Shortwave radiation calculation inconsistency b/w the formualation & the WRF/phys/module_sf_urban

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The highlighted region in the screenshot 1 represent the shortwave radiation at building wall 2 in the single-layer urban canopy model by Kusaka et.al. (2001).

$$S_{W,1} = S_D \frac{l_{\text{shadow}}}{2h}(1-\alpha_W) + S_Q F_{W\to S}(1-\alpha_W), \tag{7}$$

$$S_{W,2} = S_D \frac{(w-l_{\text{shadow}})}{w}\alpha_G F_{W\to G}(1-\alpha_W) + S_Q F_{W\to G}(1-\alpha_W) + S_D \frac{l_{\text{shadow}}}{2h}\alpha_W F_{W\to W}(1-\alpha_W) + S_Q F_{W\to S}\alpha_W F_{W\to W}(1-\alpha_W), \tag{8}$$

$$S_{G,1} = S_D \frac{(w-l_{\text{shadow}})}{w}(1-\alpha_G) + S_Q F_{G\to S}(1-\alpha_G), \tag{9}$$

$$S_{G,2} = S_D \frac{l_{\text{shadow}}}{2h}\alpha_W F_{G\to W}(1-\alpha_G) + S_Q F_{W\to S}\alpha_W F_{G\to W}(1-\alpha_G). \tag{10}$$

Screenshot 1: Actual mathematical formulation for calculating shortwave radiation over the ground, roof and building walls.

However, code that evaluates radiation flux at the building wall 2 in the module_sf_urban.F is found to be disagreeing with the equation shown in red box in screenshot 1. This discrepancy is leading to inaccuracies in the shortwave radiation balance over the wall. Screenshot 2 shows the implantation of boxed equation in screenshot 1. When the term SG1 in SB2 is replaced with its full form, the resulting equation form does not match with the red boxed equations in screenshot 1. The screenshot 2 represents the code for the case where building shadowing effects are considered.

```
SLX=(SLX1+SLX2+SLX3+SLX4+SLX5+SLX6+SLX7+SLX8)/8.

SR1=SD*(1.-ALBR)+SQ*(1.-ALBR)
SGR1=SD*(1.-ALBV)+SQ*(1.-ALBV)
SG1=SD*(RW-SLX)/RW*(1.-ALBG)+SQ*VFGS*(1.-ALBG)
SG2=SB1*ALBB/(1.-ALBB)*VFGW*(1.-ALBG)
SB1=SD*SLX/W*(1.-ALBB)+SQ*VFWS*(1.-ALBB)
SB2=SG1*ALBG/(1.-ALBG)*VFWG*(1.-ALBB)
```

<u>Screenshot 2</u>: Evaluation of the shortwave radiation with the shadowing effect of the buildings in the urban area. It is a programmed version of equations 7-10 shown in screenshot 1.

Similarly, when the shadowing effect is neglected and terms that include $\mathbf{I_{shadow}}$ in eqs 7-10 are neglected with SX = SD + SQ, the resulting equation used in the code do not agree with the one in the actual formulation.

```
SHADOW = .false.
 SHADOW = .true.

IF (SSG > 0.0) THEN

  IF(.NOT.SHADOW) THEN                ! no shadow effects model

    SR1=SX*(1.-ALBR)
    SGR1=SX*(1.-ALBV)
    SG1=SX*VFGS*(1.-ALBG)
    SB1=SX*VFWS*(1.-ALBB)
    SG2=SB1*ALBB/(1.-ALBB)*VFGW*(1.-ALBG)
    SB2=SG1*ALBG/(1.-ALBG)*VFWG*(1.-ALBB)
```

<u>Note</u>: This discrepancy is found only for the shortwave radiation calculation for the building wall 2 ($SB2/S_{W,2}$).