Application of Computer Simulations in Forestry Education

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bushfire&natural HAZARDSCRC

THE UNIVERSITY OF SYDNEY

Impact of bushfires

Economic

- Infrastructure
- Economic production
- Property
- Government services

Social

- Community
- Health
- Cultural heritage

Environmental

- Soil
- Water
- Air
- Biodiversity

Stephenson (2010) Victoria Government, Department of Sustainability and Environment

Bushfire management

- Planning and preparation
- Community protection and response
- Potential and actual impacts

Fire behaviour education

- Recommendation by the Royal Commission
- Lack of formal tertiary education in Australian universities
- 5 to 8 years of on-the-job training required post-PhD in order to be productive
- A complex interaction of meteorology, biology, chemistry, and physics
- Traditional teaching curriculum (i.e. textbook-based, physical hands-on).

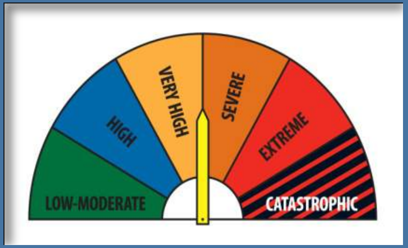
Bushfire decision support systems

Maps

VEGETATION CLASSIFICATION AND FUEL LOAD

Vegetation classification (see Clause 2.2.3)	Vegetation type (see Figure 2.3)	Fuel type	Surface fuel load (t/ha)	Overall fuel load (t/ha)
Forests	1, 2, 3, 4	Forest	25	35
Woodlands	5, 6, 7, 8, 9	Woodlands	15	25
Shrubland	10, 11, 12	Shrub and heath	15	15
Scrub	13, 14	Shrub and heath	25	25
Mallee/Mulga	15	Shrub and Heath	8	8
Rainforest	16, 17, 18	Forest	10	12
Tussock Moorland	21, 22	Tussock Moorland	17	17

Tables



Charts

Decision support layer

Decision maker

Fire spread, life, property and environment data

ArcGIS ESRI

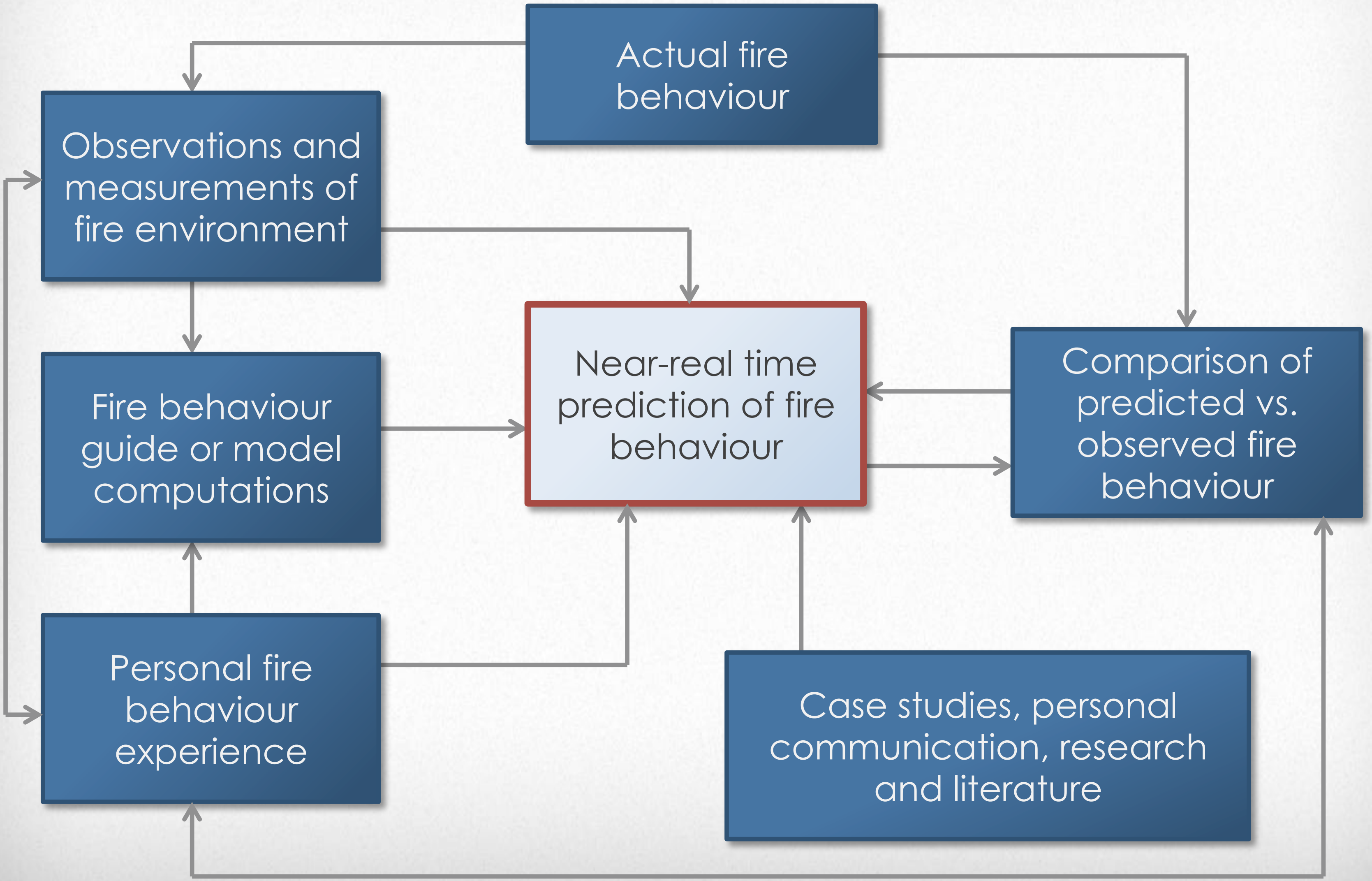
Local databases

Fire behaviour analyst (FBAN)

Phoenix RapidFire

Simulation tools

Practice and education - the gap

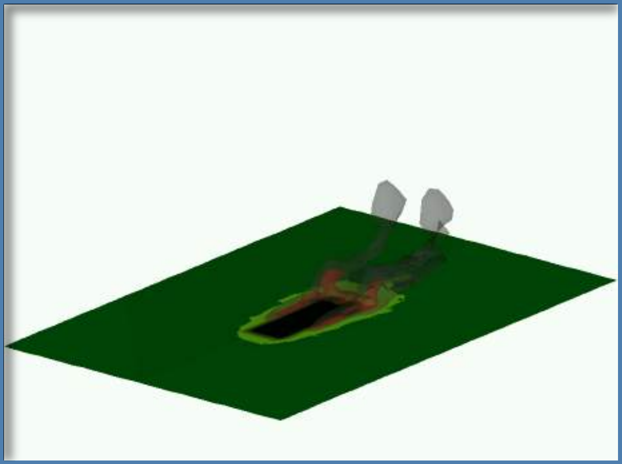


Alexander and Cruz (2013) Forestry Chronicle

Burn simulation methodologies

Computational fluid dynamic (CFD) models

- Combustion chemistry and heat transfer
- Physically-based, generic, computationally very expensive
- Model both combustion and propagation
- Large fire require a forecast in a few minutes



Sun et al. (2005) 4th Joint Meeting of the U.S. Sections of the Combustion Institute

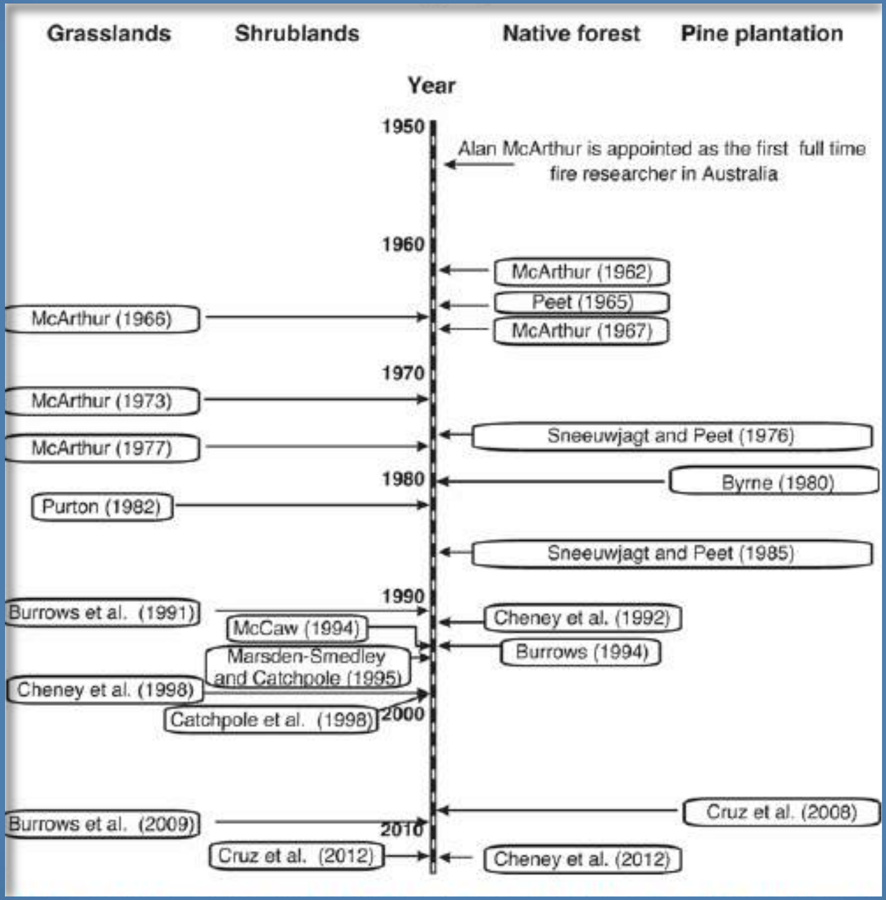
Burn simulation methodologies

Empirical and quasi-empirical models

- Restricted application
- 2D representation of fire perimeter
- Methods such as front-tracking cellular automata, or level set methods – much faster, larger areas

Australian fire behaviour models are **fuel type specific** (e.g. Grassland, shrublands, eucalypt forest and conifer plantation) – a large range of models has been developed

Fuel group



Development of a new teaching tool

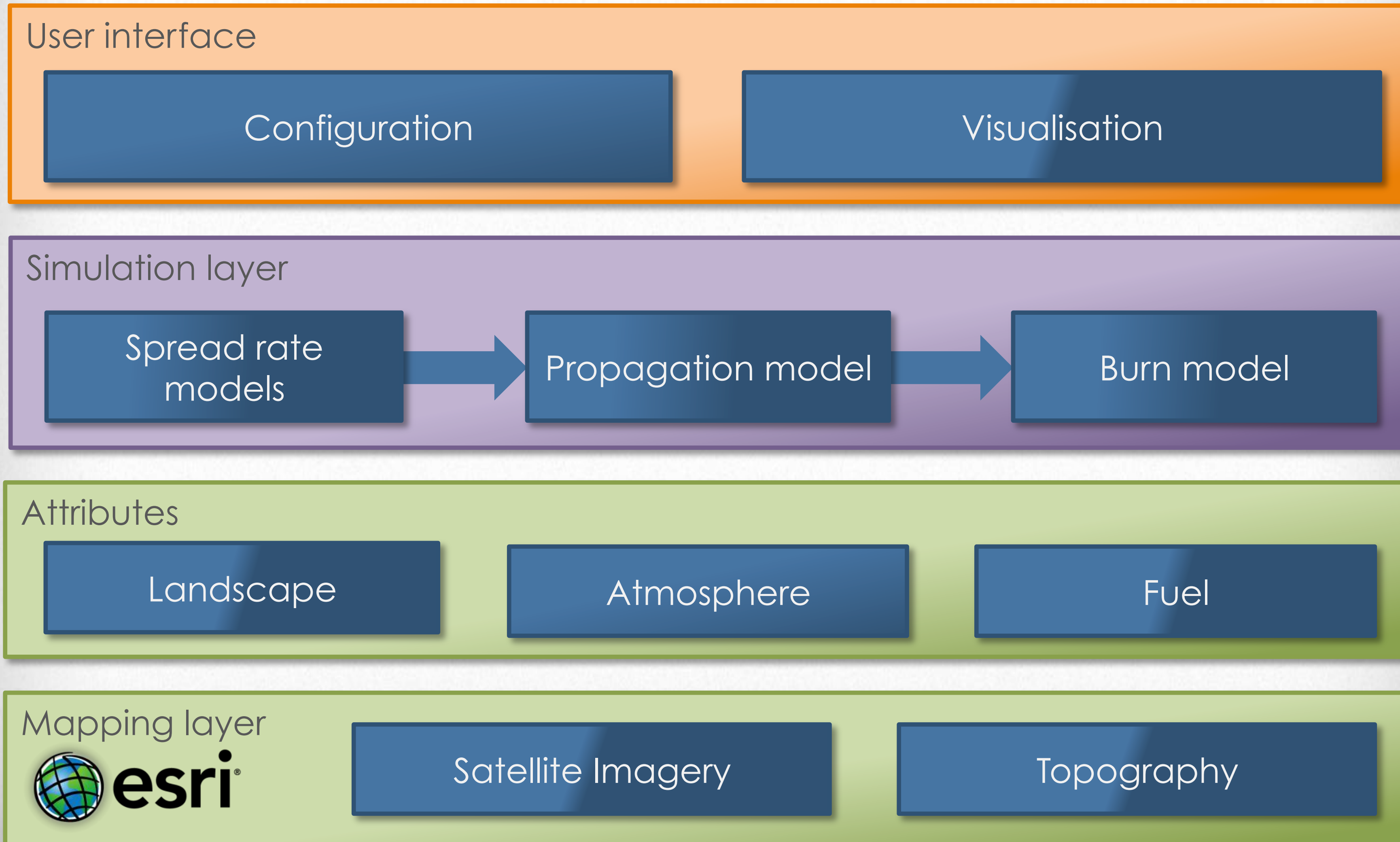
- Motivation
  - Teaching fire-related subjects
  - Graphical visualizations, parameter tuning, user interface
  - Web-based
- Structure
  - Spatially explicit
  - Fire spread model for Australian vegetation (e.g. McArthur 1967, Cheney et al. 1998)
  - Fire propagation (Elliptical fire shape, Alexander 1985) (Minimum travel time, Finney 2002)
- Application
  - Sensitivity analysis
  - Testing land management scenarios

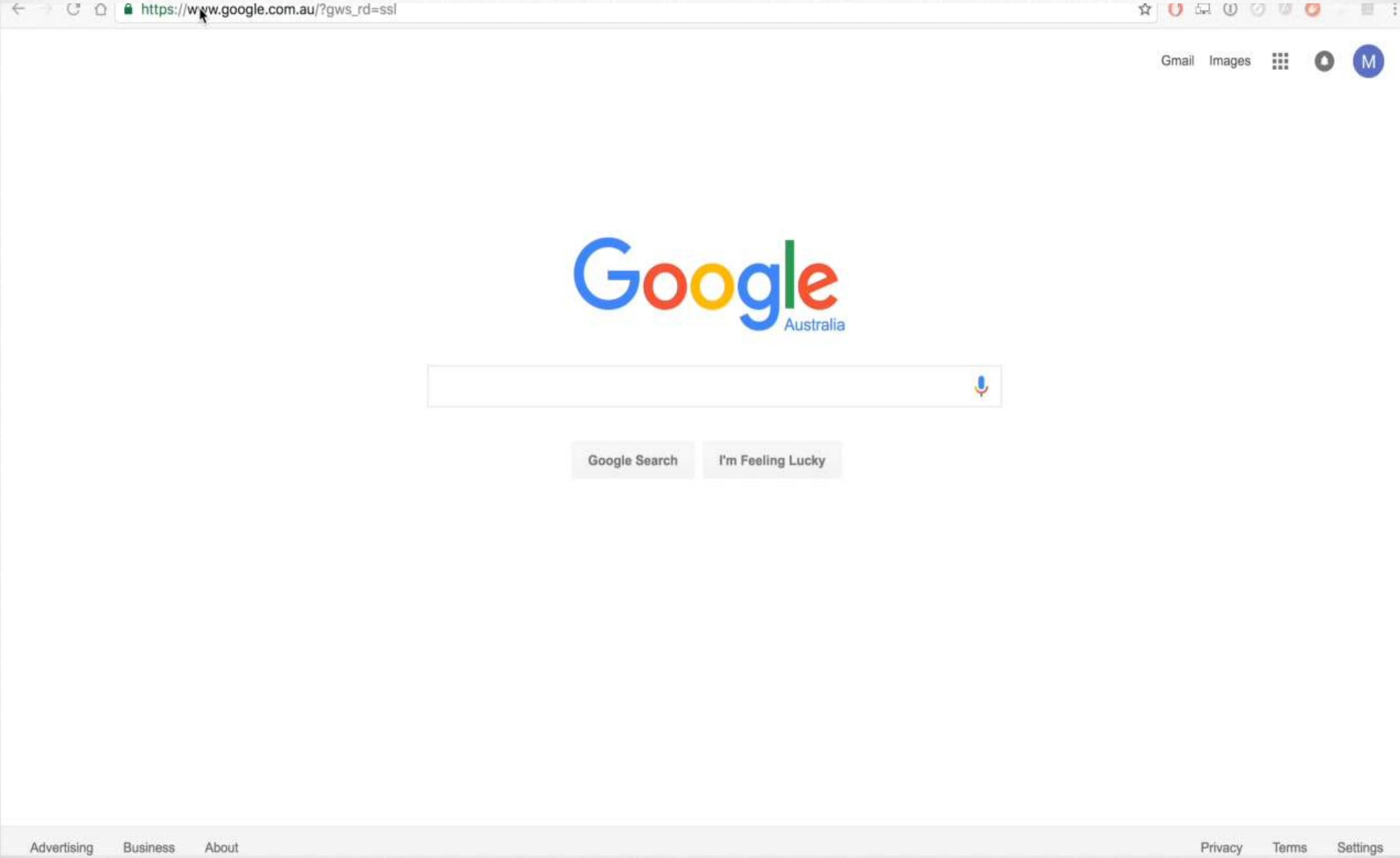
Ember-sim

http://ember-sim.s3-website-ap-southeast-2.amazonaws.com

Architecture of *Ember-sim*

A tool for teaching fire behaviour

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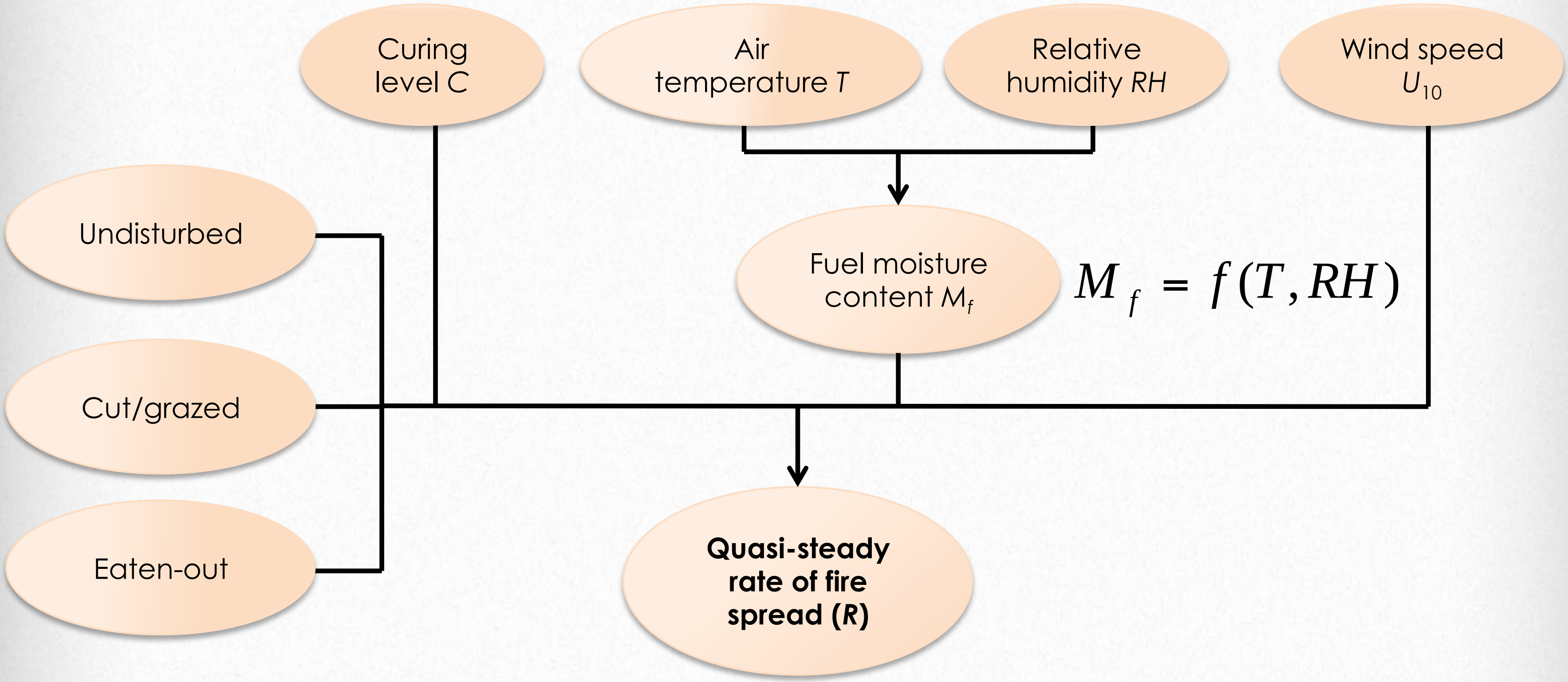
Ember-sim technology

- Browser-based – all simulation code runs in the user's web browser
- Cloud-based, hosted on Amazon AWS
- Written in performance-optimised JavaScript
- Uses Leaflet library for mapping
- AngularJS user interface

Fire spread in grasslands



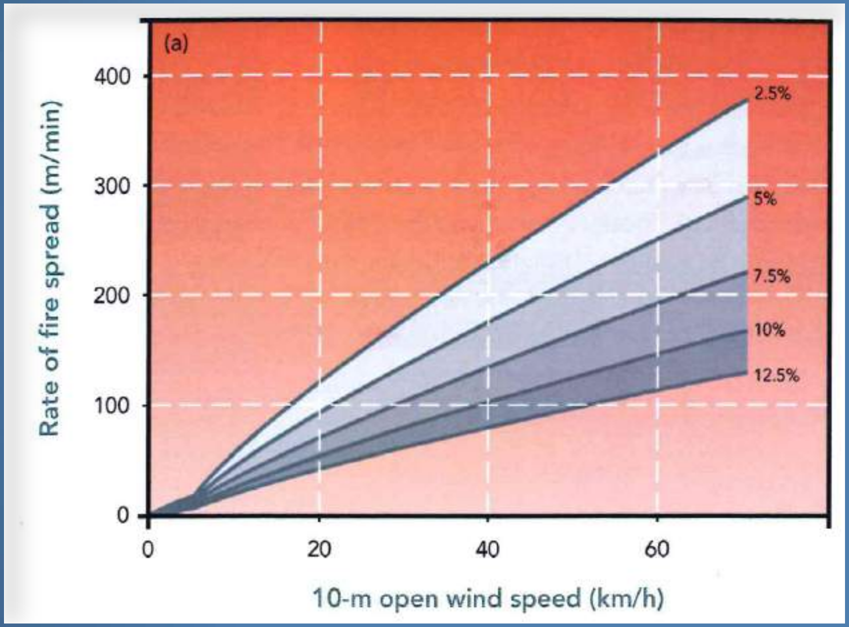
$$M_f = f(T, RH)$$

$$R = f(i, U_{10}, M_f, C)$$

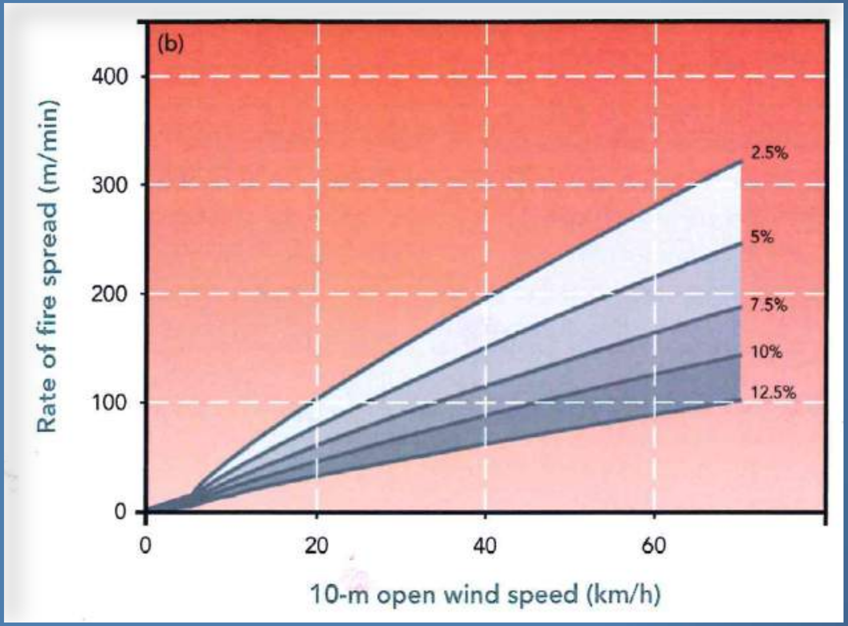
Cheney et al. (1998) International Journal of Wildland Fire

Prediction of fire spread in grasslands

Undisturbed

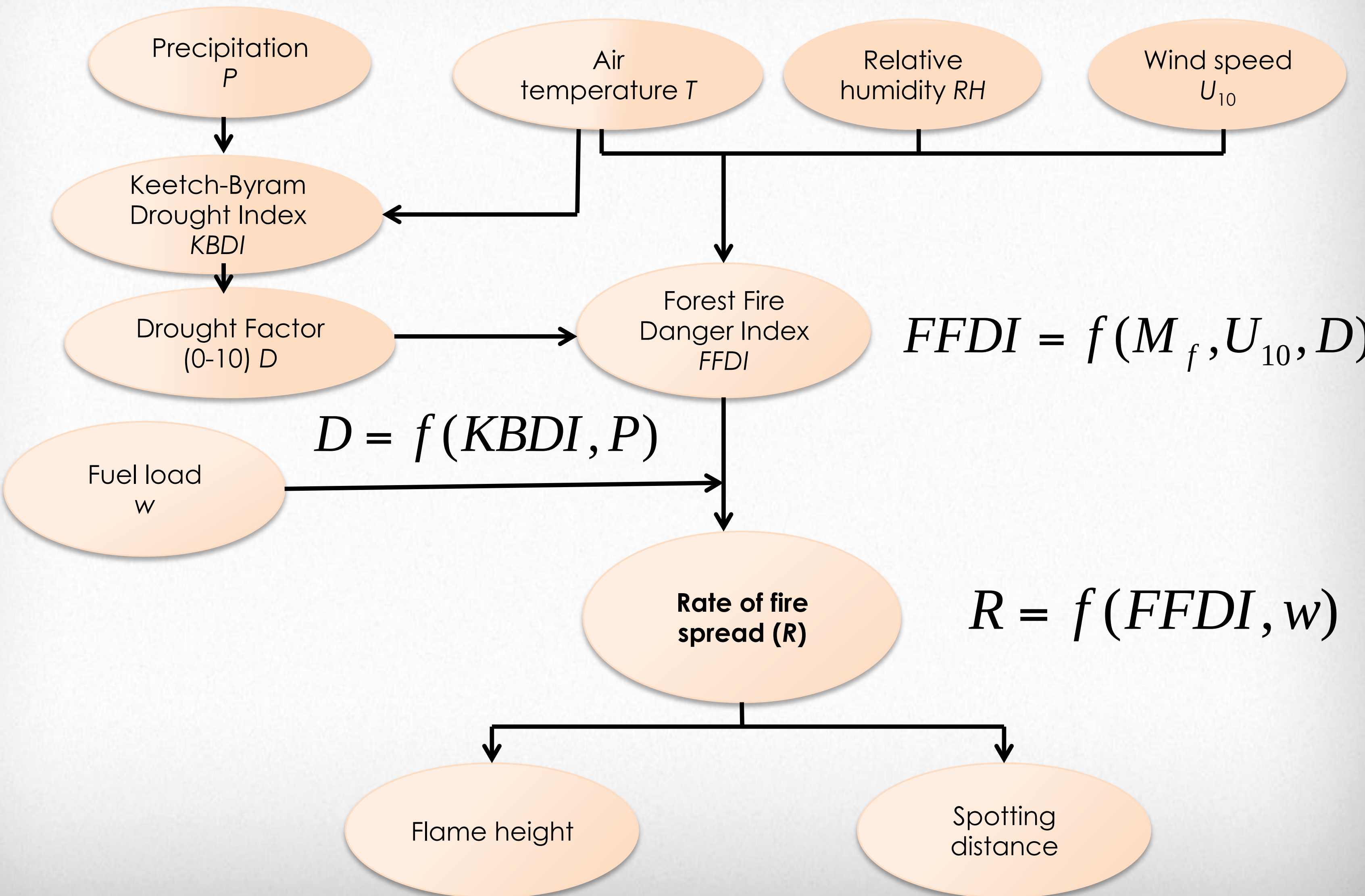


Grazed



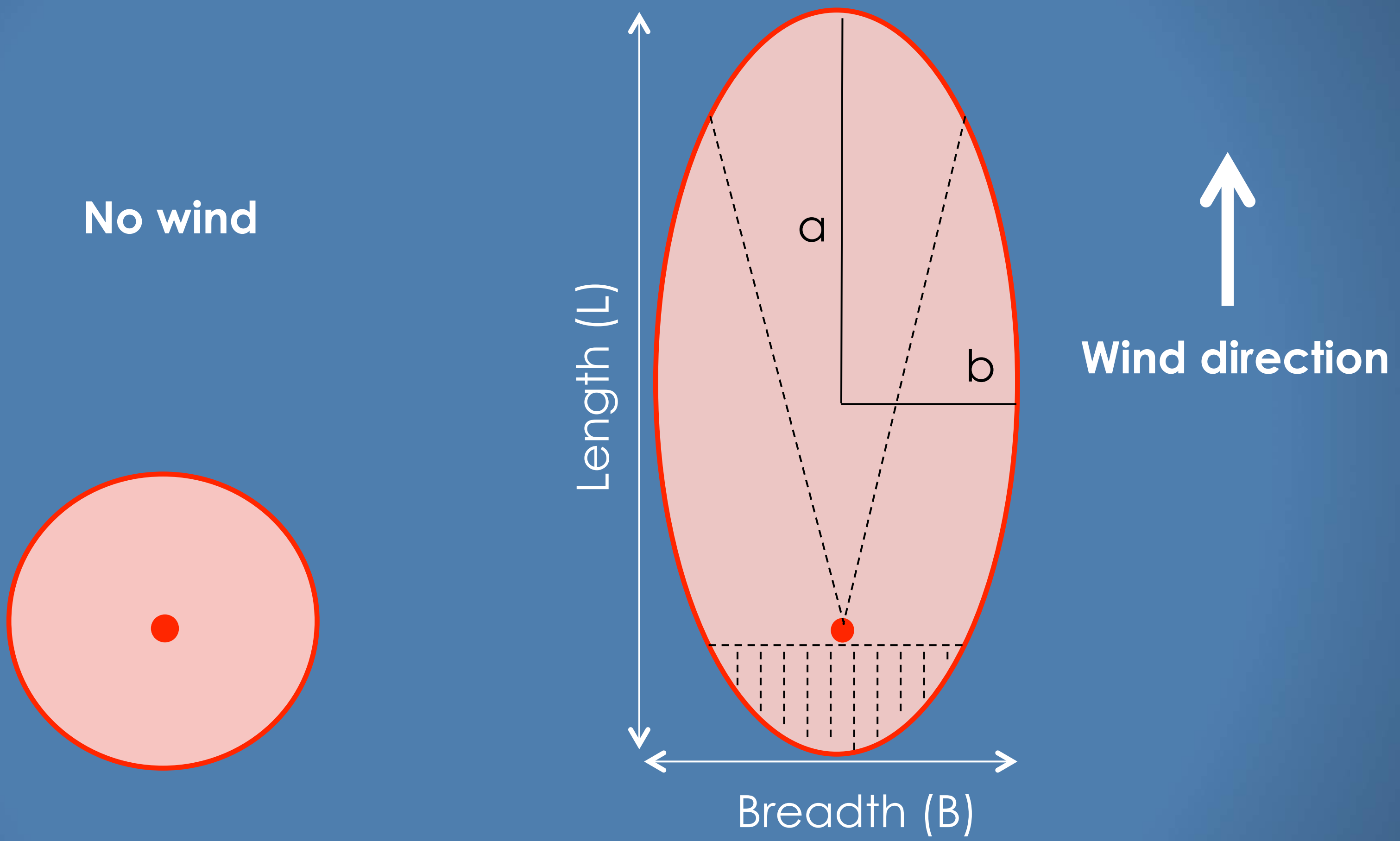
Cruz et al. (2015) A guide to rate of fire spread models, CSIRO

Fire spread in eucalypt forests



McArthur (1967) Fire behaviour in eucalypt forests

Fire growth model

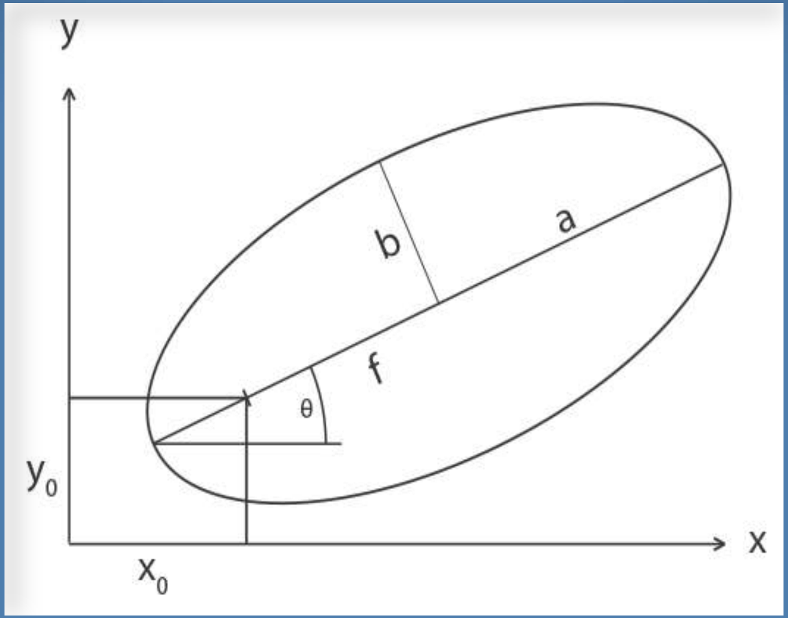


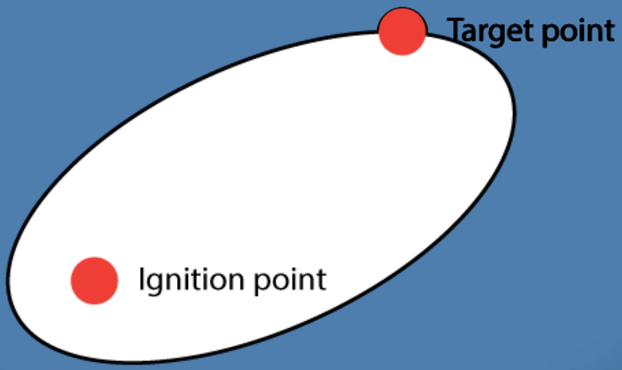
Alexander (1985) The 8th National Conference on Fire and Forest Meteorology

Fire propagation

- Fire spreads in an elliptical shape
- Ellipsis shape determined by the ratio rate of forward spread rate to flanking spread rate
- Direction of major axis is determined by vector addition of wind vector [1] and slope/aspect [2][3]
- We find the arrival time between two points on the grid by solving for the scaling factor *t*

$$\frac{(x-tf)^2}{t^2 a^2} + \frac{y^2}{t^2 b^2} = 1$$

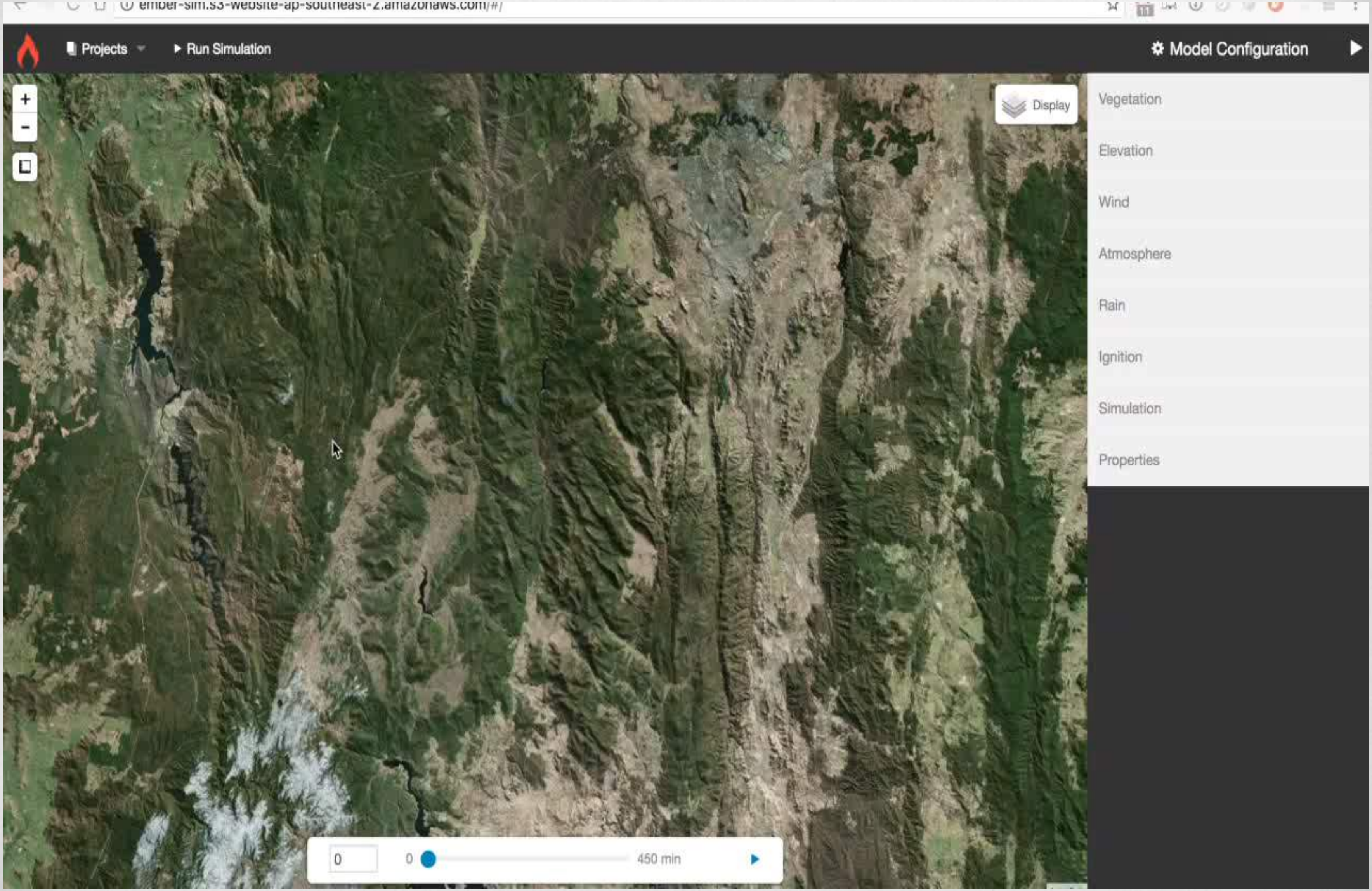




[1] Alexander (1985) Proc. 8th Conf. Fire and Forest Meteorology, 287-304
[2] New South Wales Government (2003) Bush Firefighter Manual
[3] Rothermel (1972) USDA Forest Service Research Paper INT-115

Propagation Algorithm

- For each timestep t_x:
  - Calculate spread rate *R* for each cell
  - Make list L of all cells ignited before t_x
  - For each cell c_i in L:
    - Calculate arrival time $t_{i,j}$ based on elliptical spread from c_i to each neighbour c_j
    - If $t_{i,j} \leq t_x$:
      - Mark c_j as ignited and add to L
  - Apply burn-out model (simple linear model for now)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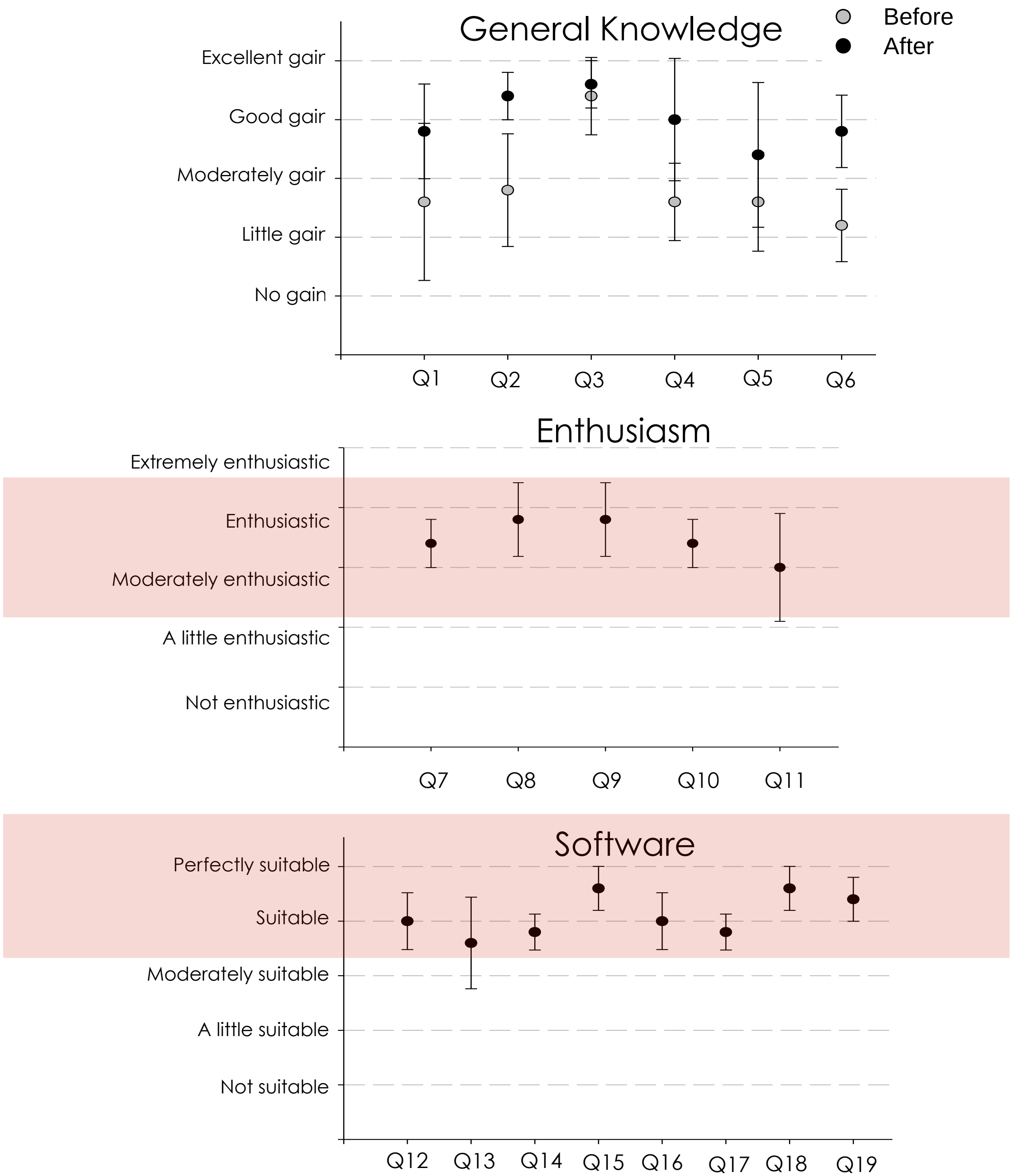
Projects
Run Simulation
Model Configuration
Display
Vegetation
Elevation
Wind
Atmosphere
Rain
Ignition
Simulation
Properties
0
0
450 min

Student learning outcome assessment

- (a) the general understanding of key processes, before and after using the tool
  - Fire spread modelling, key variables
  - Sources of uncertainty, effect of land management
- (b) impact on students' attitude and enthusiasm
  - Enthusiasm for bushfire modelling
  - Comfort and confidence in dealing with complex bushfire scenarios
- (c) user experience
  - Technical features, ease of use in solving practical cases
  - Instructional approach
  - Visualization and data management

Students' learning outcome



Summary

- Dynamic models of the real world and its processes
- Successful application in teaching e.g. Chemistry, Geoscience, geography
- Employs concepts of visualization (animation, interactivity) → active learning
- Re-create aspect of bushfire science and management that are dangerous to do in the field in a conventional classroom setting
- Improved understanding of how operational tools are applied in real-world management and suppression of bushfires
- Improved understanding of how research and technology is translated into operational tools
- Understanding of the concept of spatial models and how spatial data can be incorporated to model ecological, geo-scientific, natural and social phenomena
- Improvement of students' general knowledge, high enthusiasm for the subject, and enjoyable user experience with the software.
- Further development

Thank you for your attention!

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