Absorbed radiance and leaf to air temperature difference simulation

Wen Lin

June 21, 2017

# Contents

1. simulate absorbed radiance
2. simulate leaf-to-air temperature difference

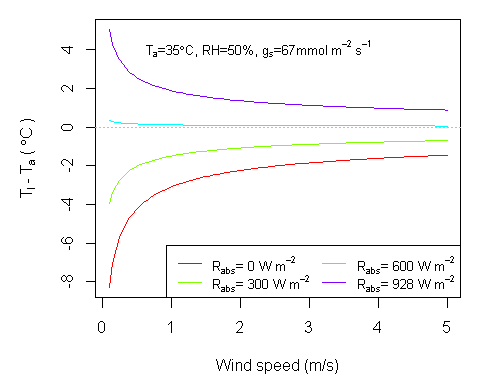
## 1. Simulation of absorbed radiance

tao <- 0.7 # atmopheric transmittance. the values are between 0.6 and 0.7 for clear conditions  
phi <- 5/180\*pi # sun zenith angle (5 degrees)  
m <- exp(-625\*0.3048/8200)/cos(phi) # optical air mass number   
Sp <- 1360\*tao^m # direct radiation  
Sd <- 0.3\*(1-tao^m)\*1360\*cos(phi) # diffuse radiation   
Fp <- cos(phi)/2 # view factor for direct radiation  
St <- Fp\*Sp+Sd # global irradiance for calculating reflected radiation   
albedo <- 0.1 # evergreen conifer conifer albedo: 0.08-0.11.   
Sr <- albedo\*St # reflected radiation   
  
alpha\_s <- 0.88 # conifer absorptivity for solar wavebands, value is from Martin's paper  
alpha\_l <- 0.96 # conifer absorptivity for thermal wavebands, value is from Martin's paper  
  
T\_a <- 35 # air temperature  
B <- 5.67E-8 \* (T\_a+273.15)^4# black body emittance   
  
e\_c <- 9.2E-6\*(T\_a+273.15)^2 # clear sky emissivity  
  
# F: view factors  
Fd <- Fr <- Fa <- Fg <- 0.5  
  
La <- e\_c\* B # long wave flux density from the atmophere  
Lg <- La # long wave flux density from the ground, assuming ground temperature is equal to air temperature  
  
# absorbed radiance  
R\_abs <- alpha\_s\*(Fp\*Sp+Fd\*Sd+Fr\*Sr)+alpha\_l\*(Fa\*La+Fg\*Lg);  
R\_abs <- round(R\_abs,0)  
paste0("Absorbed radiance at minimal sun zenith angle = ",R\_abs," W/m2")

## [1] "Absorbed radiance at minimal sun zenith angle = 928 W/m2"

## 2. Simulation of leaf-to-air temperature difference

# global variable: wind speed (u)  
u <- seq(0.1,5,l=100)  
  
# function to calculate saturated vapor pressure  
vp3 <- function(Tmpt) # unite: kpa formula source: Campbell&Norman Env. biophysics  
{return(0.611\*exp((17.502\*Tmpt)/(Tmpt+240.97)))}  
  
# the slope of the saturation vapor pressure function  
Delta.fun <- function(x)  
{return(17.502\*240.47\*vp3(x)/(240.97+x)^2)}  
  
# function to simulate leaf to air temperature difference  
leaf.T.R <- function(R\_abs)  
{  
 g\_vs <- 0.067 # stomatal conductance  
 RH <- 0.50 # RH: relative humidity  
 T\_a <- 35 # T\_a: air temperature  
 width <- 1.5E-3 # leaf diameter: 1.5mm  
   
 gamma <- 6.66E-4 # thermodynamic psychrometer constant  
 # calculate the atmospheric pressure of the site with elevation as 191m  
 p\_a <- 101.3\*exp(-191/8200)  
 c\_p <- 29.3 # specific heat of air at constant pressure, unit J/mol/K  
   
 B <- 5.67E-8 \* (T\_a+273.15)^4  
 # g\_r: radiative conductance at air temperature, simulated using a polynomial function  
 g\_r <- 7E-6\*(T\_a+273.15)^2-0.0021\*(T\_a+273.15)+0.2085;g\_r   
   
 e\_s <- vp3(T\_a); # e\_s: saturated vapor pressure at air temperature = 35C  
 Delta <- Delta.fun(T\_a) # Delta: slope of vapor pressure function at air temperature = 35C  
 s <- Delta/p\_a;s # s: slope of saturation mole fraction function  
 D <- e\_s\*(1-RH) # D: VPD  
 R\_ni <- R\_abs - B\*0.97  
   
 d <- 0.7\*width # d: leaf characteristic dimension  
 # g\_Ha: boundary layer conductance for heat, 1.4 is used for outdoor conditions  
 g\_Ha <- 1.4\*0.135\*sqrt(u/d)  
 # g\_va: boundary layer conductance for vapor, 1.4 is used for outdoor conditions  
 g\_va <- 1.4\*0.147\*sqrt(u/d)  
 g\_Hr <- g\_Ha+g\_r # g\_Hr: sum of boundary layer and radiative conductances  
 g\_v <- (g\_vs\*g\_va)/(g\_vs+g\_va);g\_v # assume abaxial and adaxial conductance to be the same  
 gamma\_star <- gamma \*g\_Hr/g\_v;gamma\_star # gamma\_star: apparent psychrometer constant  
 #T\_d: the air to leaf temperature difference   
 T\_d <- gamma\_star/(gamma\_star+s)\*(R\_ni/(g\_Hr\*c\_p)-D/p\_a/gamma\_star)  
 return(T\_d)  
}  
  
dat <- data.frame(T1=leaf.T.R(0),T2=leaf.T.R(300), T3=leaf.T.R(600), T4=leaf.T.R(928))  
par(mar=c(4.5,5,1,1))  
matplot(u,dat,type="l",col=rainbow(4),lty=1,  
 ylab=expression(T[l]~"-"~T[a]~"("~degree\*C~")"),xlab="Wind speed (m/s)")  
abline(h=0,col=8,lty=3)  
text(0.5,4,pos=4,expression(T[a]\*"=35"\*degree\*C\*", RH=50%, "\*g[s]\*"=67mmol"~m^{-2}~s^{-1}),cex=0.8)  
legend("bottomright",expression(R[abs]\*"= 0 W"~m^{-2},R[abs]\*"= 300 W"~m^{-2},R[abs]\*"= 600 W"~m^{-2},R[abs]\*"= 928 W"~m^{-2}),lty=1,col=rainbow(4),cex=0.8,ncol=2)



Where u represents wind speed, and d represents leaf characteristic dimension. 1.4 is used because of outdoor conditions.

$ g\_r $ is obtained from a table from Appendex. The table shows that $ g\_r $ is a function of temperature. Thus I used a polynomial function to simulate $ g\_r $ using temperature.