Natural Resources Canada   Ressources naturelles Canada

Infrared Remote Sensing of Wildfire Behaviour

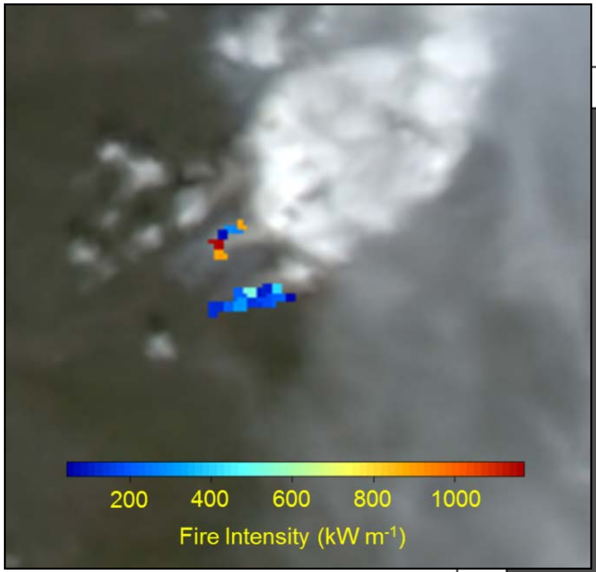
Joshua Johnston
Canadian Forest Service
King's College London, UK

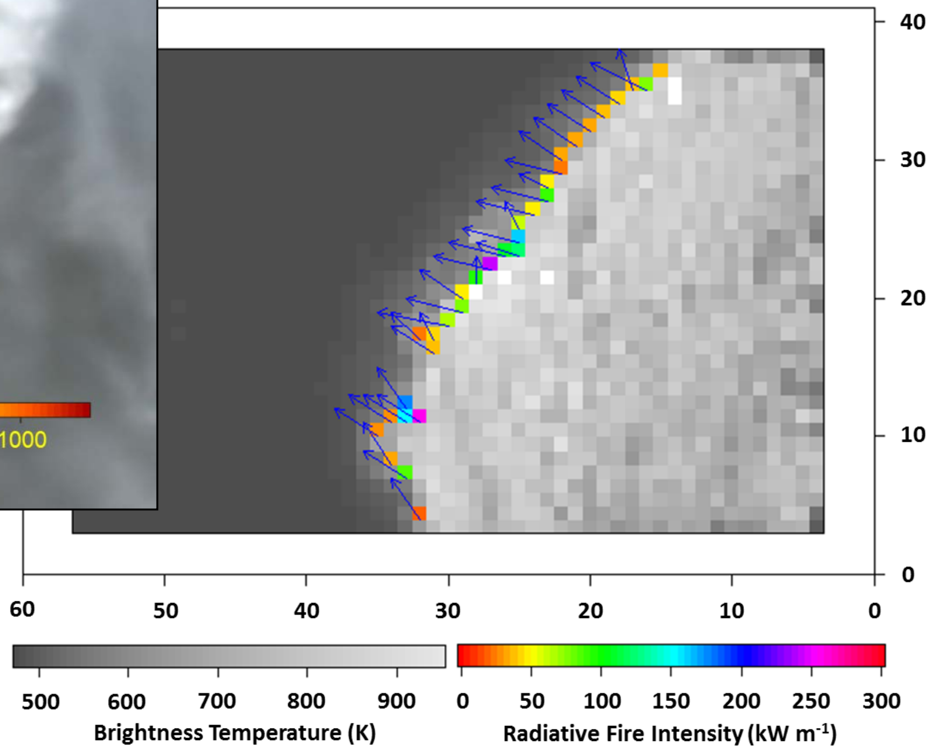
Ronan Paugam
King's College London, UK
University of Washington

Martin Wooster
King's College London, UK

Tim Lynham
Canadian Forest Service

Lynn Johnston
Canadian Forest Service





Canada

King's College London
University of London

CSA ASC

Canada

Heat Transfer

Convection

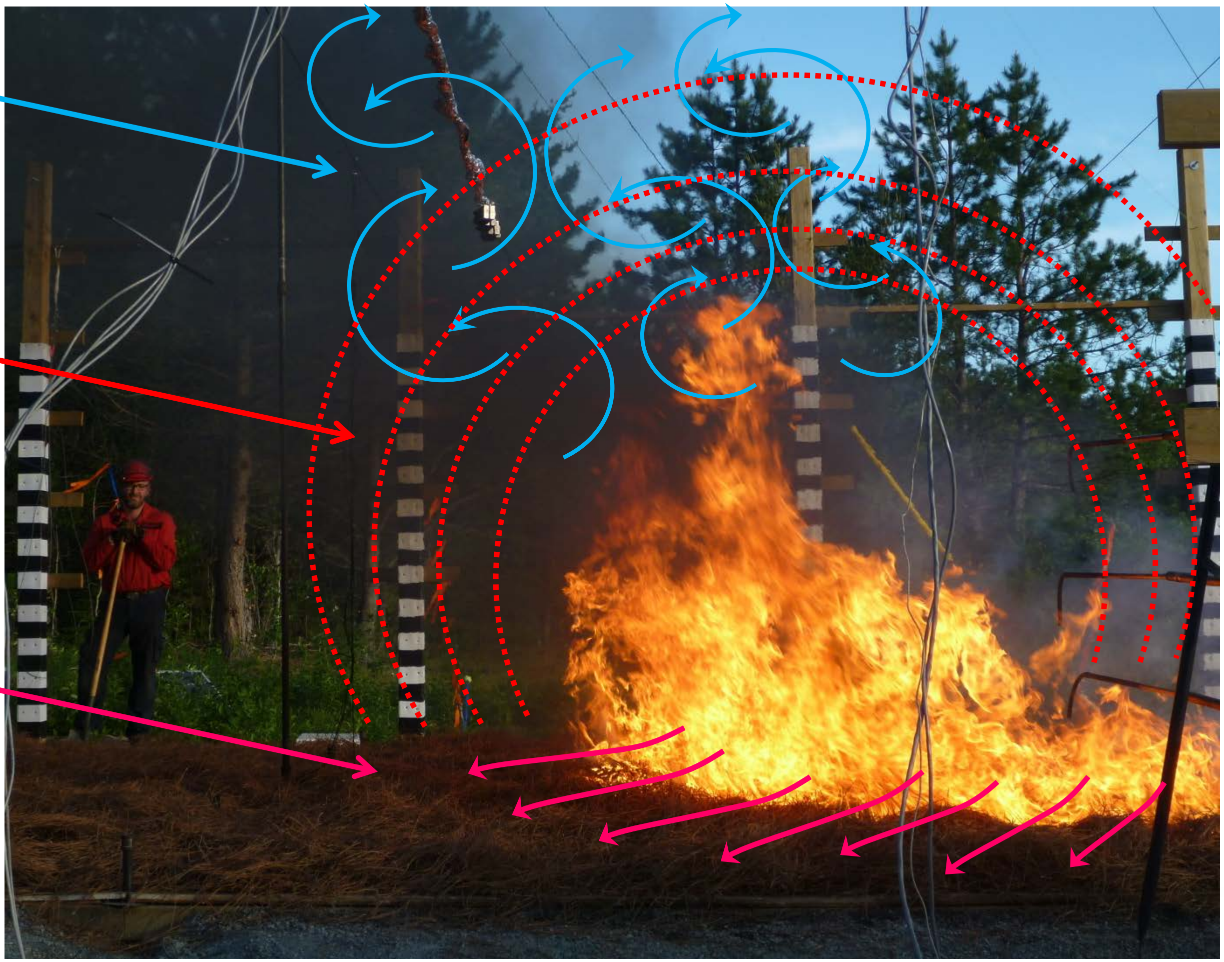
- Particle energy physically moves the body

Radiation

- Energy is emitted via electromagnetic energy

Conduction

- Particles transfer kinetic energy via collisions



Heat Transfer

Convection

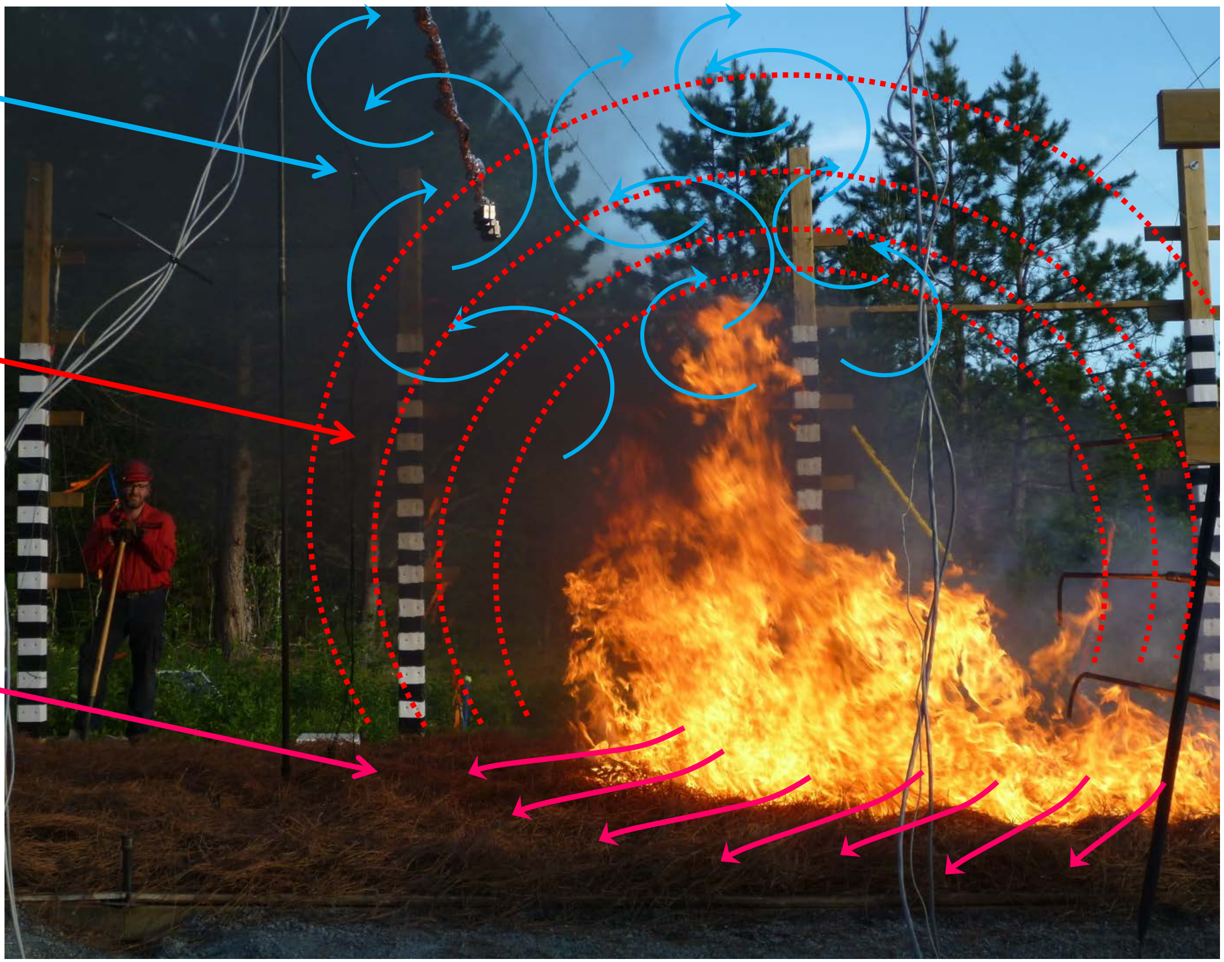
- Particle energy physically moves the body

Radiation

- Energy is emitted via electromagnetic energy

Conduction

- Particles transfer kinetic energy via collisions



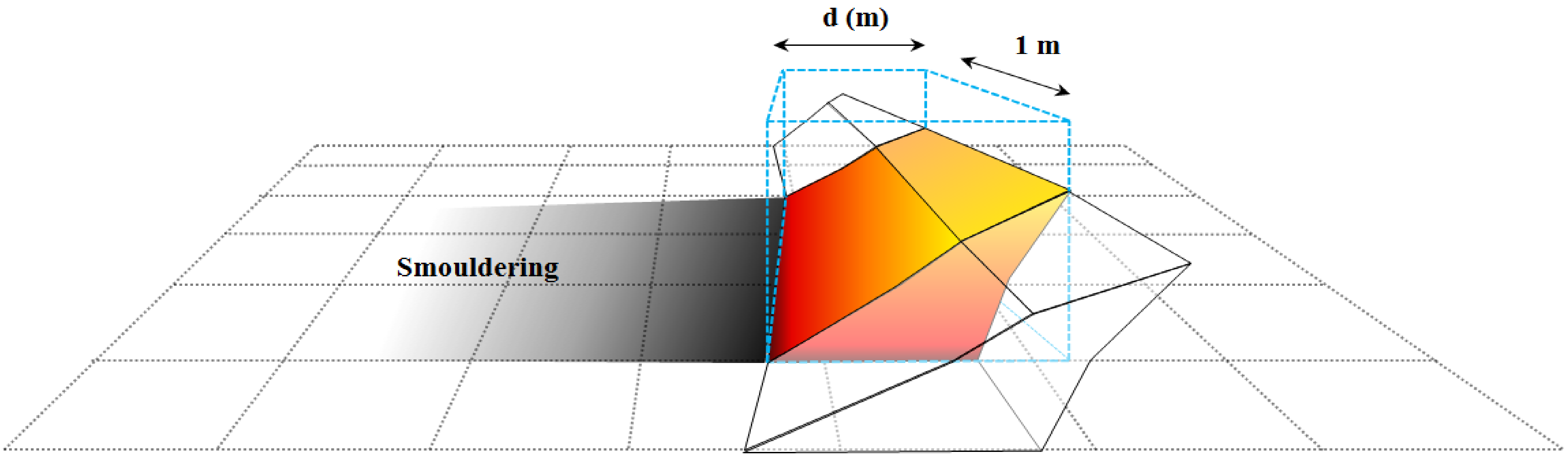
Calculating Fire Intensity

Byram's Equation: $FI = Hwr$

Where:

- FI = fire intensity (kW m^{-1})
- H = low heat of combustion (kJ kg^{-1})
- w = fuel consumed (kg m^{-2})
- r = ROS (m s^{-1})

* FI is calculated based on measurements of H, w, and r



(Byram, 1959)

Calculating FI: Part 2

Byram's *other* equations

FI = Er

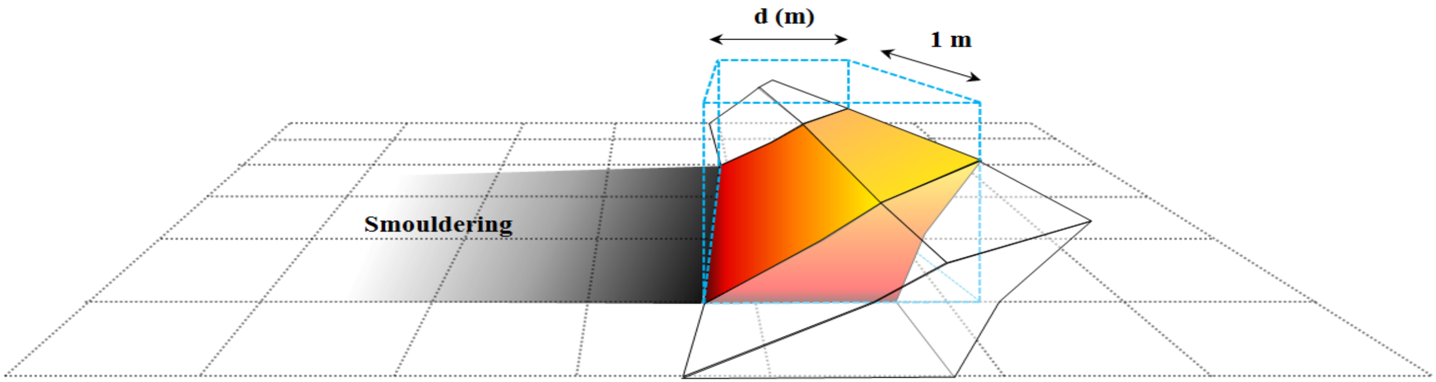
Where:

FI = fire intensity (kW m^{-1})
E = available fuel energy (kJ m^{-2})
r = ROS (m s^{-1})

FI = Rd

Where:

FI = fire intensity (kW m^{-1})
R = combustion rate (kW m^{-2})
d = depth of the combustion zone (m)



Calculating FI: Part 3

Byram meets FRP

FI = Er $\approx$ $FI_{rad} = FRE \times ROS$

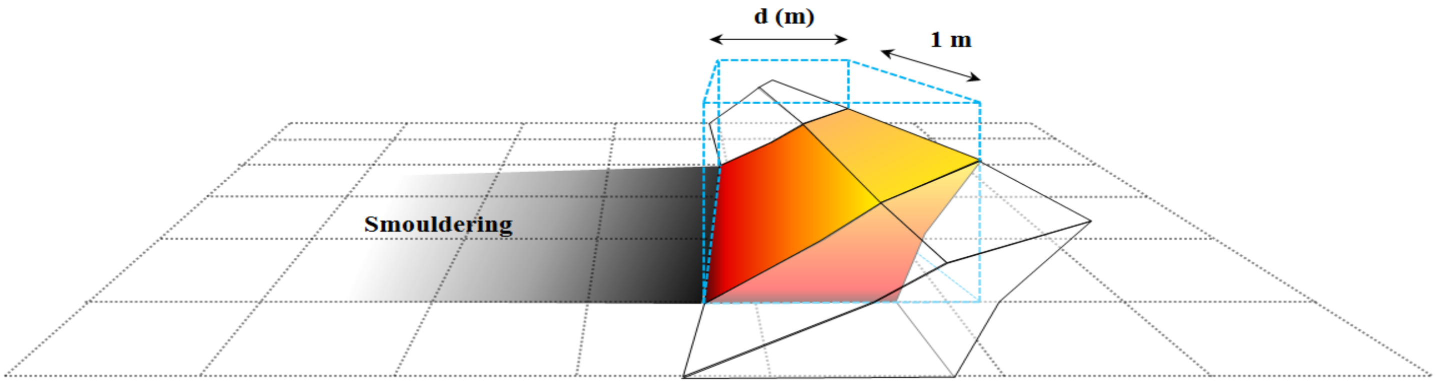
Where:

FI = fire intensity (kW m^{-1})
E = available fuel energy (kJ m^{-2})
r = ROS (m s^{-1})

FI = Rd $\approx$ $FI_{rad} = FRP \times d$

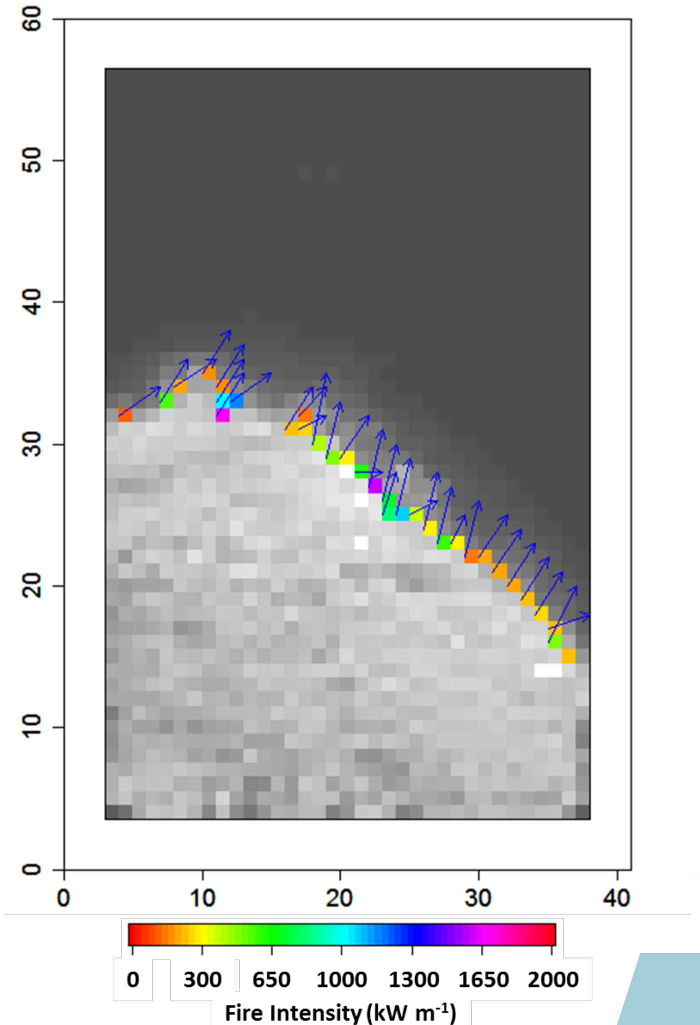
Where:

FI = fire intensity (kW m^{-1})
R = combustion rate (kW m^{-2})
d = depth of the combustion zone (m)

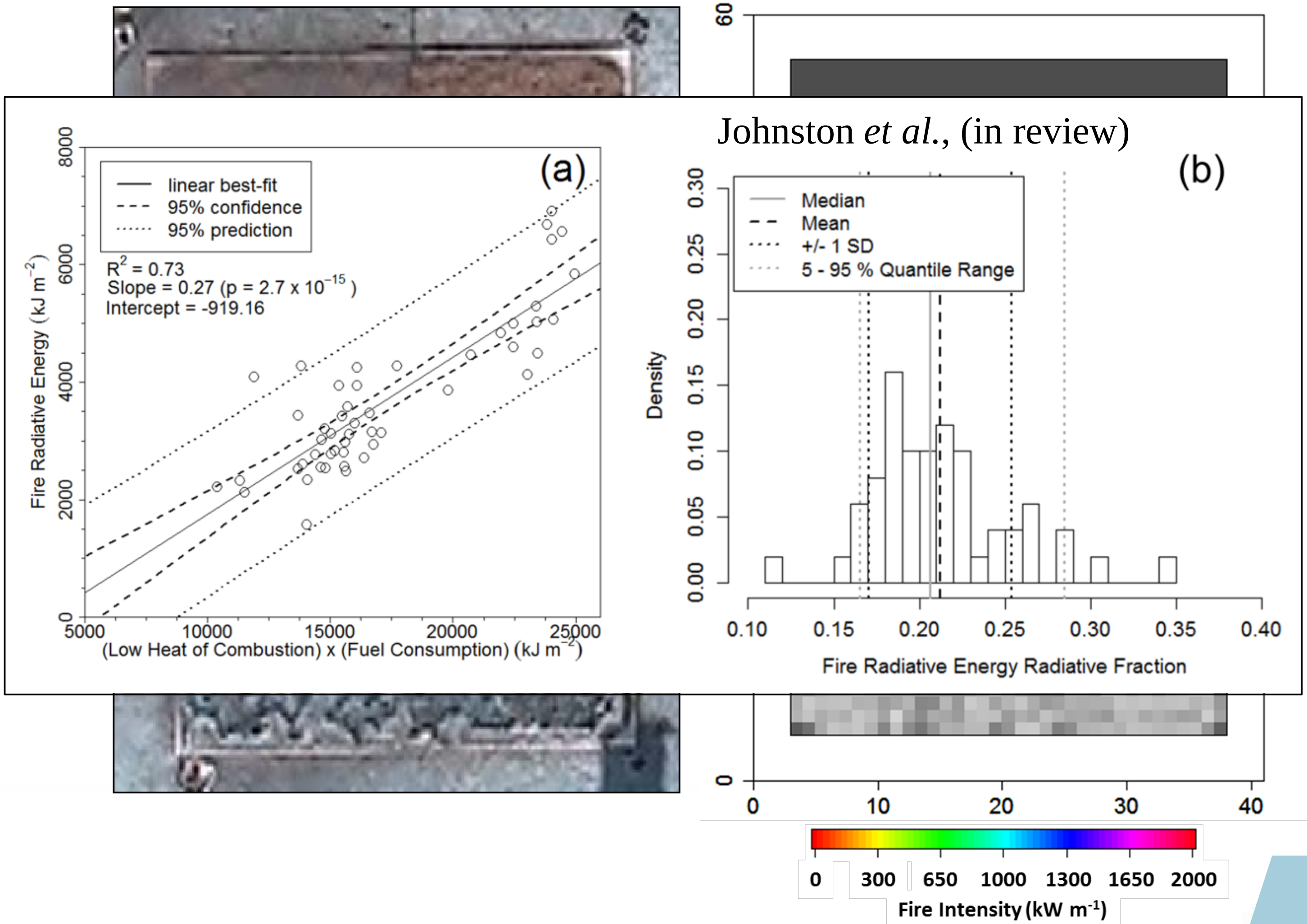


(Johnston, 2016)

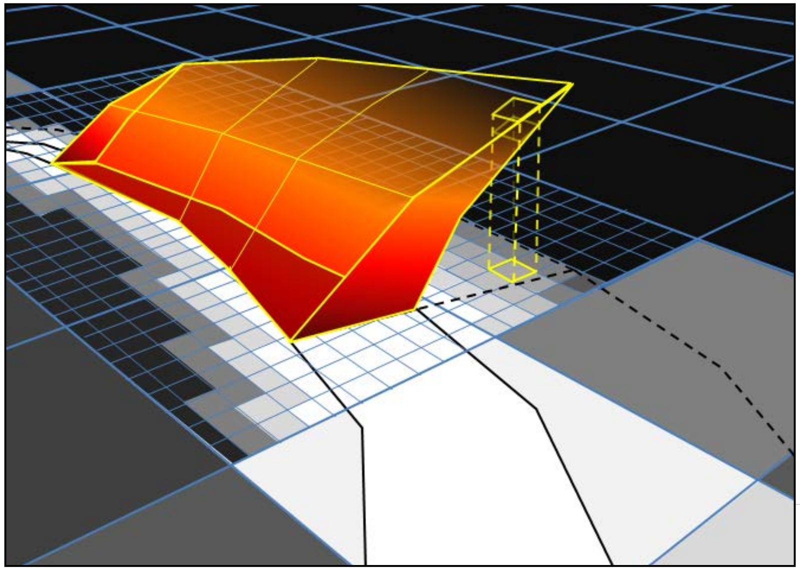
High-Resolution Fire Intensity Imaging

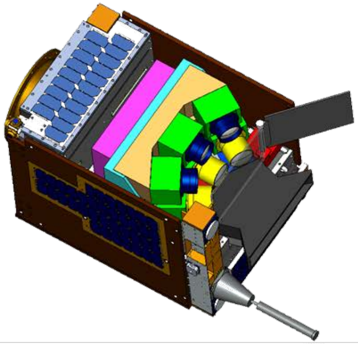


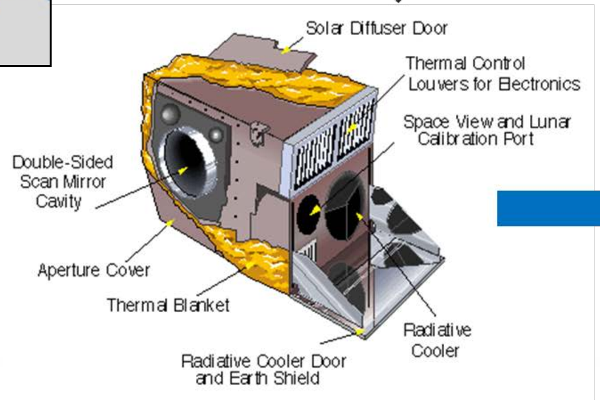
High-Resolution Fire Intensity Imaging

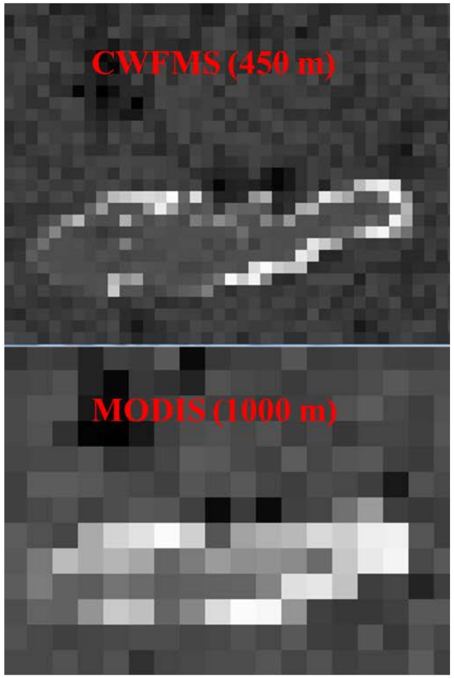


Simulating Landscape Scale Imagery









MODIS Fire Intensity:

FRP-FD: $R^2 = 0.90$ ($p = 0.001$)
RadF = 0.11

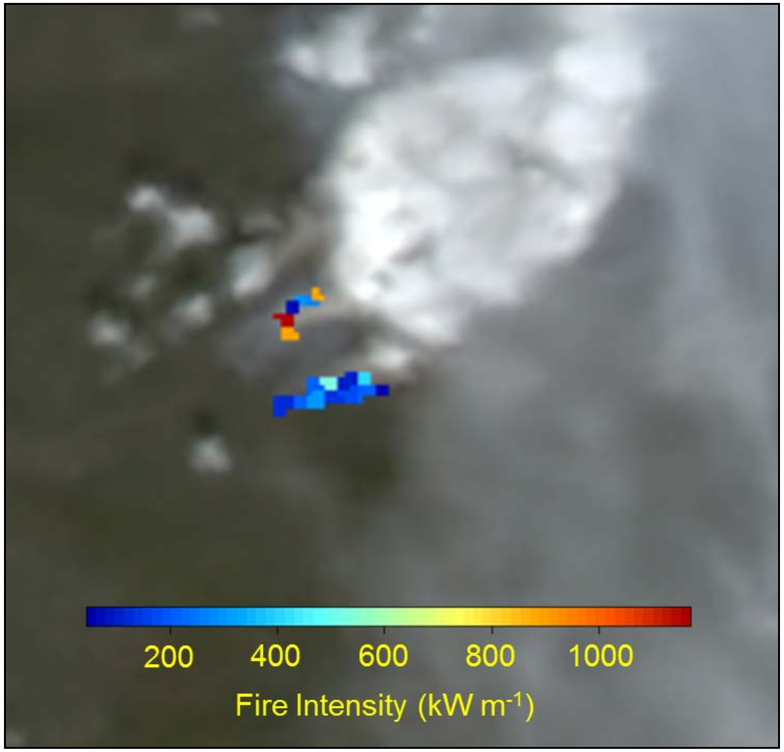
S and W: $R^2 = 0.82$ ($p = 0.002$)
RadF = 0.06

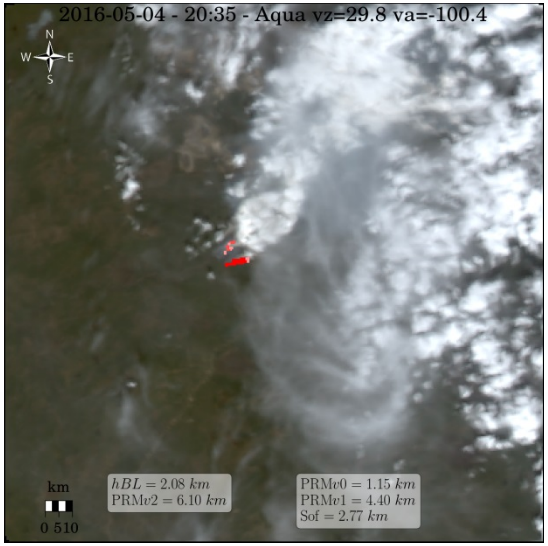
[S and W = Smith and Wooster (2005) method]

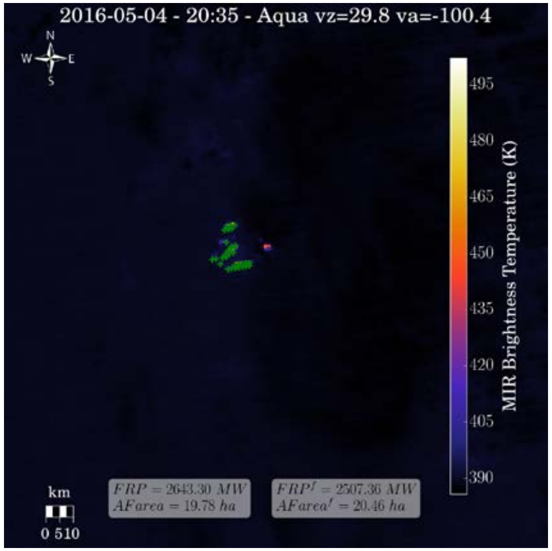
(Johnston, 2016)

Measuring Fire Intensity with MODIS

May 4, 2016
Satellite: Aqua
Time: 14:35 MDT
VZ: 29.8^{o}
GSD_{mean}: 1.23 km

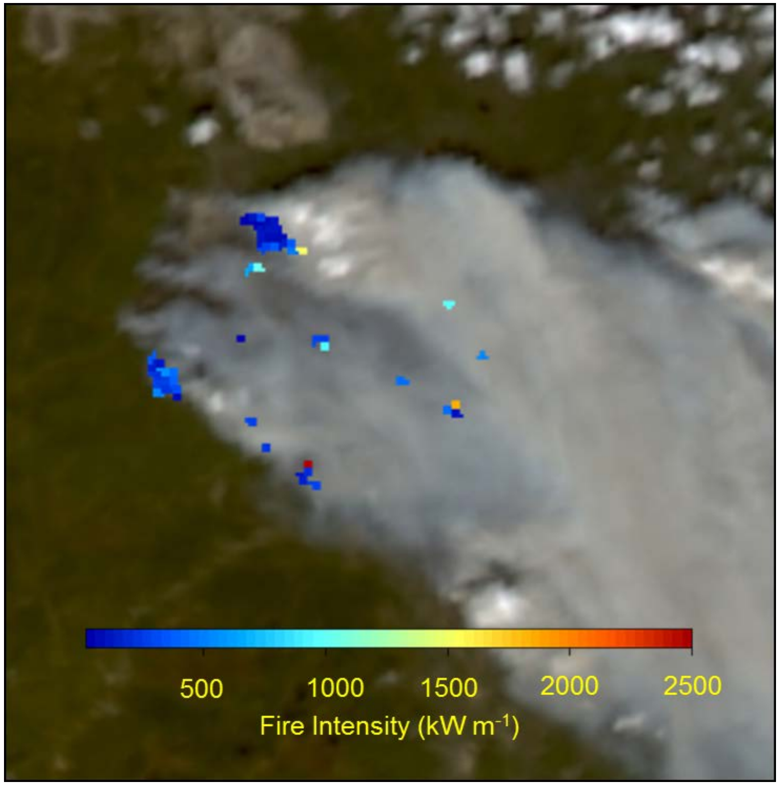


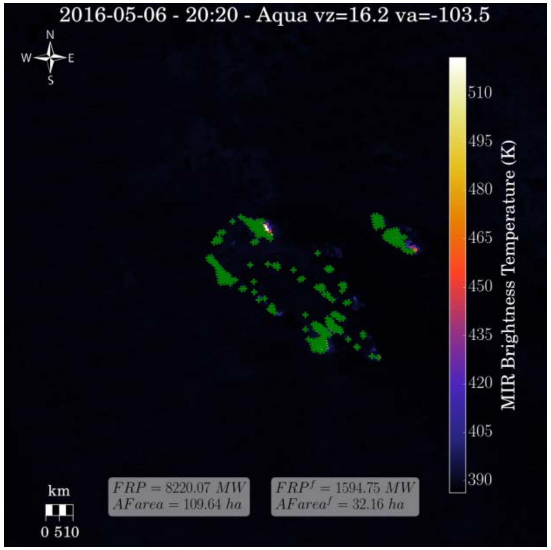




Measuring Fire Intensity with MODIS

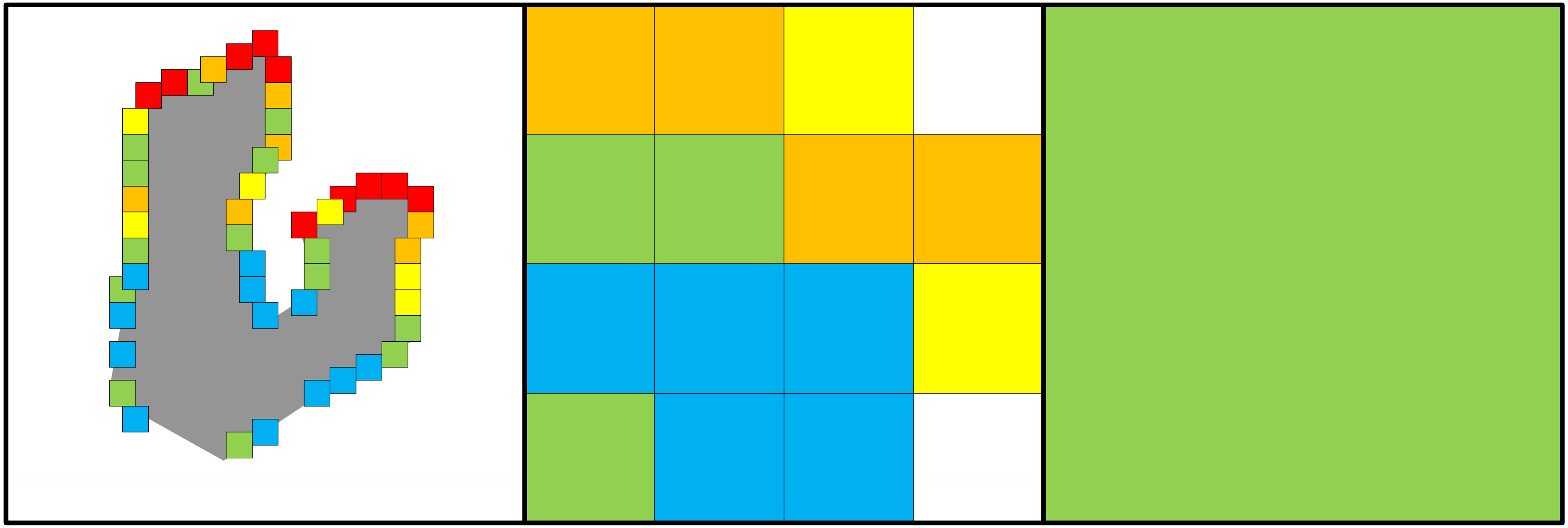
May 6, 2016
Satellite: Aqua
Time: 14:20 MDT
VZ: 16.2^o
GSD_{mean}: 1.06 km





So what's the deal with MODIS?

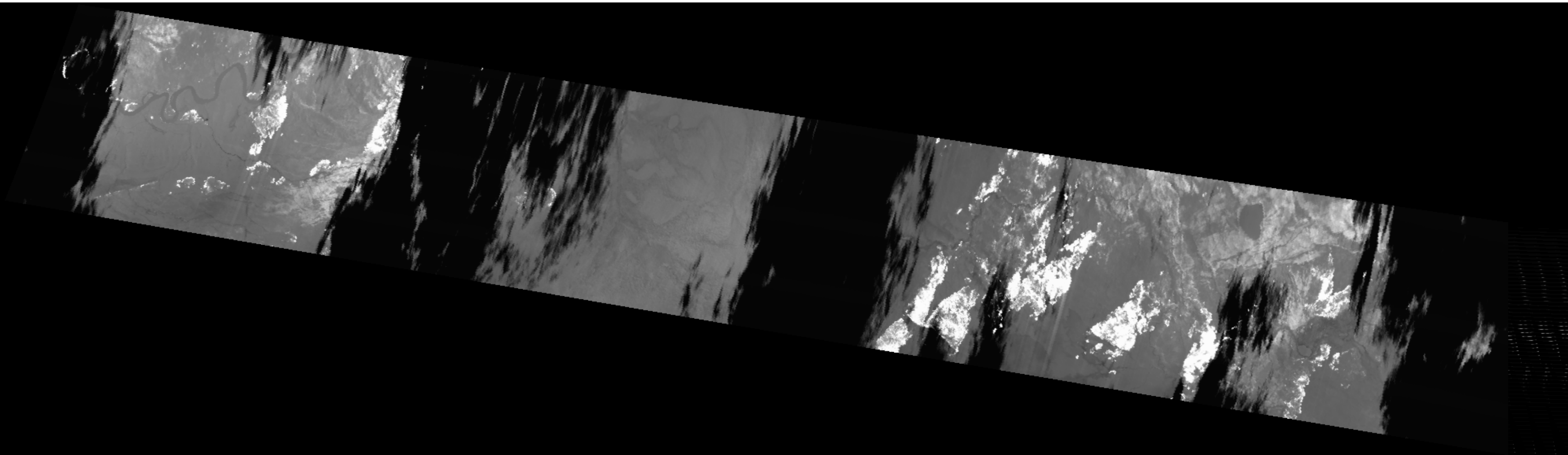
- MODIS does have some uncertainty with individual pixel FRP, which can be reduced by summing over multiple pixels (Freeborn *et al.*, 2014)
- Forest canopy interception of surface fire radiance can reduce FRP (Johnston, 2016; Mathews *et al.*, 2016)
- **But the low FI values here are more likely a question of scale…**



What is the optimum spatio-temporal resolution?

- What is your purpose?

- Ideally fire behaviour should be imaged at spatial resolutions of <100 m
  - Imaging at resolutions of < 5 m allows for detection of anomalous fire behaviour, but also introduces noise
  - This is appropriate for airborne imaging
- Rate of spread can be measured up to a spatial resolution of ~ 500m with 2-3 hour revisit period
- It is probable that spatial resolutions of 100 – 500 m are the most practical satellite scale allowing reasonable revisit times and avoiding detector saturation



Next Steps

- Continue to improve this product through foundational science
- Introduce the current product to CWFIS
- Work with airborne IR specialists to implement this in operational fire imaging
- Work with CSA and international agencies to obtain the optimum satellite system

Photo: Bo Lu, CFS

REFERENCES

Byram, G. M. (1959). Combustion of Forest Fuels. In K. P. Davis (Ed.), Forest fire: control and use (pp. 61-89). New York: McGraw-Hill.

Freeborn, P. H., Wooster, M. J., Roy, D. P., & Cochrane, M. A. (2014). Quantification of MODIS fire radiative power (FRP) measurement uncertainty for use in satellite-based active fire characterization and biomass burning estimation. *GEOPHYSICAL RESEARCH LETTERS, 41*, 1988-1994. doi: 10.1002/2013GL059086

Johnston, J. M. (2016). *Infrared Remote Sensing of Fire Behaviour in Canadian Wildland Forest Fuels.* (Doctor of Philosophy), King's College London.

Johnston, J. M., Wooster, M. J., Paugam, R., Lynham, T. J., & Johnston, L. M. (in review). Direct calculation of Byram's fire intensity from infrared remote sensing imagery. *International Journal of Wildland Fire*. WF16178

Mathews, B. J., Strand, E. K., Smith, A. M. S., Hudak, A. T., Dickinson, M. B., & Kremens, R. L. (2016). Laboratory experiments to estimate interception of infrared radiation by tree canopies. *International Journal of Wildland Fire, 25*, 1009-1014. doi: 10.1071/WF16007

Smith, A. M. S., and M. J. Wooster. 2005. "Remote classification of head and backfire types from MODIS fire radiative power and smoke plume observations." *International Journal of Wildland Fire* no. 14:249-254. doi: 10.1071/WF05012.


Thank you
Questions?
SURE SEAL
DOUBLE BOTTOM
DRIP TORCH