How Well Does the 10% Wind Speed Rule of Thumb Work for Estimating Wildfire Spread Rates?

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6:15 – 6:45 pm MDT

16th INTERNATIONAL WILDLAND FIRE SAFETY SUMMIT
6th HUMAN DIMENSIONS OF WILDLAND FIRE CONFERENCE

Tuesday, May 25, 2021

General Need for a Rule of Thumb to Estimate Fire Spread

There will undoubtedly be wildfire situations where there is little or no time available to undertake a detailed prediction of fire spread.

Yet, fire operations personnel and others still need to be able to issue warnings to the general public and/or to wildland firefighters based on the fire spread potential.

Photo: Alberta Agriculture & Forestry

2011 Slave Lake Fire, Alberta, Canada

CSIRO file image

2009 Kilmore East Fire, Victoria, Australia

In April 2019 we published an article that described the development of a simple and quick method of judging the forward spread rate of a wildfire when time is of the essence.

Annals of Forest Science (2019) 76: 44
https://doi.org/10.1007/s13595-019-0829-8

RESEARCH PAPER

The 10% wind speed rule of thumb for estimating a wildfire's forward rate of spread in forests and shrublands

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CSIRO PyroPage

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Number 23 | June 2019

A rule of thumb for estimating a bushfire's rate of forward spread using just the speed of the wind

Predictions of fire propagation across the landscape are often used to support planning of fire suppression activities and warn communities of impending threats. However, in many situations there is little time or access to the necessary data to undertake detailed predictions of fire spread. We derived a simple rule of thumb that can be quickly applied to a broad range of fuel types: the rate of forward spread of an established bushfire is equal to approximately 10% of the average 10-m open wind speed.

The need for timely spread predictions

Fire behaviour models are at the core of the prediction of the propagation--the speed, direction and intensity--of fires burning in the landscape. Model predictions, driven by prevailing environmental conditions and adjustments made by a Fire Behaviour Analyst, are coupled with experience and interpretation to determine the location of the fire perimeter at given times. These simulations of fire propagation are then used to support fire suppression decision-making and alert communities threatened by the fire.

Throughout a fire season there will be numerous instances where there will be little or no time available to undertake a detailed prediction of fire propagation. Yet, an incident controller still needs to quickly make critical decisions regarding the potential behaviour and spread of the fire, particularly if lives are at risk. In such situations, simple, uncomplicated and quick to apply rules of potential fire behaviour are required.

New research to address the need

Rules of thumb are frequently used in fire emergencies to make estimations for fire management. We conducted an analysis of many observations of the spread rate of established high-intensity wildfires to investigate the existence and validity of a simple and scientifically credible rule of thumb for predicting bushfire propagation. These observations were sourced from published wildfire case study analyses made on fires burning in a diverse range of fuel types spanning temperate shrublands, Australian dry eucalypt forests, and North American conifer forests. The analysis utilised the prior knowledge that wind speed is the dominant variable driving the spread rate of fires under typical summer-like wildfire conditions (Fig. 1).

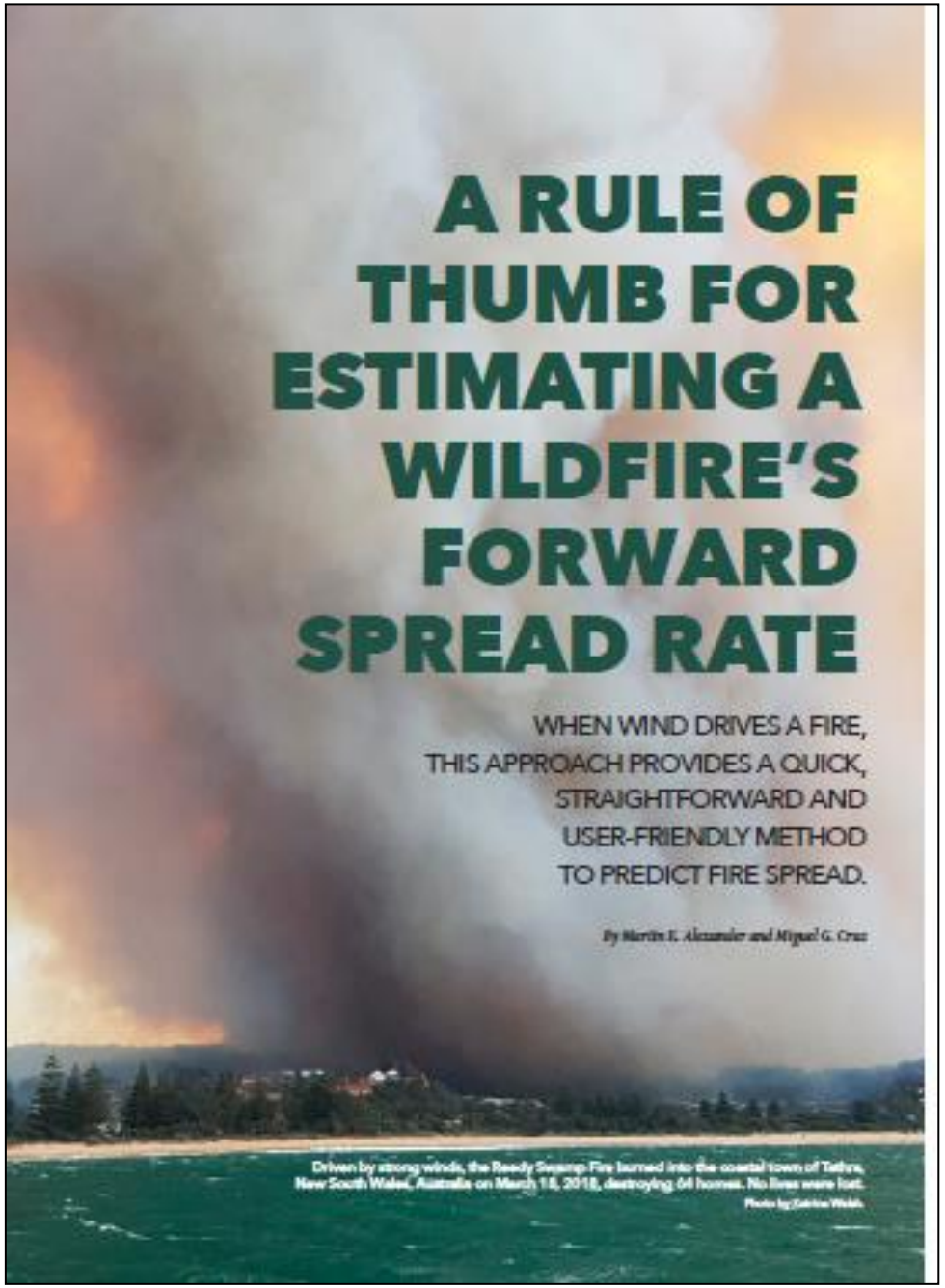
Figure 1. View of a fast approaching wind-driven bushfire from beneath the convection column.

What did we find from our analysis?

Regression analysis indicated that the rate of forward spread of the wildfires (ranging 0.3--10.5 km/h) was consistently about 8% of the average wind speed measured at 10 m in the open, irrespective of the general fuel type. However, because the calculation of 8% of the wind's speed does not readily lend itself to mental arithmetic, we

CSIRO PyroPage Number 23 – June 2019

These summaries on the development of the 10% Wind Speed Rule of Thumb have also been published.



Article in Oct.-Dec. 2019 issue of *Wildfire* magazine

So what exactly is the 10% Wind Speed Rule of Thumb?

Forward Rate of Fire Spread (ROS) ≈
10% of the average 10-m open wind speed

For example, if the 10-m open wind speed where 25 km/h (16 mi/h), then the **ROS** ≈ 2.5 km/h (1.6 mi/h). This is simply "mental math"!

Note: The 10% Rule of Thumb is independent of the unit system used, provided the same units are used for both wind speed and **ROS**.

What where the sources of data used in the development of the 10% Wind Speed Rule of Thumb?

Conifer forests

Alexander ME, Cruz MG (2006) Evaluating a model for predicting active crown fire rate of spread using wildfire observations. *Canadian Journal of Forest Research* **36,** 3015-3028.

Dry eucalypt forests

Cheney NP, Gould JS, McCaw WL, Anderson WR (2012) Predicting fire behaviour in dry eucalypt forest in southern Australia. *Forest Ecology and Management* **280**, 120-131.

Temperate shrublands

Anderson WR et al. (2015) A generic, empirical-based model for predicting rate of fire spread in shrublands. *International Journal of Wildland Fire* **24**, 443-460.

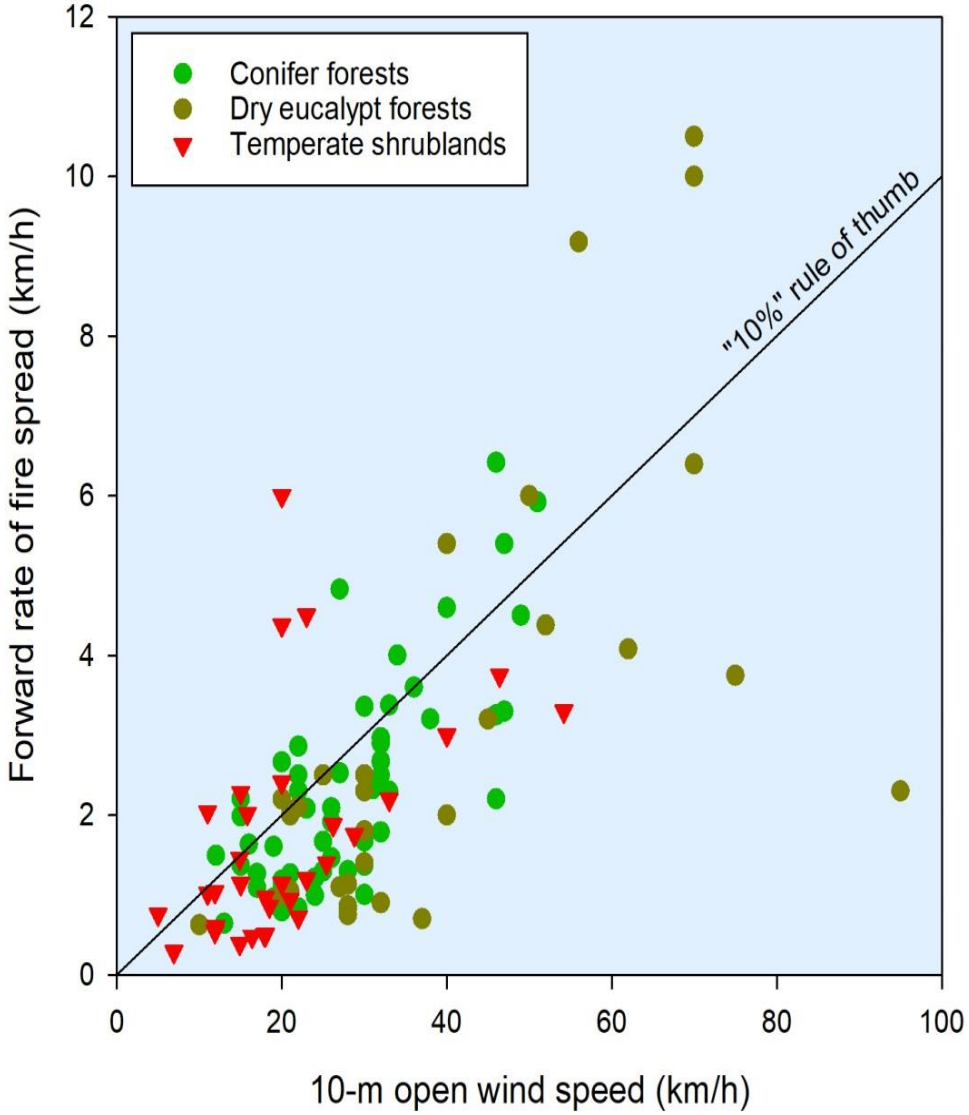
What were the characteristics of the wildfire datasets?

Variable	Conifer forests	Dry eucalypt forests	Temperate shrublands	All fuel types
Number of observations	57	29	32	118
10-m open wind (km/h)	12-51	10-95	5-54	5-95
Fine dead fuel moisture content (%)	5-11	3-10	3-18	3-18
Rate of fire spread(km/h)	0.64-6.4	0.63-10.5	0.29-6.0	0.29-10.5

Duration of the wildfire runs was typically 1 to 3 hours

Includes some of the most notorious wildfires on record

Scatterplot associated with the 10% Wind Speed Rule of Thumb



Feedback on the 10% Wind Speed Rule of Thumb received to date has been positive.

FBAN using the 10% Wind Speed Rule of Thumb on the outbreak of bushfires in New South Wales, Australia, in 2019.

In November 2020 we published on an evaluation study of the 10% Wind Speed Rule of Thumb.

Environmental Modelling and Software 133 (2020) 104818

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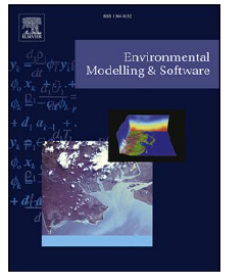
journal homepage: http://www.elsevier.com/locate/envsoft



Check for updates

Evaluating the 10% wind speed rule of thumb for estimating a wildfire's forward rate of spread against an extensive independent set of observations

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Image of the 2016 Rognac Fire on the southern coast of France as taken from the International Space Station by Oleg Skripochka at 17:45 local time on August 10. Ignited at around 15:09 with winds averaging 55 km/h (34 mi/h), its initial run propagated mainly through shrubland fuels at a rate of 5.3 km/h (3.3 mi/h) over the first hour and 20 minutes or so. After this time, as the fire reached industrial and urban areas, the main head broke into smaller separated fronts, slowing it down and eventually limiting its forward spread. The fire advanced nearly 15 km (9.3 mi) from its point of origin, burning an area of 2655 hectares (6560 acres) and impacting 181 houses within the wildland-urban interface over an eight-hour period. No lives were lost.

EVALUATING THE 10% WIND SPEED RULE OF THUMB FOR ESTIMATING A WILDFIRE'S FORWARD SPREAD RATE

BY MIGUEL G. CRUZ and MARTIN E. ALEXANDER

INTRODUCTION

In the October-December 2019 issue of WILDFIRE, we described a recently developed rule of thumb for estimating a wildfire's forward spread rate when burning conditions are severe, namely when wind speeds are high and fuels are critically dry, and the time available to prepare a more exacting prediction is limited (Alexander and Cruz 2019). Based on the analysts of three distinct datasets comprising 118 high-intensity wildfire runs from around the world in forests (conifer- and eucalypt-dominated) and shrublands, rate of spread was considered to be roughly 10% of the prevailing 10-m (33-ft) open wind speed, independent of the unit system used (Cruz and Alexander 2019). For example, given an open wind speed of 25 km/h (16 mi/h), the estimated wildfire spread rate during severe burning conditions would be approximately 2.5 km/h (1.6 mi/h).

Here we present a summary of an evaluation study that analyzed the predictive accuracy of the 10% rule of thumb against two large, independent wildfire datasets. For further details on the study, see Cruz et al. (2020).

THE INDEPENDENT DATA SOURCES

Documented observations of wildfire rate of spread were extracted from two different databases totalling 350 wildfire runs. The analysis focused on the wildfires

These summaries on the evaluation study of the 10% Wind Speed Rule of Thumb have also been published.

Article in Jan.-Mar. 2021 issue of *Wildfire* magazine

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Evaluating the 10% wind speed rule of thumb for estimating a wildfire's forward spread rate

Accurate prediction of wildfire rate of spread under high wind speeds and dry fuel moisture conditions is key to taking effective actions to proactively warn and protect communities. We evaluated an existing rule of thumb that equates forward rate of fire spread to 10% of the average open wind speed against an independent dataset and found the rule predicted the observed rates of fire spread with an overall mean absolute error of less than 2.0 km/h across the range of observed rates of fire spread.

The need for timely spread predictions

In the June 2019 Pyropage (#23), we described a new rule of thumb for quickly estimating a wildfire's forward spread rate when burning conditions are severe(i.e. high wind speeds and critically dry fuels) and the time available to prepare a more exacting prediction is limited (Alexander and Cruz 2019). The analysis of wildfire data collected across the world comprising 118 high-intensity fire runs showed the rate of spread to be roughly 10% of the prevailing 10-m open wind speed. For example, with an open wind speed of 30 km/h, the estimated wildfire spread rate under severe burning conditions would be approximately 3.0 km/h.

Here we present a summary of an evaluation study that analysed the predictive accuracy of the 10% rule of thumb against two large, independent wildfire datasets.

The independent dataset

Documented observations of wildfire rate of spread were extracted from two databases totalling 350 high intensity fire runs. The analysis focused on the wildfires spreading during periods of strong wind speeds (>30 km/h) and low fine dead fuel moisture content values (<7% oven-dry weight). These criteria reduced the data used in the analysis to 88 fire runs. Thirty of these runs came from a database of fires burning in native eucalypt forests of southern Australia compiled by researchers from the Monash University in collaboration with the Victorian Country Fire Authority and Department of Sustainability and Environment (Harris et al. 2011; Kilinc et al. 2012). The rates of fire spread and corresponding wind speeds in this dataset ranged 0.8-8.0 km/h and 30-100 km/h, respectively.

The second dataset consisted of 58 fire runs in shrublands, eucalypt forests and conifer forests garnered from the BONFIRE global fire behaviour database project led by the Universidade de Trás-os-Montes e Alto Douro in Vila Real, Portugal, starting in 2015 (Fernandes et al. 2020). The rates of fire spread and corresponding wind speeds in this dataset ranged from 0.55-12.5 km/h and 30-80 km/h, respectively.

Outcomes of the Analysis

The analysis of the performance of the 10% rule of thumb against wildfires spreading during severe burning conditions revealed:

- Its predictive accuracy is comparable to other evaluation studies of empirical fire spread models using wildfire data.
- No significant differences were observed in error trends between the three fuel types considered (i.e. shrublands, conifer or eucalypt forests).
- An over-prediction bias was detected for fires that spread at rates of less than 2 km/h. This was

CSIRO PyroPage Number 30 – May 2021

What were the characteristics of the independent datasets used in the evaluation study?

Variable	Southern Australia*	Project BONFIRE	Total
Fuel type(s)	Eucalypt Forests	Shrublands, Eucalypt & Conifer Forests	Shrublands, Eucalypt & Conifer Forests
Number of observations	30	58	88
10-m open wind (km/h)	30-100	30-80	30-100
Fine dead fuel moisture content (%)	2.5-6.2	2.0-7.0	2.0-7.0
Rate of fire spread (km/h)	0.8-8.0	0.55-12.5	0.55-12.5

*Compiled by Monash University in cooperation with the Country Fire Authority and the Department of Sustainability & Environment of Victoria, Australia.

**Coordinated by the Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

We also explored in some depth the adequacy of the 10% Wind Speed Rule of Thumb in relation to the observed spread rates of five recent fatality fires:

- 2009 Kilmore East Fire, Victoria, Australia

- 2017 Tubbs Fire, California, USA

- 2017 Arganil – Seia Fire, Portugal

- 2018 Mati Fire, Greece

- 2018 Camp Fire, California, USA

What were the main conclusions of the evaluation study?

1. The predictive accuracy of the 10% wind speed rule of thumb is comparable to other evaluation studies of empirical fire spread models based on using wildfire data.

2. No significant differences were observed in error trends between the three fuel types.

3. An over-prediction trend was detected for fires that spread at rates <2.0 km/h; this was also observed in the development of the rule of thumb.

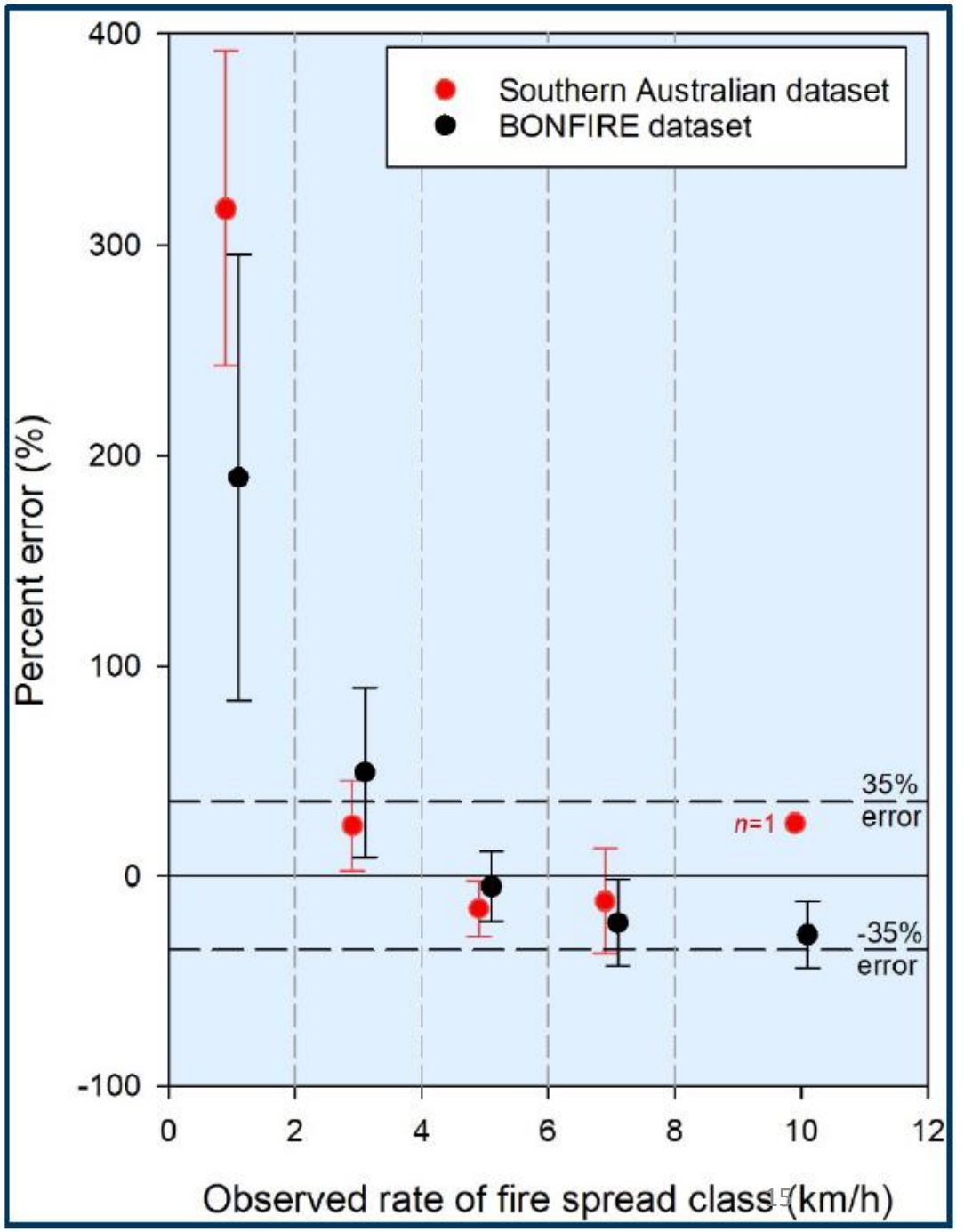
continued …

4. The rule of thumb works best for wildfires spreading at rates >2.0 km/h.

As shown in the accompanying graph, most of the wildfires from the two independent datasets were within the ±35% error prediction band.

Percent Error =

$$\frac{\text{Predicted ROS} - \text{Observed ROS}}{\text{Observed ROS}} \times 100$$



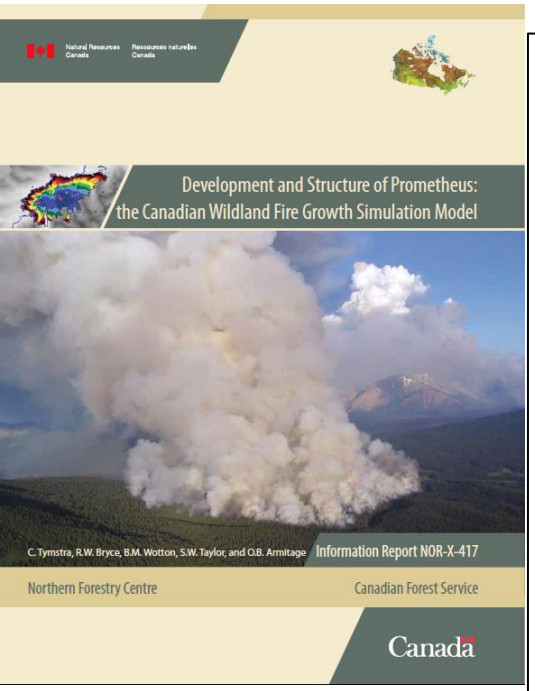
What are the principal assumptions and limitations of the 10% Wind Speed Rule of Thumb?

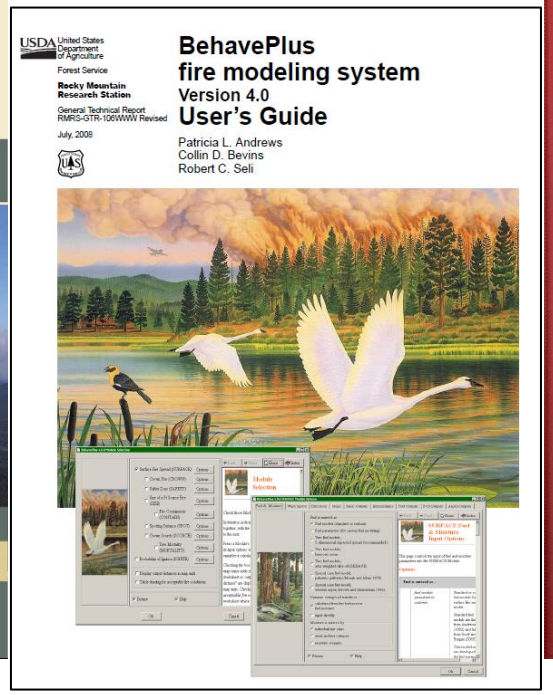
- Wind speed is either measured and/or forecasted for a standard 10-m open height.
- Applicable to large, multi-hour wildfire runs.
- Wildfire is spreading on level to undulating topography or across drainages with alternating upslope and downslope runs in either conifer forest, dry eucalypt forest and/or shrubland fuel types; not applicable to grasslands but has shown to work in mountain pine beetle-attacked forests.

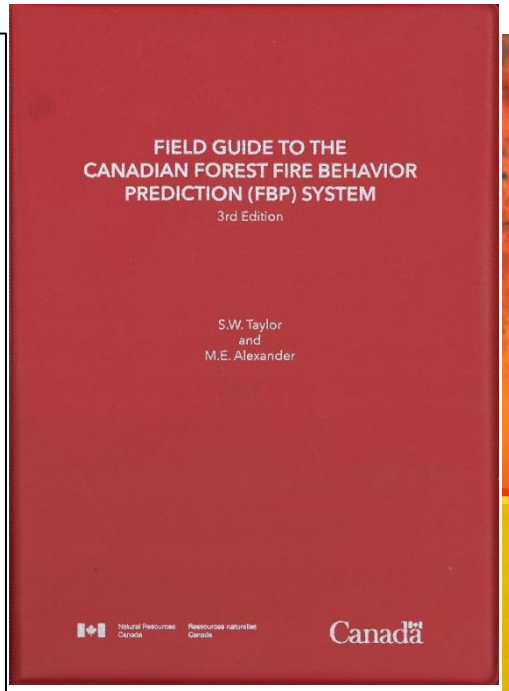
continued …

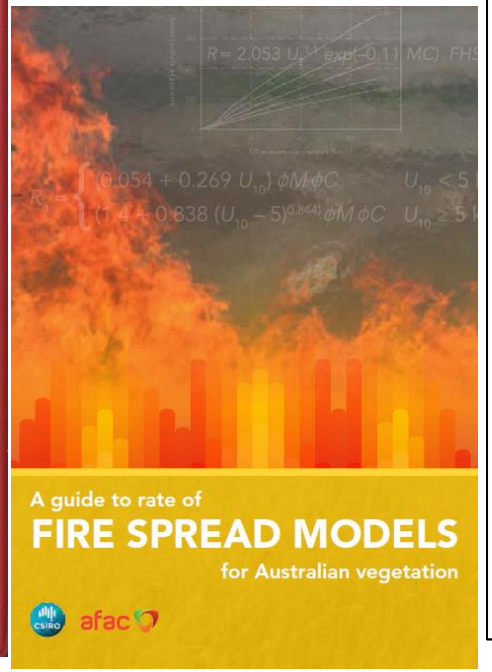
- A homogeneously dry landscape is assumed (e.g., Australian Drought Factor >9.0). It works best when fine dead fuel moisture content is low (i.e., <7%; even better if ≤5%) and winds are >30 km/h. Its use under moister conditions and with winds <30 km/h will tend to result in over-predictions.
- The effect of spotting in determining the overall fire spread rate is implicitly accounted for. Any long-range spot fires >10-15 km will result in under-predictions.
- There are no appreciable barriers to fire growth; existent ones are easily overcome by spotting.

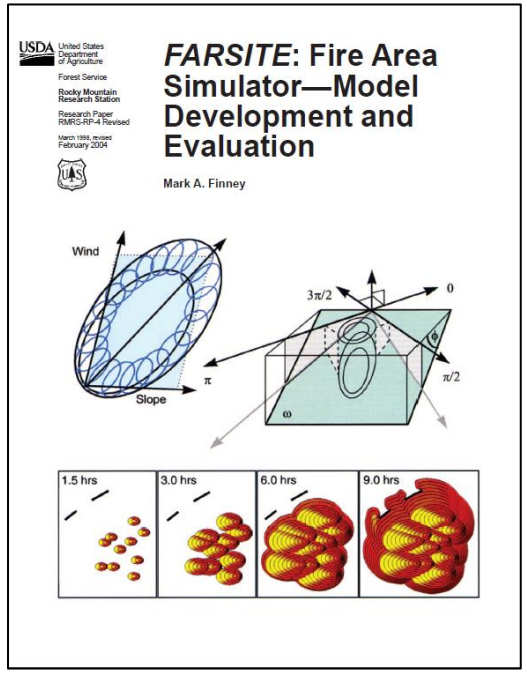
The 10% Wind Speed Rule of Thumb is not intended as a replacement for any of the more traditional empirical-based fire spread guidelines or modelling systems.











What is a “Rule of Thumb”?

- A principle with broad application that is not intended to be strictly accurate or reliable for every situation.
- It refers to an easily learned and easily applied procedure or standard, based on practical experience rather than theory.

Wildfires burning under the influence of strong winds coupled with critically dry fuels are the kind of conditions that typically surprise emergency response agencies and communities due to the rapid associated spread rates.

U.S. National Park Service

Could a simple rule of thumb like the one described here have provided a better appreciation of the fire propagation potential and possibly averted the fatalities associated with past wildfire disasters?

Tubbs Fire, Northern California, USA
Initial Run of October 8-9, 2017

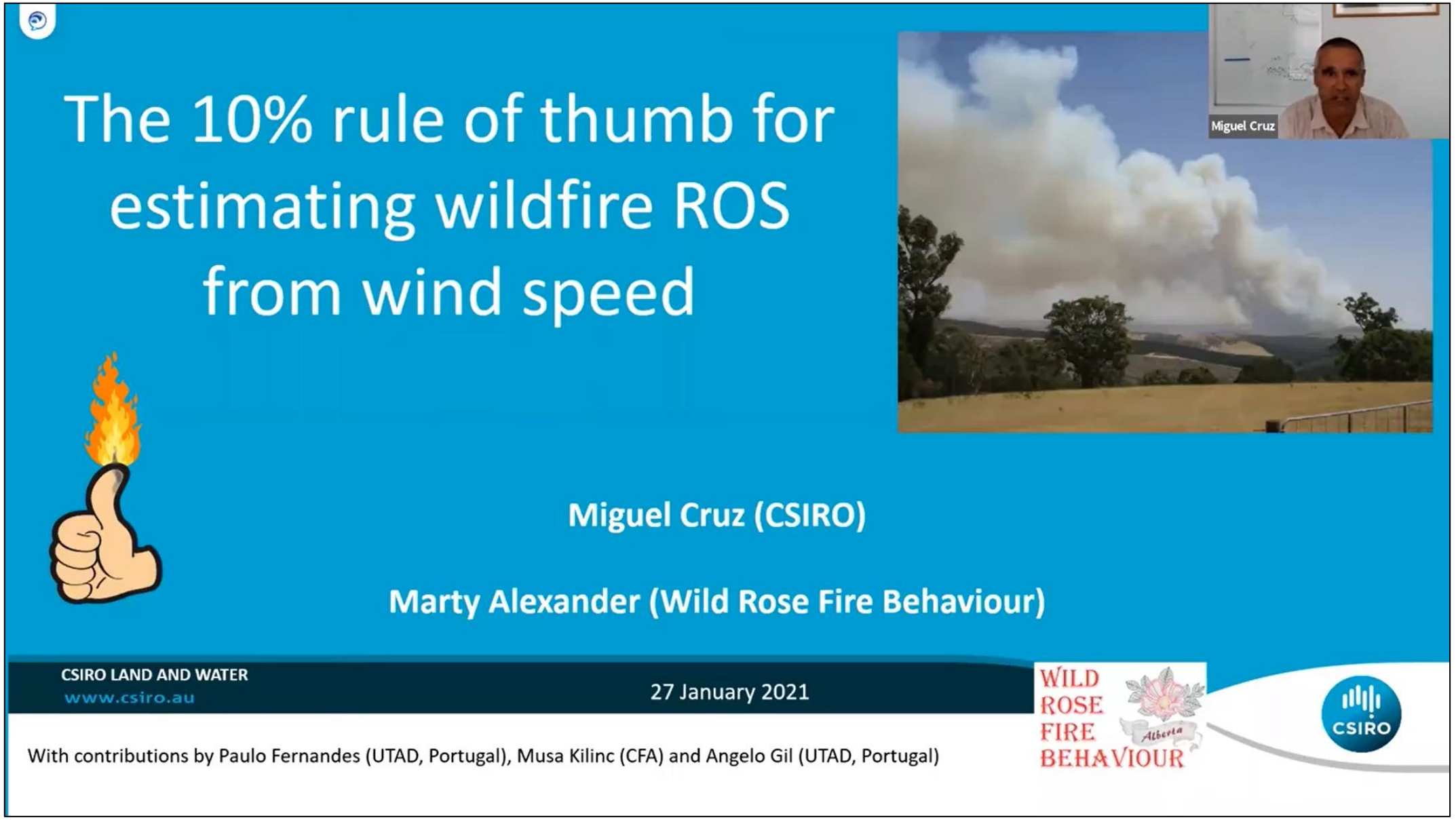
- 22 persons were killed in Santa Rosa;
  5643 structures destroyed
- ROS: 3.0-5.2 km/h
- 10-m Open Winds: 32-70 km/h
- 10% Rule of Thumb estimate:
  3.2-7.0 km/h

- Wildfire first detected at 9:43 pm and started impacting WUI communities within 3 hours; an evacuation order for Santa Rosa was not issued until 11:58 pm (2 hours and 15 minutes after detection).

So What's Next?

- This is hopefully not the last word on the 10% Wind Speed Rule of Thumb. The evaluation of fire behaviour guidelines and modelling systems should be viewed as an ongoing process.
- Data will continue to be added to the Southern Australia and BONFIRE databases as they become available.
- Publications will be produced and other technology and information transfer activities undertaken as appropriate.
- We need your feedback on experiences with using the 10% Rule of Thumb. Please feel free to contact one or both of us.

For a more detailed discussion, see:



https://www.youtube.com/watch?v=o7qCfbWBRy0

Thank you your attention!

Questions and comments are welcome.

If you wish to contact us and/or request any of the publications mentioned here:

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WILD ROSE FIRE BEHAVIOUR Alberta

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