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HW#1 ATS 761

Problem 1)

## Constants

E=0.4091 #radians

Sc=1367 #W\*m-2

e=0.0167

w=1.7963

Ps=1013.25

tau=0.7

P1=855 #Foco Aug 21 All in mb

P2=845 #Foco Feb 21

P3=1010 #Somalia Mar 21

P4=1010 #New Zealand Oct 21

daynum1=234

daynum2=52

daynum3=81

daynum4=295

theta1=0.70831971124 #latitude

theta2=0.70831971124

theta3=0.035697289004

theta4=-0.7208176824

phi1=2\*pi\*(daynum1 - 81)/365

phi2=2\*pi\*(daynum2 - 81)/365

phi3=2\*pi\*(daynum3 - 81)/365

phi4=2\*pi\*(daynum4 - 81)/365

delta1=E\*sin(phi1) #declination

delta2=E\*sin(phi2)

delta3=E\*sin(phi3)

delta4=E\*sin(phi4)

#S1

LST=seq(from=0, to=23, by=1)\*0

S1=seq(from=0, to=23, by=1)\*0

LST[1]=0

S1[1]=0

for (i in 1:23) {

 LST[i+1]=LST[i]+1

 h=-pi+LST[i]/24\*2\*pi

 rv=1/((1-e^2)/(1+e\*cos(phi1-w)))

 cosZ=sin(theta1)\*sin(delta1)+cos(theta1)\*cos(delta1)\*cos(h)

 if (cosZ<0) {

 Sc=0

 } else {

 Sc=1367

}

 Sh=(Sc/(rv^2))\*cosZ

 m=1/cosZ\*P1/Ps

 S1[i+1]=Sh\*tau^m

}

#S2

LST=seq(from=0, to=23, by=1)\*0

S2=seq(from=0, to=23, by=1)\*0

LST[1]=0

S2[1]=0

for (i in 1:23) {

 LST[i+1]=LST[i]+1

 h=-pi+LST[i]/24\*2\*pi

 rv=1/((1-e^2)/(1+e\*cos(phi2-w)))

 cosZ=sin(theta2)\*sin(delta2)+cos(theta2)\*cos(delta2)\*cos(h)

 if (cosZ<0) {

 Sc=0

 } else {

 Sc=1367

 }

 Sh=(Sc/(rv^2))\*cosZ

 m=1/cosZ\*P2/Ps

 S2[i+1]=Sh\*tau^m

}

#S3

LST=seq(from=0, to=23, by=1)\*0

S3=seq(from=0, to=23, by=1)\*0

LST[1]=0

S3[1]=0

for (i in 1:23) {

 LST[i+1]=LST[i]+1

 h=-pi+LST[i]/24\*2\*pi

 rv=1/((1-e^2)/(1+e\*cos(phi3-w)))

 cosZ=sin(theta3)\*sin(delta3)+cos(theta3)\*cos(delta3)\*cos(h)

 if (cosZ<0) {

 Sc=0

 } else {

 Sc=1367

 }

 Sh=(Sc/(rv^2))\*cosZ

 m=1/cosZ\*P3/Ps

 S3[i+1]=Sh\*tau^m

}

#S4

LST=seq(from=0, to=23, by=1)\*0

S4=seq(from=0, to=23, by=1)\*0

LST[1]=0

S4[1]=0

for (i in 1:23) {

 LST[i+1]=LST[i]+1

 h=-pi+LST[i]/24\*2\*pi

 rv=1/((1-e^2)/(1+e\*cos(phi4-w)))

 cosZ=sin(theta4)\*sin(delta4)+cos(theta4)\*cos(delta4)\*cos(h)

 if (cosZ<0) {

 Sc=0

 } else {

 Sc=1367

 }

 Sh=(Sc/(rv^2))\*cosZ

 m=1/cosZ\*P4/Ps

 S4[i+1]=Sh\*tau^m

}

## Plot

x <- seq(1, 24, 1)

plot(x,S1,ylim=c(0,1000), xlab = "Time (hr)", ylab = "Insolation (W/m2)", col='red', type='l')

par(new=TRUE)

plot(x,S2,ylim=c(0,1000), xlab = "Time (hr)", ylab = "Insolation (W/m2)", col='blue', type='l')

par(new=TRUE)

plot(x,S3,ylim=c(0,1000), xlab = "Time (hr)", ylab = "Insolation (W/m2)", col='green', type='l')

par(new=TRUE)

plot(x,S4,ylim=c(0,1000), xlab = "Time (hr)", ylab = "Insolation (W/m2)", col='black', type='l')

legend(1,950, legend=c("Foco Aug", "Foco Feb", "Somalia Mar", "New Zealand Oct"), col=c("red", "blue", "green", "black"), lty=1)

title(main="Insolation Over Time", xlab = "Time (hr)", ylab = "Insolation (W/m2)")



Figure 1. Insolation of one day for four locations and days on Earth.

Problem #2

time.step=3600

albedo=0.08

hours.per.lunar.day <- 24 \* 29 + 12.75

n.lunar.days <- 10

n.steps <- n.lunar.days \* hours.per.lunar.day \* 3600 / time.step

heat.capacity <- 4.4e6 # (J/m3 per Kelvin, from Colozza 1991, pages 2-3)

thermal.conductivity <- 0.025 # (W/m per Kelvin, also from Colozza 1991)

sigma <- 5.67e-8 # (W/m2/K4, Stefan-Boltzmann coefficient)

solar.constant <- 1367. # Watts/m2

n.layers <- 15

dz <- rep(NA, n.layers) # layer thickness (meters)

depth <- dz

dz[1] <- 0.02 # Top layer is thinnest (2 cm)

depth[1] <- dz[1] / 2

layer.mult <- 1.5

for (L in 2:n.layers) {

 dz[L] <- dz[L-1] \* layer.mult

 depth[L] <- sum(dz[1:(L-1)]) + dz[L] / 2

}

empty <- rep(NA, n.steps-1)

R.net <- empty

SW.down <- empty

SW.up <- empty

LW.down <- empty

LW.up <- empty

lunar.date <- empty

soilT <- matrix(NA, nrow=n.layers, ncol=n.steps) # array to hold soil temps (Kelvin)

soilT[ , 1] <- 273. # Initial soil temps = 298 K = 25 C

flux <- matrix(NA, nrow=n.layers+1, ncol=n.steps-1) # array to hold heat fluxes (W/m2)

flux[ ,1] <- NA # upward flux at top of layer L

elapsed <- 0

for (i in 1:(n.steps-1)) {

 # Calculate date and time (lunar solar time = LST)

 elapsed <- elapsed + time.step

 hours <- elapsed / 3600.

 lunar.date[i] <- hours/hours.per.lunar.day

 day <- floor(lunar.date[i])

 LST <- hours - (hours.per.lunar.day \* day)

 # Calculate position of Sun in Lunar sky

 hour.angle <- -pi + (LST / hours.per.lunar.day) \* 2 \* pi

 cos.z <- max(cos(hour.angle), 0.)

 # Calculate SW gain using Bonan (Chapter 4)

 SW.down[i] <- solar.constant \* cos.z

 SW.up[i] <- SW.down[i] \* albedo

 # Calculate LW using sky temp = 5 Kelvin

 LW.down[i] <- sigma \* 5^4

 # Upward longwave from surface assumes blackbody (emissivity = 1)

 LW.up[i] <- sigma \* soilT[1,i] ^ 4

 # Net radiation

 R.net[i] <- SW.down[i] - SW.up[i] + LW.down[i] - LW.up[i]

 # Soil temperature

 # Compute upward flux at top of each layer

 flux[1,i] <- -R.net[i] # top flux boundary condition

 for (L in 2:n.layers){

 flux[L,i] <- -thermal.conductivity \* (soilT[L-1,i] - soilT[L,i]) / ((dz[L-1]+dz[L])/2)

 }

 flux[n.layers+1,i] <- 0. # bottom flux boundary condition

 # Compute new temperatures for each layer

 for (L in 1:n.layers) {

 soilT[L,i+1] <- soilT[L,i] - (flux[L,i] - flux[L+1,i]) \* time.step /

 (heat.capacity \* dz[L])

 }

}



Figure2. Temperature by depth for 10 lunar days.