$$(1-\alpha)S\downarrow + L\downarrow - \sigma\theta_s^4 = G + H + \beta L_v E_p$$

$$\sigma\theta_s^4 \approx \sigma T_0^4 \left(1 + 4\left(\frac{\theta_s - T_0}{T_0}\right)\right) \qquad \text{———————(A)}$$

$$H = \rho c_p C_h(\theta_s - \theta_0)$$

$$= \rho c_p C_h[(\theta_s - T_0) - (\theta_0 - T_0)]$$

$$(1-\alpha)S\downarrow + L\downarrow - \sigma T_0^4 - 4\sigma T_0^4\left(\frac{\theta_s - T_0}{T_0}\right) =$$

$$G + \rho c_p C_h[(\theta_s - T_0) - (\theta_0 - T_0)] + \beta L_v E_p$$

$$F = (1 - \alpha)S\downarrow + L\downarrow$$

$$G = K_T(\Theta)\frac{(\theta_s - T_{1soil})}{\Delta z}$$

$$\theta_s = \frac{T_0 + \dfrac{\dfrac{F - \sigma T_0^4}{\rho c_p C_h} + (\theta_0 - T_0) - \dfrac{\beta L_v E_p}{\rho c_p C_h}}{r + 1} + \dfrac{K_T(\Theta)T_{1soil}}{\Delta z \rho c_p C_h (r+1)}}{1 + \dfrac{K_T(\Theta)}{\Delta z \rho c_p C_h (r+1)}}$$

$$YY = T_0 + \frac{\dfrac{(F - \sigma T_0^4)}{RCH} + (\theta_0 - T_0) - \beta EPSCA}{RR}$$

$$ZZ = \frac{K_T(\Theta)}{\Delta z \cdot RCH \cdot RR}$$

$$ZZ1 = ZZ + 1$$

$$RR = \frac{4\sigma\, T_0^4\, R_d}{P_{sfc} C_h\, c_p} + 1 \qquad r + 1 = RR$$

$$\theta_s = \frac{YY + ZZ \cdot T_{1soil}}{ZZ1}$$

```
RGR = EPSV*(RX-SIG*(TGRP**4.)/60.)
RGRR= (SGR+RGR) * 697.7 * 60.
RCH = RHOO*CPP*CHGR
RR1 = EPSV*(TA**4) * 6.48E-8 / (PS* CHGR) + 1.0
IF (RAIN >  0.0) then
RR2 = RR1 + RAIN / 3600 * 4.218E+3 / RCH
else
RR2 = RR1
end if
YY  = TA + (RGRR / RCH - BETGR * EPGR * ELL/ RCH) / RR2
ZZ1 = DF1 / (-0.5 * ZSOILR (KZ) * RCH * RR2 ) + 1.0
```

If we do not use the approximation in equation (A), we won't be having the term highlighted in green in slide 4. The TA^4*Rd/(Cp*PS) use approximation from the comes from the ideal gas equation (P = \rho R T) which needs a TA in the denominator which comes because of the approximation used in equation (A) on slide 1 (more details on highlighted ellipse on slide 3). Hence, if we use that equation and rest of equations used in the module are correct, there should be TA instead of TGRP. Also, the term highlighted in light red on slide 2 is missing from equation in the WRF/phys/module_sf_urban.F. Note: (6.48E-8 = 4*sigma*Rd/Cp)