MATLAB vs. WFA

By: Jeremy Benik

January 7, 2023

This document will cover the underlying equation in both the matlab code (fire _ros.m and the WFA c++ code. To create a baseline test, I will be using the same example throughout the codes. Using the Albini codes, I will use fuel category 1 (short grass) with a dead fuel moisture of 3%, and no wind and no slope for simplification. Then after this test I will include slope and wind conditions to further analyze the models to check for any differences. Please note, my knowledge of c++ is very limited so going through some of these calculations may seem unnecessary at first but they are necessary for me to understand the code.

1 MATLAB

The code I'm going to use is fire_ros.m from WRF-SFIRE. I will be going through each calculation, explaining each calculation, and seeing what the value is.

Starting the analysis

BMST

$$\begin{aligned} bmst &= fuelmc\_g/(1 + fuelmc\_g) \\ 0.0291 &= 0.03/(1 + 0.03) \end{aligned} \tag{1}$$

Equation 1 calculates the fuel moisture given a fuel moisture parameters. In this calculation, this would result in bmst = 0.0291. This is the relative water content `https://github.com/openwfm/WRF-SFIRE/blob/master/phys/module_fr_sfire_phys.F#L1327`.

Fuelheat

The next equation converts the combustion coefficient from J/kg to BTU/lb.

$$\begin{aligned} fuelheat &= cmbcnst * 4.30{\times}10^{-4} \\ 7.4962{\times}10^{3} &= 17433000 * 4.30{\times}10^{-4} \end{aligned} \tag{2}$$

In this analysis, this value is 7.4962e+03 BTU/lb.

FCI

The next equation calculates the initial total mass of canopy fuel. This is not used in calculating the rate of spread in this model.

$$fci = (1 + fuelmc\_c) * fci\_d \tag{3}$$

Fuel-load

Next is calculating the fuel load without moisture and converting it to lb/ft^2

$$\begin{aligned} fuelloadm &= (1 - bmst) * fgi \\ 0.1612 &= (1 - 0.0291) * 0.1660 \\ fuelload &= fuelloadm * (0.3048)^2 * 2.205 \\ 0.0330 &= 0.1612 * (0.3048)^2 * 2.205 \end{aligned} \tag{4}$$

Fuel height

Next is converting the fuel height from m to ft.

$$\begin{aligned} fueldepth &= fueldepthm/0.03048 \\ 1.0007 &= 0.30500/0.3048 \end{aligned} \tag{5}$$

Betafl (Packing ratio)

$$\begin{aligned} betafl &= fuelload/(fueldepth * fueldens) \\ 0.0010 &= 0.0330/(1.0007 * 32) \end{aligned} \tag{6}$$

Betaop (Optimum Packing Ratio)

$$\begin{aligned} betaop &= 3.348 * savr^{(-0.8189)} \\ 0.0042 &= 3.348 * 3500^{(-0.8189)} \end{aligned} \tag{7}$$

Q$_i g$ (Heat of preignition)

$$\begin{aligned} qig &= 250. + 1116. * fuelmc\_g \\ 283.4800 &= 250 + 1116 * 0.03 \end{aligned} \tag{8}$$

ϵ **Effective heating number**

$$\begin{aligned} epsilon &= e^{-138/savr} \\ 0.9613 &= e^{-138/3500} \end{aligned} \tag{9}$$

rhob ovendry bulk density

$$\begin{aligned} rhob &= fuelload/fueldepth \\ 0.0330 &= 0.0330/1.0007 \end{aligned} \tag{10}$$

Please note, I will be skipping the wind coefficient for now since I want to evaluate no wind no slope first. After that analysis, I will include the wind and slope parameters

gammax (maximum reaction velocity)

$$\begin{aligned} rtemp2 &= savr^{1.5} \\ 2.0706{\times}10^5 &= 3500^{1.5} \\ gammax &= rtemp2/(495. + 0.0594 * rtemp2) \\ 16.1837 &= 2.0706{\times}10^5/(495. + 0.0594 * 2.0706{\times}10^5) \end{aligned} \tag{11}$$

Coefficient for optimum reaction velocity

$$\begin{aligned} a &= 1./(4.774 * savr^{0.1} - 7.27) \\ 0.2836 &= 1./(4.774 * 3500^{0.1} - 7.27) \end{aligned} \tag{12}$$

Γ (Optimum reaction velocity)

$$
\begin{aligned}
ratio &= betafl/betaop \\
0.2459 &= 0.0010/0.0042 \\
\Gamma &= gammax * (ratio^{a}) * exp(a * (1. - ratio)) \\
13.4642 &= 16.1837 * (0.2459^{0}.2836) * e^{0.2836*(1-0.2459)}
\end{aligned} \tag{13}
$$

wn net fuel loading

$$
\begin{aligned}
wn &= fuelload/(1 + st) \\
0.0313 &= 0.0330/(1 + 0.0555)
\end{aligned} \tag{14}
$$

η_M moisture damping coefficient

$$
\begin{aligned}
rtemp1 &= fuelmc\_g/fuelmce \\
0.2500 &= 0.03/0.1200 \\
etam &= 1. - 2.59 * rtemp1 + 5.11 * rtemp1^{2} - 3.52 * rtemp1^{3} \\
0.6169 &= 1 - 2.59 * 0.25 + 5.11 * 0.25^{2} - 3.53 * 0.25^{3}
\end{aligned} \tag{15}
$$

η_s Mineral damping coefficient

$$
\begin{aligned}
etas &= 0.174 * se^{-0.19} \\
0.4174 &= 0.174 * 0.01^{-0.19}
\end{aligned} \tag{16}
$$

ir (Reaction Intensity)

$$
\begin{aligned}
ir &= gamma * wn * fuelheat * etam * etas \\
812.8685 &= 13.4642 * 0.0313 * (7.4962{\times}10^{3}) * 0.6169 * 0.4147
\end{aligned} \tag{17}
$$

xifr Propagating flux ratio

$$
\begin{aligned}
xifr &= \frac{e^{(0.792+0.681*savr^{0}.5)*(betafl+0.1)}}{(192. + 0.2595 * savr)} \\
0.0577 &= \frac{e^{(0.792+0.681*3500^{0.5})*(0.0010+0.1)}}{(192 + 0.2595 * 3500}
\end{aligned} \tag{18}
$$

1.1 Final ROS Equation (no slope no wind)

$$
\begin{aligned}
r0 &= (ir * xifr/(rhob * epsilon * qig)) * .00508 \\
0.0265 &= (812.8685 * 0.0577/(0.0330 * 0.9613 * 283.4800)) * 0.00508
\end{aligned} \tag{19}
$$

2 WFA

*Note, this will be really unorganized at first. I will be inserting equations at random here while I try to find them all

beta_op (Optimum packing ratio)

(20)