An improved canopy wind model for predicting wind adjustment factors and wildland fire behavior

W. J. Massman
J. M. Forthofer, M. A. Finney

US Forest Service
Rocky Mountain Research Station
Fort Collins, CO & Missoula, MT

AMS – Salt Lake City – June 2016
Current models used to predict the spread rate of prescribed fire require input wind speed at a height of 20 feet above the top of a canopy to make a rapid estimate of the output wind speed beneath the canopy or near the ground.

- output wind speed/input wind speed = WAF
- spread rate = Metric of Fire Behavior
- rapid = numerically efficient and robust to uncertainties in input parameters
Current (Albini) Wind Model

(a) Logarithmic profile above
(b) \( \frac{d}{h}, \frac{z_0}{h} = \) full canopy
(c) No foliage structure
(d) Uniform profile within

New (Massman) Model

(a) Logarithmic profile above
(b) Function of LAI, \( a(z), C_d \)
(c) Variable structure
(d) Function of LAI, \( a(z), C_d \)

Logarithmic wind profile
\[
\frac{u(z)}{u(h)} = \ln\left(\frac{[z/h - d/h]}{z_0/h}\right)
\]

- \( z \) = height above the ground
- \( h \) = canopy height
- \( z_0 \) = roughness length
- \( d \) = displacement height

Uniform Wind Profile
\[\xi_{\text{max}}, \sigma_u, \sigma_l\]

- Aspen: \([0.36, 0.60, 0.20]\)
- Scots Pine: \([0.60, 0.30, 0.10]\)
- Jack Pine: \([0.58, 0.20, 0.20]\)
- Loblolly Pine: \([0.60, 0.27, 0.10]\)
$l =$ Loblolly Pine
$h =$ Hardwood
$s =$ Scots Pine
$j =$ Jack Pine
$p =$ Spruce
$a =$ Aspen
$c =$ Corn
$r =$ Rice

$\frac{z_0}{h}$ vs $\zeta(h)$

$\zeta_{\text{max}} = 0.2$
$\zeta_{\text{max}} = 0.5$
$\zeta_{\text{max}} = 0.8$

$\zeta(h)$ -- Drag Area Index $= C_d \text{LAI}$
Albini vs. Massman Spread Rate

Unsheltered

Spread Rate (ft/h)

Canopy Cover

Sheltered
Conclusions

(1) New model is more physically realistic than the older model and its predictions of WAF and spread rate are reasonable.

(1) Model WAF is not particularly sensitive to foliage distribution, but it is sensitive to LAI and $C_d$ and to the ground surface roughness length. This latter sensitivity is most significant for unsheltered fires in ecosystems of sparse canopy cover.

(3) The “universal” wind profile developed for this study does work well for full or complete canopies and it needs further verification in sparse or thin canopies where LAI < 1.
Thank you!

Questions?