e.g. FireDST
- PHOENIX has opened the door for different ways of managing fire and fire emergencies (e.g. Victorian Code based on Fire Risk Landscapes, Power distribution business investment and maintenance priorities)
- Created a need to have trained users and ongoing testing, development and support.

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PUBLICATIONS (2011-13)

Chong, Duff & Tolhurst (2012) Evaluation of weather data at different spatial and temporal scales on fire behaviour prediction using PHOENIX RapidFire 4.0 – Kilmore case study. University of Melbourne / Bushfire CRC Technical Report. 19pp.

Chong, Tolhurst & Duff (2012) Incorporating vertical winds into PHOENIX RapidFire's ember dispersal model. University of Melbourne / Bushfire CRC Technical Report. 17pp.

Chong, Tolhurst & Duff (2012) PHOENIX RapidFire 4.0 convection and ember dispersal model. Bushfire CRC – University of Melbourne Technical Report. 22pp.

Chong, Tolhurst & Duff (2012) PHOENIX RapidFire 4.0's convective plume model. University of Melbourne / Bushfire CRC Technical Report. 23pp

Cirulis, Duff, Chong & Tolhurst (2013) Sensitivity analysis of PHOENIX RapidFire. University of Melbourne / Bushfire CRC Technical Report. 27pp

Duff, Chong & Tolhurst (2013) The Area Difference Index (ADI), an improved index for the comparison of patterns of fire spread. (submitted)

Duff, Chong & Tolhurst (2014) Using discrete event simulation cellular automata models to determine multi-mode travel times and routes of terrestrial suppression resources to wildland fires. (submitted)

Duff, Chong, Taylor & Tolhurst (2012) Procrustes based metrics for spatial validations and calibration of two-dimensional perimeter spread models – A case study considering fire. *Agricultural and Forest Meteorology*, **160** (2012) 110-117.

Duff, Chong, Tolhurst (2013) Quantifying spatio-temporal differences between fire shapes: Estimating fire travel paths for the improvement of dynamic spread models. *Environmental Modelling & Software* **46** (2013) 33-43.

Tolhurst & Chong (2011) Assessing potential house losses using PHOENIX RapidFire. R.P.Thornton (ed.) Proc. Bushfire CRC & AFAC 2011 Conference Science Day, 1 Sept 2011, Sydney Aust. Pp. 74-86.

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