

Climate Modelling

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2019-08-26 / Turin University

Introduction

Packages

```
library(tidyverse)
library(plotly)
library(scales)
library(gganimate)
library(knitr)
library(DT)
library(colorRamps)
library(webshot)
#webshot::install_phantomjs()
```

Input Parameters

```
S <- 1370
A <- 204
B <- 2.17
K <- 3.86
ai <- 0.62
ab <- 0.25
aW <- 0.75
aB <- 0.25
gamma <- 2.2
delta <- 10/gamma
c <- 7
k <- 0.003265*0.75
T0 <- 20
D <- 0.3 # Death Rate
w0 <- 0.5
b0 <- 0.2
u0 <- 1-w0-b0
```

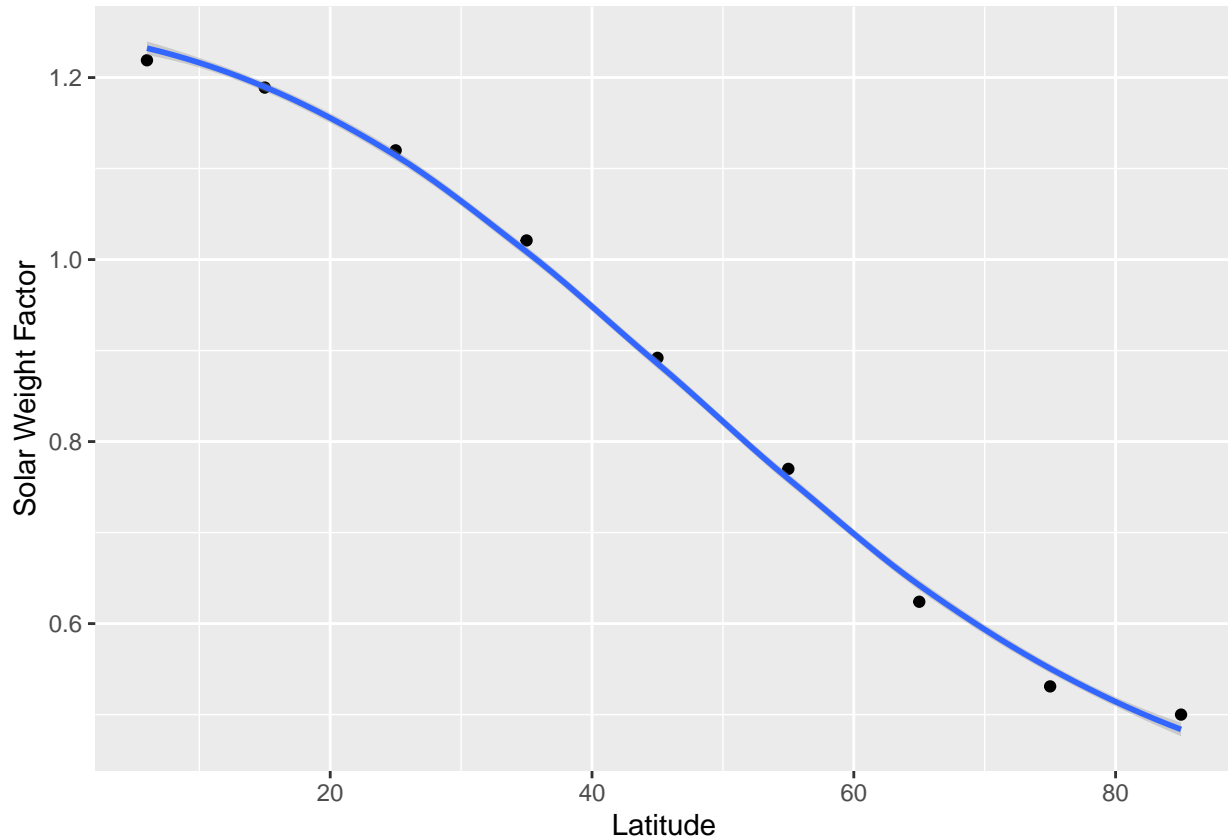
Fit from Textbook Spreadsheet

```
zones <- c(85,75,65,55,45,35,25,15,6)
coszones <- cospi(zones/180)
sunWt <- c(0.5,0.531,0.624,0.77,0.892,1.021,1.12,1.189,1.219)
df <- data.frame(zones,sunWt)
f <- function(zones,d,n,k){
```

```
d*cos(n*zones)^2+k } #cos or cos^2 ??
```

```
Fit <- nls(sunWt ~ f(zones,d,n,k),data= df, start=list(d=1,n=0.015,k=0.3))
```

```
ggplot(df, aes(zones,sunWt))+geom_point()+geom_smooth(aes(y=f(zones,0.7768699,0.0164348,0.4617747)))+xlab("Latitude")
```



Functional Forms

```
gauss <- function(x,m,sd,b){
  ((24+b)/(0.00798*sqrt(2*pi*sd^2)))*exp(-(x-m)^2/(2*sd^2))-b
}

#SOLAR LUMINOSITY (Latitude)
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }

# SOLAR LUMINOSITY (Time)
Sun1 <- function(x,a){a*x/100}
Sun2 <- function(x){1370*(sinpi((x+90)/180))^2}
Sun3 <- function(x){1370-(((1370)/(sqrt(2*pi*1^2)))*exp(-(x-50)^2/(2*1^2)))}
Sun4 <- function(x){ifelse(x==50,1370/3,1370)}
Sun5 <- function(x){(1/100) * (abs(x-150)+25)}
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
Incident <- function(x,y){x*y/4}

# ALBEDO
Step <- function(x,c){ifelse(x<c, 0.6, 0.3)}
```

```

alb <- function(x,a,b,c,d){ (exp(c*(x+d)) / (exp(c*(x+d))+1)) * (b-a) + a }

# EBM
ebm01 <- function(cycles,A,B,K,ai,ab,gamma,delta) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  t <- c(1:cycles)
  Temperature <- rep(0,cycles)
  Ti <- gauss(Zones,0,50,31.6)
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  T <- Ti
  a <- alb(T,ai,ab,gamma,delta)

  for(i in t) { Tcos <- cosZones*T
    Tm <- sum(Tcos)/sum(cosZones)
    T <- (Rin*(1-a)+K*Tm-A) / (B+K)
    a <- alb(T,ai,ab,gamma,delta)
    Temperature[i] <- Tm }

  return( data.frame(Zones,T,a,Ti)) }
ebm02 <- function(cycles,A,B,K,ai,ab,gamma,delta) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  t <- c(1:cycles)
  Temperature <- rep(0,cycles)
  Ti <- gauss(Zones,0,50,31.6)
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  T <- Ti
  a <- alb(T,ai,ab,gamma,delta)
  for(i in t)
    {Tcos <- cosZones*T
      Tm <- sum(Tcos)/sum(cosZones)
      T <- (Rin*(1-a)+K*Tm-A) / (B+K)
      a <- alb(T,ai,ab,gamma,delta)
      Temperature[i] <- Tm }
  return( data.frame(t,Temperature) ) }

ebm11 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun1 <- function(x,a){a*x/100}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  J <- rep(0,cycles1)
  TEMP1 <- matrix(NA, nrow=90, ncol=cycles1)

```

```

Temp <- rep(0,cycles1)
Sun1 <- function(x,a){a*x/100}
SunWt <- Func(Zones)

for(j in c(1:cycles1)){
  T <- gauss(Zones,0,50,31.6)
  a <- alb(T,ai,ab,gamma,delta)
  S <- Sun1(1370,j)
  Rin <- Incident(S,SunWt)

  for(i in c(1:cycles2))
  {Tcos <- cosZones*T
  Tm <- sum(Tcos)/sum(cosZones)
  T <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T,ai,ab,gamma,delta)
  TEMP1[,j] <- T
  J[j] <- j
  Temp[j] <- Tm } }

  return( data.frame(J,Temp) ) }
ebm12 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun1 <- function(x,a){a*x/100}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  J <- rep(0,cycles1)
  TEMP1 <- matrix(NA, nrow=90, ncol=cycles1)
  Temp <- rep(0,cycles1)

  for(j in c(1:cycles1)){
    T <- gauss(Zones,0,50,31.6)
    a <- alb(T,ai,ab,gamma,delta)
    S <- Sun1(1370,j)
    Rin <- Incident(S,SunWt)

    for(i in c(1:cycles2))
    {Tcos <- cosZones*T
    Tm <- sum(Tcos)/sum(cosZones)
    T <- (Rin*(1-a)+K*Tm-A) / (B+K)
    a <- alb(T,ai,ab,gamma,delta)
    TEMP1[,j] <- T
    J[j] <- j
    Temp[j] <- Tm } }

    return( TEMP1 ) }

ebm21 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }

```

```

Sun2 <- function(x){1370*(sinpi((x+90)/180))^2}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
J <- rep(0,cycles1)
Temp2 <- rep(0,cycles1)
T2 <- gauss(Zones,0,50,31.6)
TEMP2 <- matrix(NA, nrow=90, ncol=cycles1)
a <- alb(T2,ai,ab,gamma,delta)
Sarr <- rep(0,cycles1)

for(j in c(1:cycles1)){
  S <- Sun2(j)
  Rin <- Incident(S,SunWt)
  for(i in c(1:cycles2))
  {Tcos <- cosZones*T2
  Tm <- sum(Tcos)/sum(cosZones)
  T2 <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T2,ai,ab,gamma,delta)
  }
  Sarr[j] <- Sun2(j)
  TEMP2[,j] <- T2
  J[j] <- j
  Temp2[j] <- Tm }

return( data.frame(J,Temp2) ) }

ebm22 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun2 <- function(x){1370*(sinpi((x+90)/180))^2}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  J <- rep(0,cycles1)
  Temp2 <- rep(0,cycles1)
  T2 <- gauss(Zones,0,50,31.6)
  TEMP2 <- matrix(NA, nrow=90, ncol=cycles1)
  a <- alb(T2,ai,ab,gamma,delta)
  Sarr <- rep(0,cycles1)
  SunWt <- Func(Zones)

  for(j in c(1:cycles1)){
    S <- Sun2(j)
    Rin <- Incident(S,SunWt)
    for(i in c(1:cycles2))
    {Tcos <- cosZones*T2
    Tm <- sum(Tcos)/sum(cosZones)
    T2 <- (Rin*(1-a)+K*Tm-A) / (B+K)
    a <- alb(T2,ai,ab,gamma,delta)
    }
    Sarr[j] <- Sun2(j)
    TEMP2[,j] <- T2
  }
}

```

```

J[j] <- j
Temp2[j] <- Tm }

return( TEMP2 ) }
ebm23 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun2 <- function(x){1370*(sinpi((x+90)/180))^2}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  J <- rep(0,cycles1)
  Temp2 <- rep(0,cycles1)
  T2 <- gauss(Zones,0,50,31.6)
  TEMP2 <- matrix(NA, nrow=90, ncol=cycles1)
  a <- alb(T2,ai,ab,gamma,delta)
  Sarr <- rep(0,cycles1)
  SunWt <- Func(Zones)

for(j in c(1:cycles1)){
  S <- Sun2(j)
  Rin <- Incident(S,SunWt)
  for(i in c(1:cycles2))
  {Tcos <- cosZones*T2
  Tm <- sum(Tcos)/sum(cosZones)
  T2 <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T2,ai,ab,gamma,delta)
  }
  Sarr[j] <- Sun2(j)
  TEMP2[,j] <- T2
  J[j] <- j
  Temp2[j] <- Tm }

return( data.frame(Sarr,Temp2) ) }

ebm31 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun3 <- function(x){1370-(((1370)/(sqrt(2*pi*1^2)))*exp(-(x-50)^2/(2*1^2)))}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  J <- rep(0,cycles1)
  TEMP3 <- matrix(NA, nrow=90, ncol=cycles1)
  Temp <- rep(0,cycles1)
  T3 <- gauss(Zones,0,50,31.6)
  a <- alb(T3,ai,ab,gamma,delta)

for(j in c(1:cycles1)){
  S <- Sun3(j)
  Rin <- Incident(S,SunWt)
  for(i in c(1:cycles2))

```

```

{Tcos <- cosZones*T3
Tm <- sum(Tcos)/sum(cosZones)
T3 <- (Rin*(1-a)+K*Tm-A) / (B+K)
a <- alb(T3,ai,ab,gamma,delta)
}
TEMP3[,j] <- T3
J[j] <- j
Temp[j] <- Tm
}

return( data.frame(J,Temp) ) }

ebm32 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun3 <- function(x){1370-(((1370)/(sqrt(2*pi*1^2)))*exp(-(x-50)^2/(2*1^2)))}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  J <- rep(0,cycles1)
  TEMP3 <- matrix(NA, nrow=90, ncol=cycles1)
  Temp <- rep(0,cycles1)
  T3 <- gauss(Zones,0,50,31.6)
  a <- alb(T3,ai,ab,gamma,delta)

  for(j in c(1:cycles1)){
    S <- Sun3(j)
    Rin <- Incident(S,SunWt)
    for(i in c(1:cycles2))
    {Tcos <- cosZones*T3
    Tm <- sum(Tcos)/sum(cosZones)
    T3 <- (Rin*(1-a)+K*Tm-A) / (B+K)
    a <- alb(T3,ai,ab,gamma,delta)
    }
    TEMP3[,j] <- T3
    J[j] <- j
    Temp[j] <- Tm
  }

  return( TEMP3 ) }

ebm41 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun4 <- function(x){ifelse(x==50,1370/3,1370)}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  J <- rep(0,cycles1)
  Temp <- rep(0,cycles1)
  T4 <- gauss(Zones,0,50,31.6)
  TEMP4 <- matrix(NA, nrow=90, ncol=cycles1)

```

```

a <- alb(T4,ai,ab,gamma,delta)

for(j in c(1:cycles1)){
  S <- Sun4(j)
  Rin <- Incident(S,SunWt)
  for(i in c(1:cycles2))
  {Tcos <- cosZones*T4
  Tm <- sum(Tcos)/sum(cosZones)
  T4 <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T4,ai,ab,gamma,delta)
  }
  TEMP4[,j] <- T4
  J[j] <- j
  Temp[j] <- Tm
}

return( data.frame(J,Temp) ) }

ebm42 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun4 <- function(x){ifelse(x==50,1370/3,1370)}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  J <- rep(0,cycles1)
  Temp <- rep(0,cycles1)
  T4 <- gauss(Zones,0,50,31.6)
  TEMP4 <- matrix(NA, nrow=90, ncol=cycles1)
  a <- alb(T4,ai,ab,gamma,delta)

for(j in c(1:cycles1)){
  S <- Sun4(j)
  Rin <- Incident(S,SunWt)
  for(i in c(1:cycles2))
  {Tcos <- cosZones*T4
  Tm <- sum(Tcos)/sum(cosZones)
  T4 <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T4,ai,ab,gamma,delta)
  }
  TEMP4[,j] <- T4
  J[j] <- j
  Temp[j] <- Tm
}

return( TEMP4 ) }

ebm51 <- function(cycles1,cycles2,A,B,K,ai,ab,gamma,delta ) {
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun5 <- function(x){(1/100) * (abs(x-150)+25)}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))

```



```

SunWt <- Func(Zones)
J <- rep(0,cycles1)
Temp5 <- rep(0,cycles1)
T5 <- gauss(Zones,0,50,31.6)
TEMP5 <- matrix(NA, nrow=90, ncol=cycles1)
a <- alb(T5,ai,ab,gamma,delta)
Sarr <- rep(0,cycles1)

for(j in c(0:cycles1)){
  S <- Sun5(j)
  Rin <- 1370*Incident(S,SunWt)
  for(i in c(1:cycles2))
  {Tcos <- cosZones*T5
  Tm <- sum(Tcos)/sum(cosZones)
  T5 <- (Rin*(1-a)+K*Tm-A) / (B+K)
  a <- alb(T5,ai,ab,gamma,delta)
  }
  Sarr[j] <- Sun5(j)
  J[j] <- j
  Temp5[j] <- Tm
}
return( data.frame(Sarr,Temp5) ) }

ebm_ND1 <- function(cycles,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
T <- gauss(Zones,0,50,31.6)-6

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)
Uarr <- rep(0,cycles)
Tarr <- rep(0,cycles)
I <- rep(0,cycles)

TEMP <- matrix(NA, nrow=90, ncol=cycles)

for(i in c(1:cycles)) {
  S <- Sun6(i) # oppure costante S <- 1370
  Rin <- Incident(S,SunWt)
  Tcos <- cosZones*T

```

```

Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
TEMP[,i] <- T
a <- alb(T,ai,ab,gamma,delta)
I[i] <- i
Tarr[i] <- T[45]
}

return( data.frame(Zones,w,b,u,T) )}

ebm_ND2 <- function(cycles,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
T <- gauss(Zones,0,50,31.6)-6

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)
Uarr <- rep(0,cycles)
Tarr <- rep(0,cycles)
I <- rep(0,cycles)

TEMP <- matrix(NA, nrow=90, ncol=cycles)

for(i in c(1:cycles)) {
  S <- Sun6(i) # oppure costante S <- 1370
  Rin <- Incident(S,SunWt)
  Tcos <- cosZones*T
  Tm <- sum(Tcos)/sum(cosZones)
  T <- (Rin*(1-a)+K*Tm-A) / (B+K)
  TEMP[,i] <- T
  a <- alb(T,ai,ab,gamma,delta)
  I[i] <- i
  Tarr[i] <- T[45]
}

return( data.frame(I,Barr,Warr,Uarr,Tarr) )}

ebm_ND3 <- function(cycles,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

Zones <- seq(-89, 89, by = 2)

```

```

cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
T <- gauss(Zones,0,50,31.6)-6

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)
Uarr <- rep(0,cycles)
Tarr <- rep(0,cycles)
I <- rep(0,cycles)

TEMP <- matrix(NA, nrow=90, ncol=cycles)

for(i in c(1:cycles)) {
  S <- Sun6(i) # oppure costante S <- 1370
  Rin <- Incident(S,SunWt)
  Tcos <- cosZones*T
  Tm <- sum(Tcos)/sum(cosZones)
  T <- (Rin*(1-a)+K*Tm-A) / (B+K)
  TEMP[,i] <- T
  a <- alb(T,ai,ab,gamma,delta)
  I[i] <- i
  Tarr[i] <- T[45]
}
return( TEMP )}

ebm_ND4 <- function(cycles,s,A,B,K,ai,ab,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun7 <- function(x,y){x*y}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sarr1 <- rep(0,length(Zones)+30)
#Sarr[1] <- Sun7(S,s)
Tarr1 <- rep(0,length(Sarr1))

for(h in c(1:length(Sarr1))) {
S <- 920+(h-1)*10
Sarr1[h] <- S
T <- gauss(Zones,0,50,31.6)-6

a <- alb(T,ai,ab,gamma,delta)

for(i in c(1:cycles)) {

```

```

Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
TM <- sum(T)/length(Zones)
Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
a <- alb(T,ai,ab,gamma,delta)
}

Tarr1[h] <- Tm
}
return (data.frame(Tarr1,Sarr1))

}

ebm_D1 <- function(cycles,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
T <- gauss(Zones,0,50,31.6)-6

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)
Uarr <- rep(0,cycles)
Tarr <- rep(0,cycles)
I <- rep(0,cycles)

TEMP <- matrix(NA, nrow=length(Zones), ncol=cycles)

for(i in c(1:cycles)) {
S <- Sun6(i) # oppure costante S <- 1370
Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
TEMP[,i] <- T
Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2
Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))){
if(Fw[j]<0){Fw[j]=0}
if(Fb[j]<0){Fb[j]=0} }
}

```

```

w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001} }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
Barr[i] <- b[45]
Warr[i] <- w[45]
Uarr[i] <- u[45]
I[i] <- i
Tarr[i] <- T[45]
}
return ( data.frame(Zones,w,b,u,T) )
}
ebm_D2 <- function(cycles,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
  T <- gauss(Zones,0,50,31.6)-6

  w <- rep(w0,length(Zones)) #0.5
  b <- rep(b0,length(Zones)) #0.2
  u <- rep(1-w0-b0,length(Zones))

  a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

  Barr <- rep(0,cycles)
  Warr <- rep(0,cycles)
  Uarr <- rep(0,cycles)
  Tarr <- rep(0,cycles)
  I <- rep(0,cycles)

  TEMP <- matrix(NA, nrow=90, ncol=cycles)

  for(i in c(1:cycles)) {
    S <- Sun6(i) # oppure costante S <- 1370
    Rin <- Incident(S,SunWt)
    Tcos <- cosZones*T
    Tm <- sum(Tcos)/sum(cosZones)
    T <- (Rin*(1-a)+K*Tm-A) / (B+K)
    TEMP[,i] <- T
    Tw <- T+c*(a-aW)
    Tb <- T+c*(a-aB)
    Fw <- 1-k*(T0-Tw)^2
    Fb <- 1-k*(T0-Tb)^2
    for(j in c(1:length(Zones))){

```

```

    if(Fw[j]<0){Fw[j]=0}
    if(Fb[j]<0){Fb[j]=0}  }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001}  }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
Barr[i] <- b[45]
Warr[i] <- w[45]
Uarr[i] <- u[45]
I[i] <- i
Tarr[i] <- T[45]
}
return ( data.frame(I,Barr,Warr,Uarr,Tarr) )
}
ebm_D3 <- function(cycles,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
T <- gauss(Zones,0,50,31.6)-6

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)
Uarr <- rep(0,cycles)
Tarr <- rep(0,cycles)
I <- rep(0,cycles)

TEMP <- matrix(NA, nrow=length(Zones), ncol=cycles)

for(i in c(1:cycles)) {
S <- Sun6(i) # oppure costante S <- 1370
Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
TEMP[,i] <- T
Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2

```

```

Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))){
  if(Fw[j]<0){Fw[j]=0}
  if(Fb[j]<0){Fb[j]=0} }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001} }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
Barr[i] <- b[45]
Warr[i] <- w[45]
Uarr[i] <- u[45]
I[i] <- i
Tarr[i] <- T[45]
}
return ( TEMP )
}
ebm_Db1 <- function(cycles,s,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun7 <- function(x,y){x*y}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sarr <- rep(0,length(Zones))
#Sarr[1] <- Sun7(S,s)

BLACK <- matrix(NA, nrow=length(Zones), ncol=length(Zones))
WHITE <- matrix(NA, nrow=length(Zones), ncol=length(Zones))

for(h in c(1:length(Zones))) {
S <- 920+(h-1)*10
Sarr[h] <- S
T <- gauss(Zones,0,50,31.6)-6
w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
for(i in c(1:cycles)) {
Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2
Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))){
  if(Fw[j]<0){Fw[j]=0}

```

```

    if(Fb[j]<0){Fb[j]=0}  }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001}  }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
}

BLACK[h,] <- b
WHITE[h,] <- w
}

return ( plot_ly( x=Zones, y=Sarr, z=~BLACK ,colors = colorRamp(c("white", "black")), type = "heatmap")

}
ebm_Db2 <- function(cycles,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
  T <- gauss(Zones,0,50,31.6)-6

  w <- rep(w0,length(Zones)) #0.5
  b <- rep(b0,length(Zones)) #0.2
  u <- rep(1-w0-b0,length(Zones))

  a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

  Barr <- rep(0,cycles)
  Warr <- rep(0,cycles)
  Uarr <- rep(0,cycles)
  Tarr <- rep(0,cycles)
  I <- rep(0,cycles)

  TEMP <- matrix(NA, nrow=length(Zones), ncol=cycles)
  BLACK <- matrix(NA, nrow=length(Zones), ncol=cycles)
  WHITE <- matrix(NA, nrow=length(Zones), ncol=cycles)

  for(i in c(1:cycles)) {
    S <- Sun6(i) # oppure costante S <- 1370
    Rin <- Incident(S,SunWt)
    Tcos <- cosZones*T
    Tm <- sum(Tcos)/sum(cosZones)
    T <- (Rin*(1-a)+K*Tm-A) / (B+K)

```



```

Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2
Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))){
  if(Fw[j]<0){Fw[j]=0}
  if(Fb[j]<0){Fb[j]=0} }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001} }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
Barr[i] <- b[45]
Warr[i] <- w[45]
Uarr[i] <- u[45]
I[i] <- i
Tarr[i] <- T[45]
TEMP[,i] <- T
BLACK[,i] <- b
WHITE[,i] <- w

}
return ( BLACK )
}
ebm_Dw1 <- function(cycles,s,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
Incident <- function(x,y){ x*y/4 }
Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
Sun7 <- function(x,y){x*y}

Zones <- seq(-89, 89, by = 2)
cosZones <- abs(cospi(Zones/180))
SunWt <- Func(Zones)
Rin <- Incident(S,SunWt)
Sarr <- rep(0,length(Zones))
#Sarr[1] <- Sun7(S,s)

BLACK <- matrix(NA, nrow=length(Zones), ncol=length(Zones))
WHITE <- matrix(NA, nrow=length(Zones), ncol=length(Zones))

for(h in c(1:length(Zones))) {
S <- 920+(h-1)*10
Sarr[h] <- S
T <- gauss(Zones,0,50,31.6)-6
w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
for(i in c(1:cycles)) {
Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
Tm <- sum(Tcos)/sum(cosZones)

```

```

T <- (Rin*(1-a)+K*Tm-A) / (B+K)
Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2
Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))){
  if(Fw[j]<0){Fw[j]=0}
  if(Fb[j]<0){Fb[j]=0} }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))){
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001} }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
}

BLACK[h,] <- b
WHITE[h,] <- w
}

return ( plot_ly( x=Zones, y=Sarr, z=~WHITE ,colors = colorRamp(c("white", "black")), type = "heatmap")
)

ebm_Dw2 <- function(cycles,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  Sun6 <- function(x){1370*(1+0.1*cospi(x/180))}
  T <- gauss(Zones,0,50,31.6)-6

  w <- rep(w0,length(Zones)) #0.5
  b <- rep(b0,length(Zones)) #0.2
  u <- rep(1-w0-b0,length(Zones))

  a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

  Barr <- rep(0,cycles)
  Warr <- rep(0,cycles)
  Uarr <- rep(0,cycles)
  Tarr <- rep(0,cycles)
  I <- rep(0,cycles)

  TEMP <- matrix(NA, nrow=length(Zones), ncol=cycles)
  BLACK <- matrix(NA, nrow=length(Zones), ncol=cycles)
  WHITE <- matrix(NA, nrow=length(Zones), ncol=cycles)

```

```

for(i in c(1:cycles)) {
  S <- Sun6(i) # oppure costante S <- 1370
  Rin <- Incident(S,SunWt)
  Tcos <- cosZones*T
  Tm <- sum(Tcos)/sum(cosZones)
  T <- (Rin*(1-a)+K*Tm-A) / (B+K)
  Tw <- T+c*(a-aW)
  Tb <- T+c*(a-aB)
  Fw <- 1-k*(T0-Tw)^2
  Fb <- 1-k*(T0-Tb)^2
  for(j in c(1:length(Zones))) {
    if(Fw[j]<0){Fw[j]=0}
    if(Fb[j]<0){Fb[j]=0}
    w <- w+w*(u*Fw-D)
    b <- b+b*(u*Fb-D)
    for(j in c(1:length(Zones))) {
      if(w[j]<0.001){w[j]=0.001}
      if(b[j]<0.001){b[j]=0.001}
    }
    u <- 1-w-b
    a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
    Barr[i] <- b[45]
    Warr[i] <- w[45]
    Uarr[i] <- u[45]
    I[i] <- i
    Tarr[i] <- T[45]
    TEMP[,i] <- T
    BLACK[,i] <- b
    WHITE[,i] <- w
  }
  return ( WHITE )
}

ebm_D4 <- function(p,cycles,s,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta){
  Incident <- function(x,y){ x*y/4 }
  Func <- function(x){ 0.7768699*cos(0.0164348*x)^2+0.4617747 }
  Sun7 <- function(x,y){x*y}

  Zones <- seq(-89, 89, by = 2)
  cosZones <- abs(cospi(Zones/180))
  SunWt <- Func(Zones)
  Rin <- Incident(S,SunWt)
  Sarr <- rep(0,length(Zones)+30)
  #Sarr[1] <- Sun7(S,s)

  BLACK <- matrix(NA, nrow=length(Sarr), ncol=cycles)
  WHITE <- matrix(NA, nrow=length(Sarr), ncol=cycles)
  Tarr <- rep(0,length(Sarr))

  for(h in c(1:length(Sarr))) {
    S <- 920+(h-1)*10
    Sarr[h] <- S
    T <- gauss(Zones,0,50,31.6)-6
  }
}

```

```

w <- rep(w0,length(Zones)) #0.5
b <- rep(b0,length(Zones)) #0.2
u <- rep(1-w0-b0,length(Zones))

a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)

Barr <- rep(0,cycles)
Warr <- rep(0,cycles)

for(i in c(1:cycles)) {
Rin <- Incident(S,SunWt)
Tcos <- cosZones*T
TM <- sum(T)/length(Zones)
Tm <- sum(Tcos)/sum(cosZones)
T <- (Rin*(1-a)+K*Tm-A) / (B+K)
Tw <- T+c*(a-aW)
Tb <- T+c*(a-aB)
Fw <- 1-k*(T0-Tw)^2
Fb <- 1-k*(T0-Tb)^2
for(j in c(1:length(Zones))) {
  if(Fw[j]<0){Fw[j]=0}
  if(Fb[j]<0){Fb[j]=0} }
w <- w+w*(u*Fw-D)
b <- b+b*(u*Fb-D)
for(j in c(1:length(Zones))) {
  if(w[j]<0.001){w[j]=0.001}
  if(b[j]<0.001){b[j]=0.001} }
u <- 1-w-b
a <- w*aW+b*aB+u*alb(T,ai,ab,gamma,delta)
Warr[i] <- w[45]
Barr[i] <- b[45]

}

WHITE[h,] <- Warr
BLACK[h,] <- Barr
Tarr[h] <- Tm
}
if(p==0){return (WHITE)}
if(p==1){return (BLACK)}
if(p==2){return (data.frame(Tarr,Sarr))}
}

```

Solar Luminosity

$$S_1(t) = \frac{S}{100}t$$

$$S_2(t) = S(\sin^2(t + 90))$$

$$S_3(t) = S\left(1 - \frac{1}{\sqrt{2\pi}}e^{-(t-50)^2/2}\right)$$

$$S_4(t) = S\left(1 - \frac{1}{3}\delta(t - 50)\right)$$

$$S_5(t) = \frac{1}{100}(|t - 150| + 25)$$

$$S_6(t) = S\left(1 + \frac{1}{10}\cos(t)\right)$$

Albedo

$$a(T) = \frac{e^{\gamma(T+\delta)}}{e^{\gamma(T+\delta)} + 1}(\beta - \alpha) + \alpha$$

EBM

$$T = \frac{R_{in}(1 - a(T)) + KT_m - A}{B + K}$$

Daisyworld

$$a(T) = wa_w + ba_b + u\left(\frac{e^{\gamma(T+\delta)}}{e^{\gamma(T+\delta)} + 1}(\beta - \alpha) + \alpha\right)$$

$$T_w = T + c(a - a_w)$$

$$T_b = T + c(a - a_b)$$

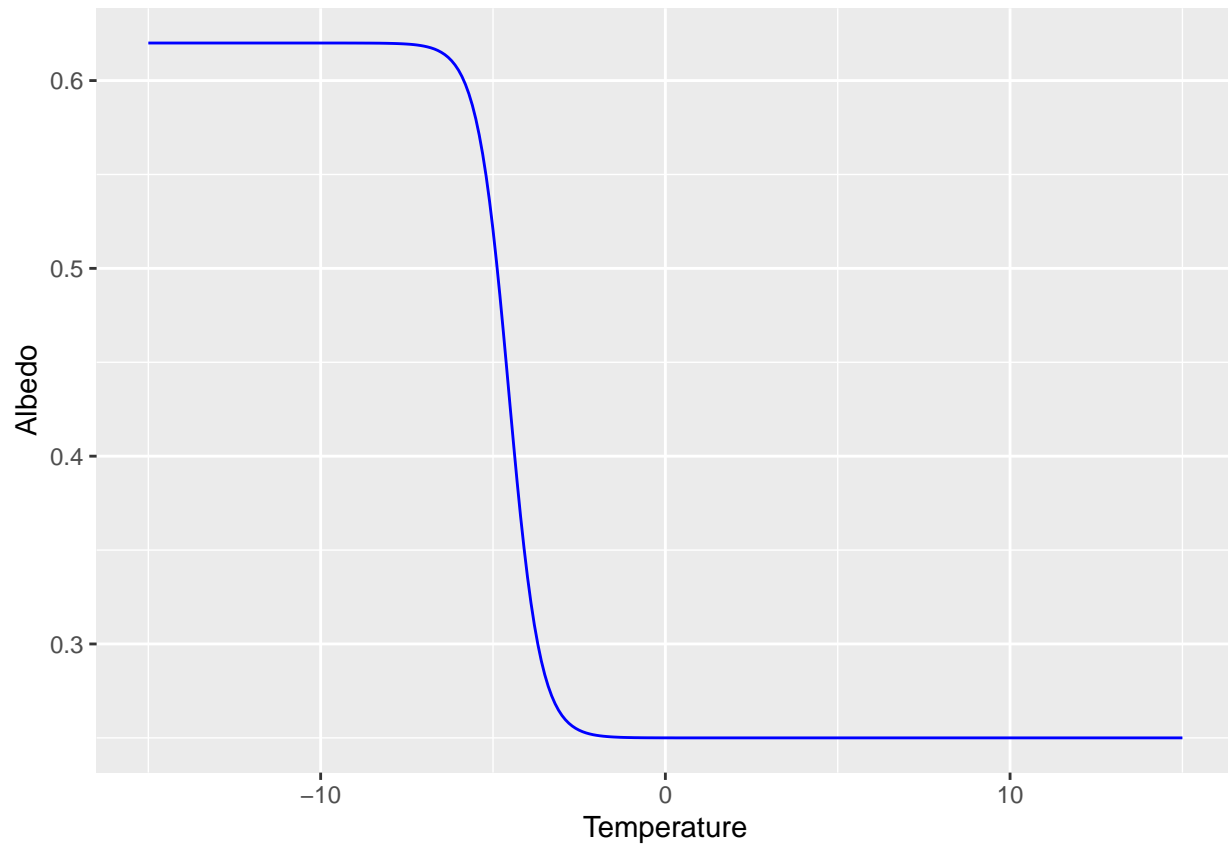
$$F_w = 1 - k(T_0 - T_w)^2$$

$$F_b = 1 - k(T_0 - T_b)^2$$

$$w' = w + w(uF_w - D)$$

$$b' = b + b(uF_b - D)$$

```
plot_albedo <- ggplot(data.frame(x= seq(-15,15, by=0.1),y=alb(seq(-15,15, by=0.1),ai,ab,gamma,delta))) +
plot_albedo
```



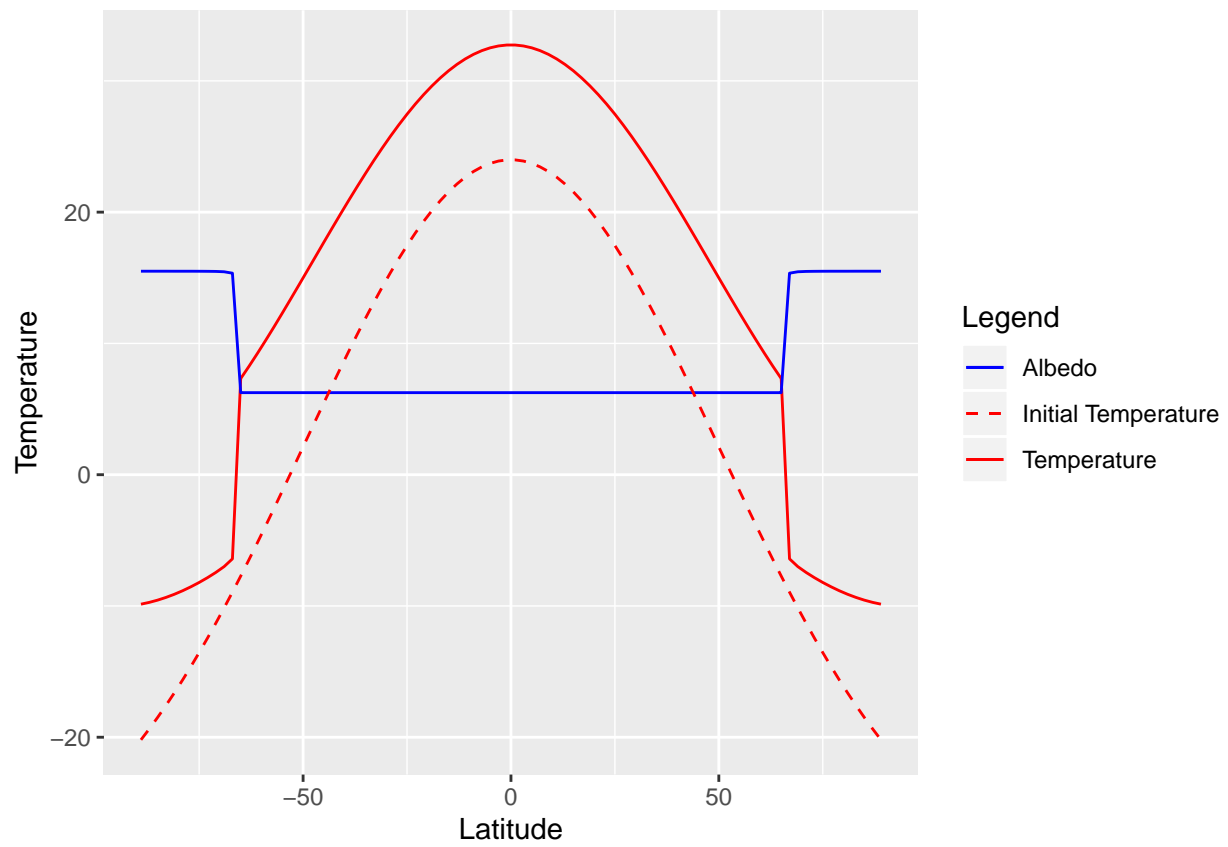
Run 0

```
data01 <- ebm01(150,A,B,K,ai,ab,gamma,delta) #from 300
data02 <-ebm02(150,A,B,K,ai,ab,gamma,delta) #from 300

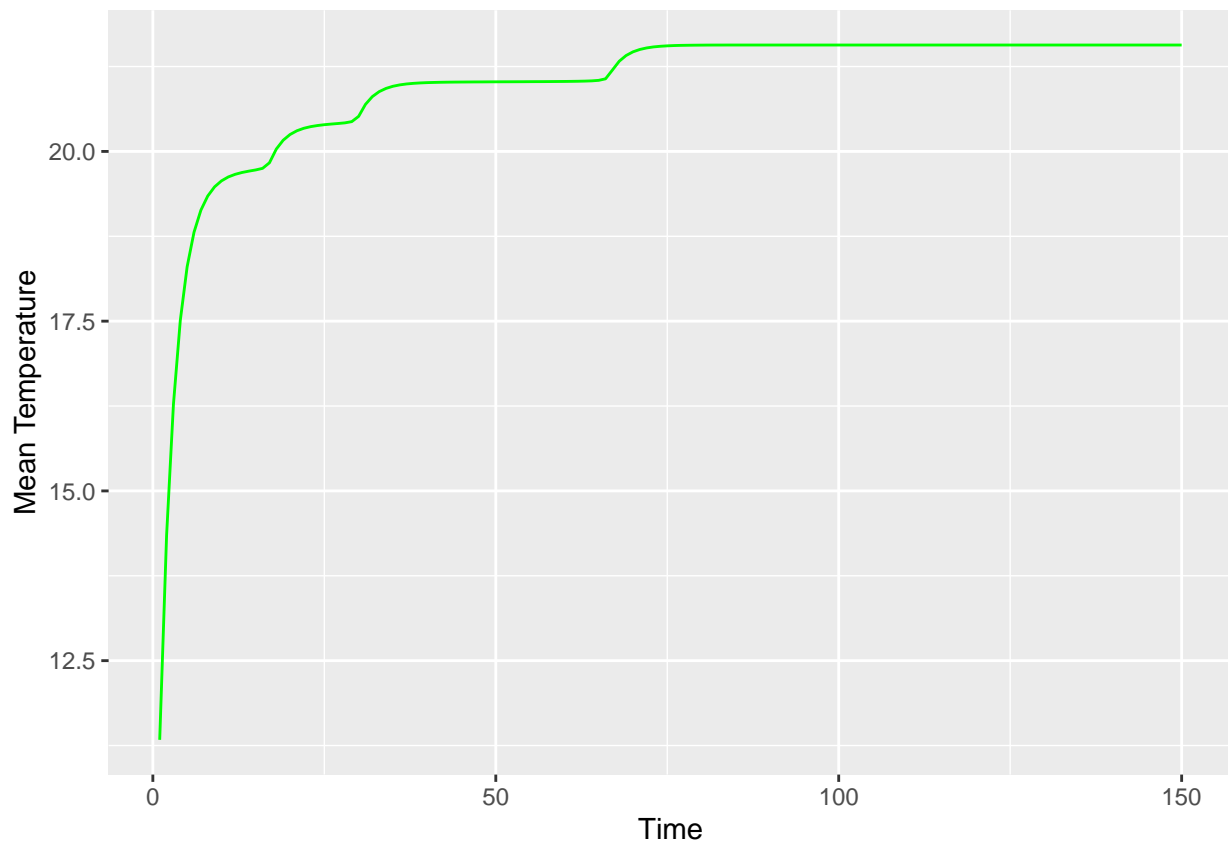
plot01 <- ggplot(data01,aes(Zones)) +
  geom_line(aes(y=T, colour = "Temperature",linetype="Temperature")) +
  geom_line(aes(y=a*25, colour = "Albedo",linetype="Albedo"))+
  geom_line(aes(y=Ti, colour = "Initial Temperature",linetype="Initial Temperature"))+xlab("Latitude")+

plot02 <- ggplot(data02) +
  geom_line(aes(t, Temperature),colour = 'green')+xlab("Time")+ylab("Mean Temperature")

plot01
```



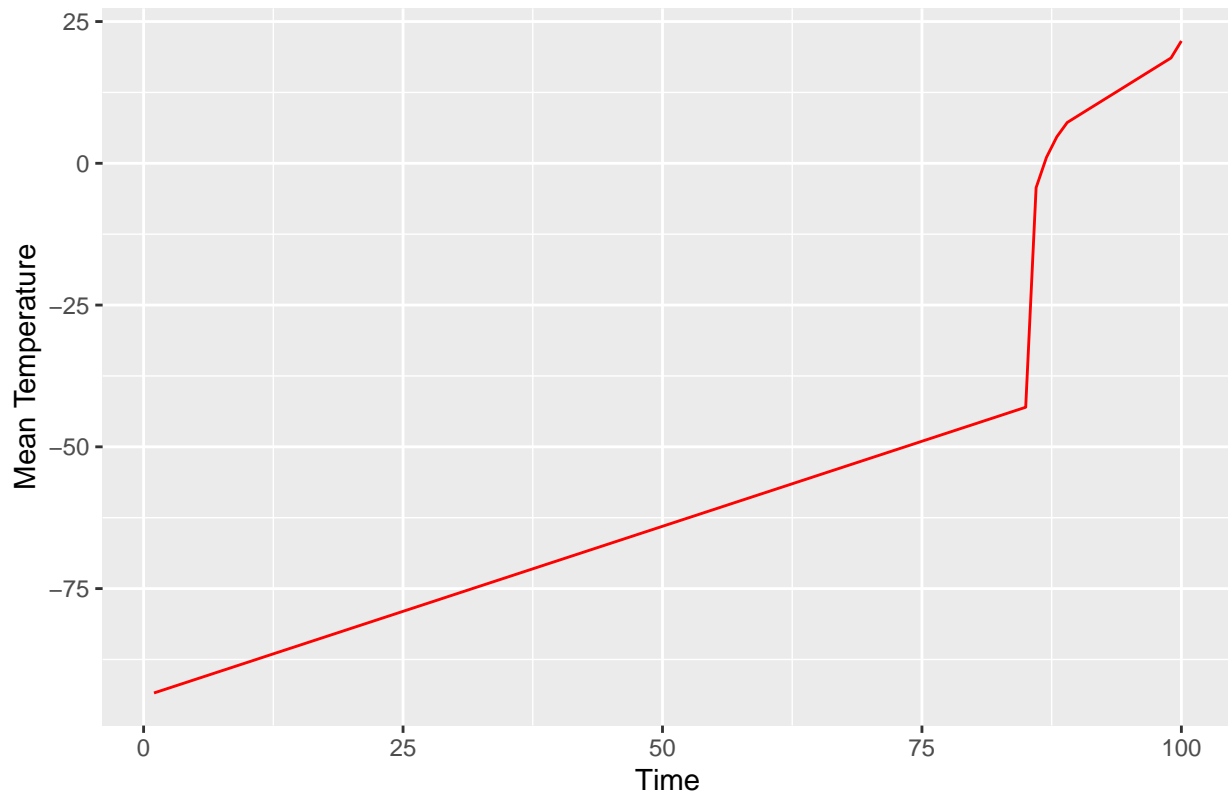
plot02



Run 1

```
data11 <- ebm11(100,300,A,B,K,ai,ab,gamma,delta)
plot11 <- ggplot(data11,aes(J,Temp))+geom_line(aes(J, Temp),colour = 'red')+xlab("Time")+ylab("Mean Temp")
plot11
```


Non Dynamic Mean Temperature ($T(t)$ independent from $T(t-1)$)



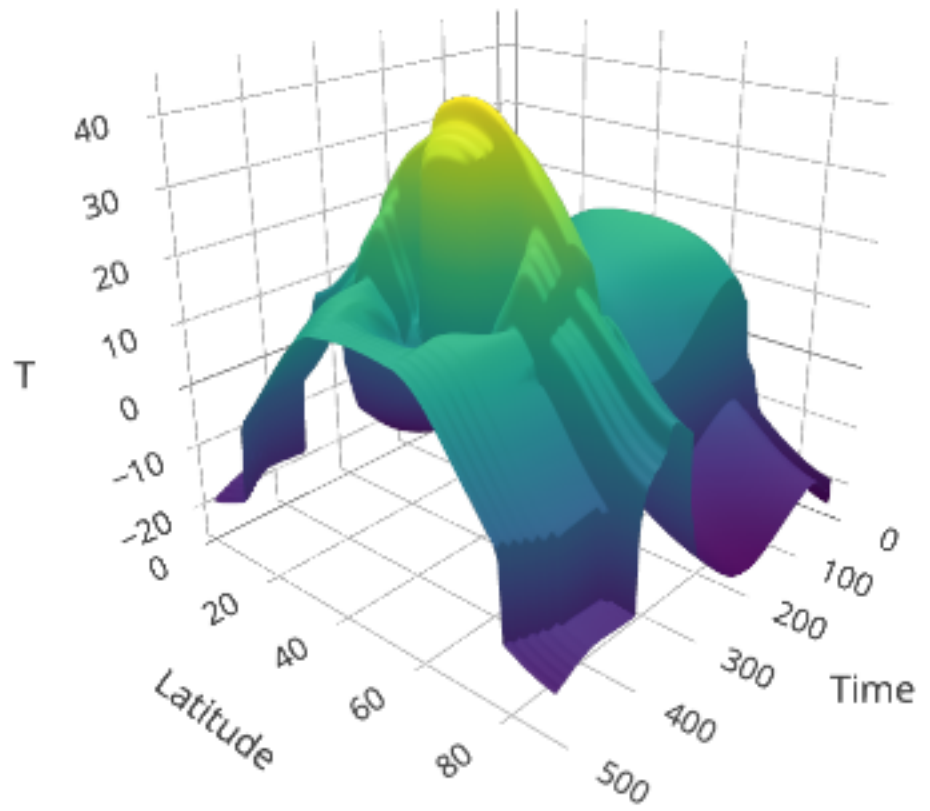
```
TEMP1 <- ebm12(100,300,A,B,K,ai,ab,gamma,delta)

plot_ly(z=~TEMP1)%>% add_surface() %>% layout(
  title = "With Initialization", scene = list(
    xaxis = list(title = "S/100"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "T") ))
```

WebGL is not
supported by
your browser -
visit
<https://get.webgl.org>
for more info

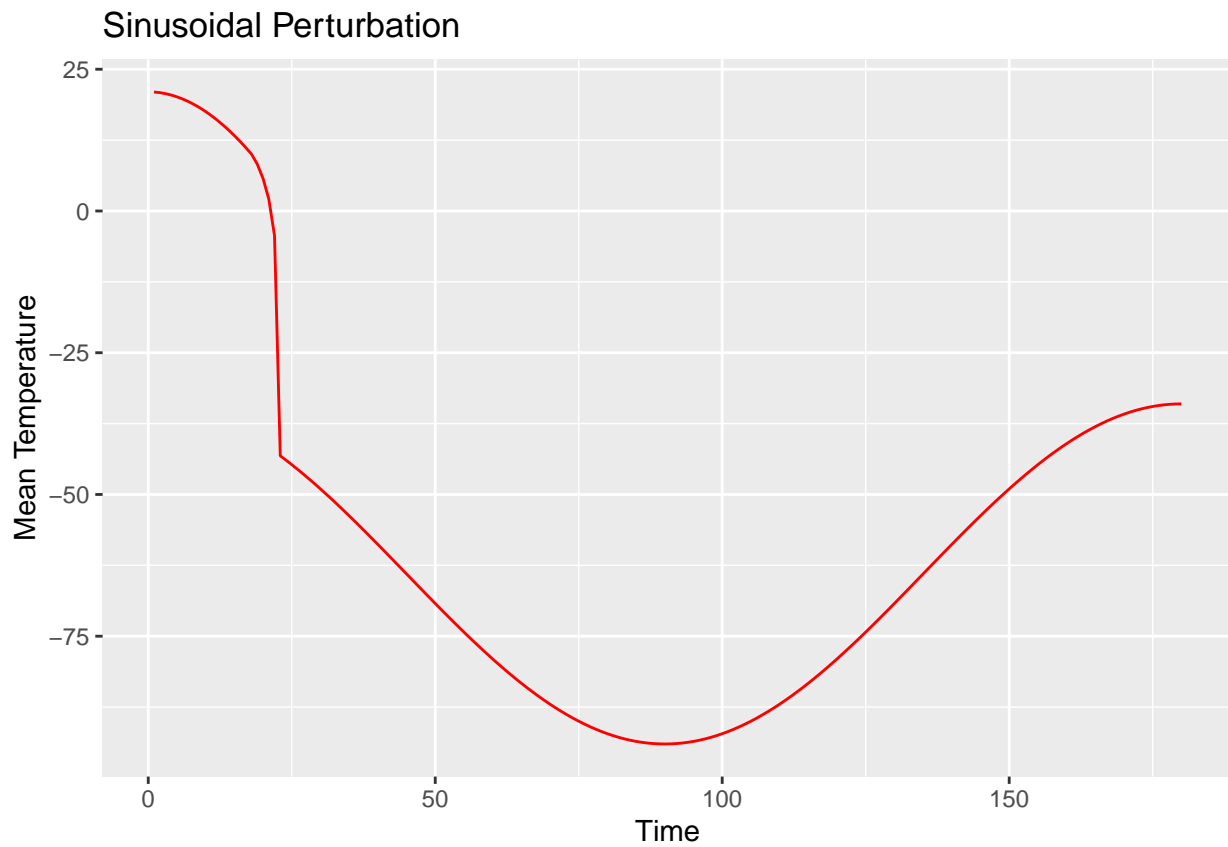
```
include_graphics("plotly/D1.png")
```

Temperature With Daisies



Run 2

```
data21 <- ebm21(180,300,A,B,K,ai,ab,gamma,delta )  
plot21 <- ggplot(data21,aes(J,Temp2))+geom_line(aes(J, Temp2),colour = 'red')+xlab("Time")+ylab("Mean T")  
plot21
```



```
TEMP2 <- ebm22(180,300,A,B,K,ai,ab,gamma,delta )
plot_ly(z=~TEMP2) %>% add_surface() %>% layout(
  title = "Without Initialization",scene = list(
    xaxis = list(title = "S/100"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "T") ))
```

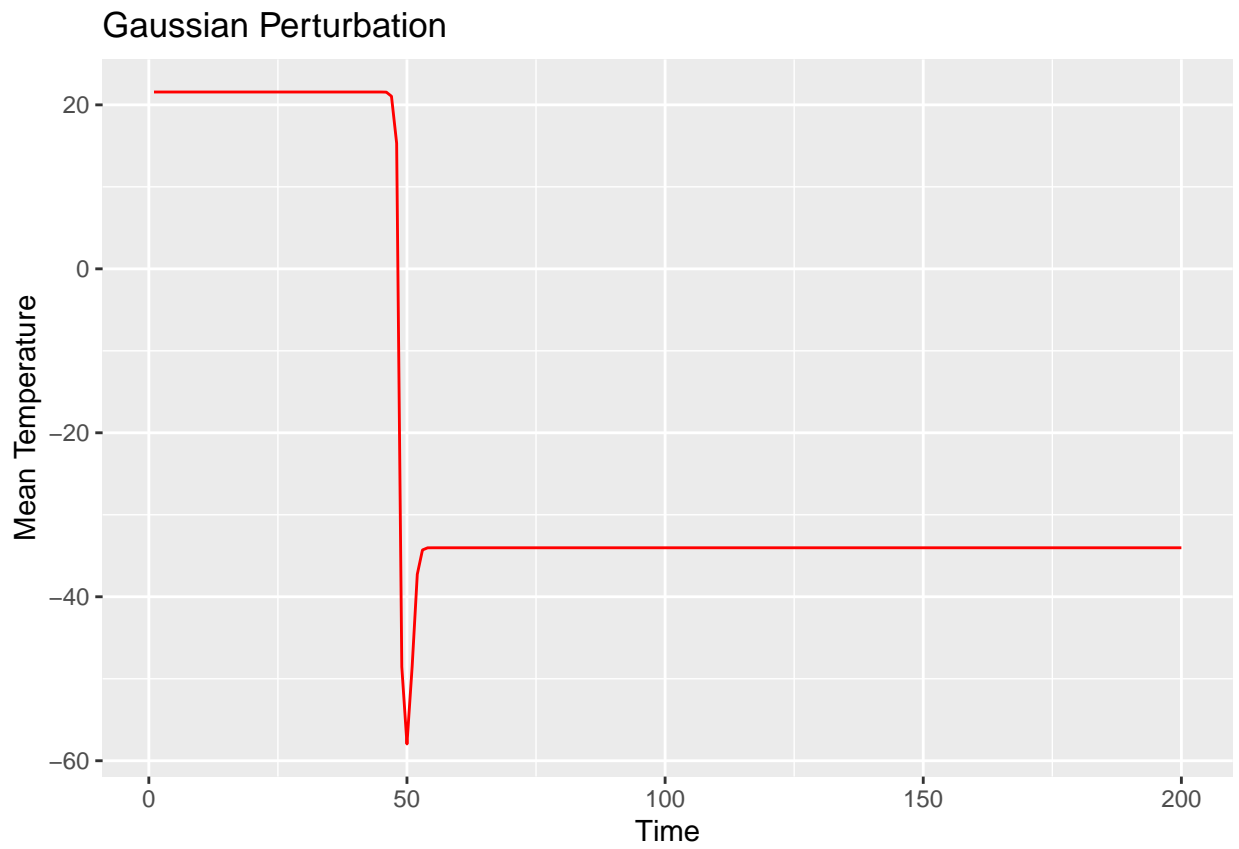
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Run 3 & 4

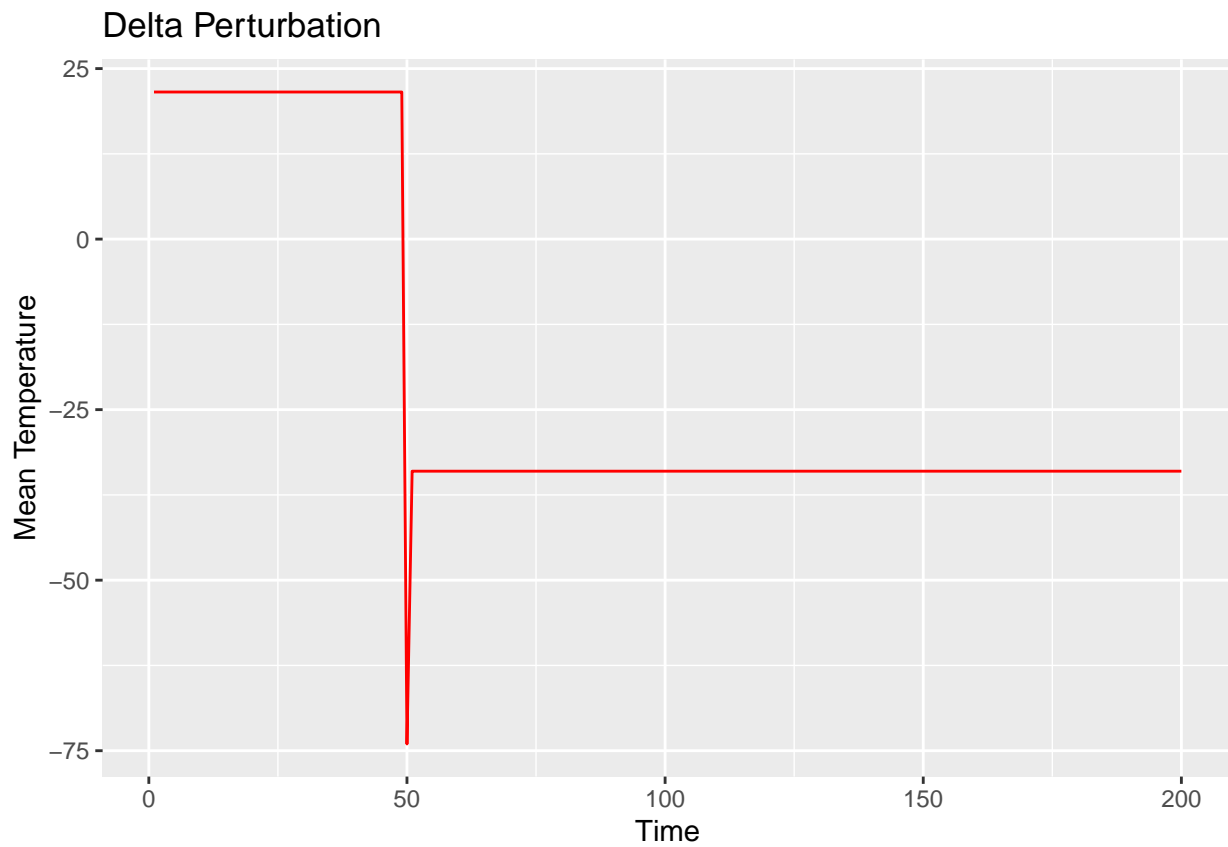
```
data31 <- ebm31(200,300,A,B,K,ai,ab,gamma,delta )
data41 <- ebm41(200,300,A,B,K,ai,ab,gamma,delta )

plot31 <- ggplot(data31,aes(J,Temp))+geom_line(aes(J, Temp),colour = 'red')+xlab("Time")+ylab("Mean Temp")
plot41 <- ggplot(data41,aes(J,Temp))+geom_line(aes(J, Temp),colour = 'red')+xlab("Time")+ylab("Mean Temp")

plot31
```



plot41



```
TEMP3 <- ebm32(200,300,A,B,K,ai,ab,gamma,delta )
TEMP4 <- ebm42(200,300,A,B,K,ai,ab,gamma,delta)

plot_ly(z=~TEMP3) %>% add_surface()%>% layout(
  title = "Without Initialization", scene = list(
    xaxis = list(title = "S/100"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "T")  ))
```

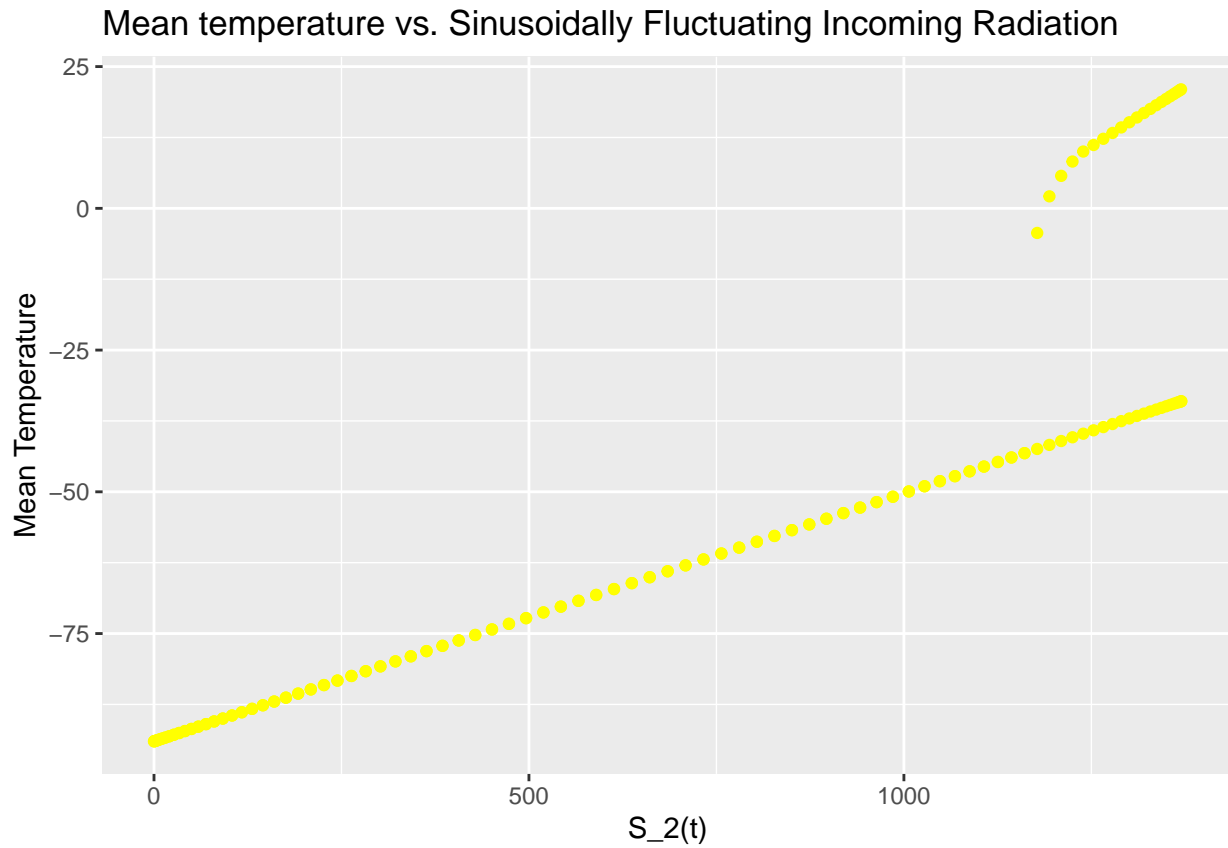
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```
plot_ly(z=~TEMP4) %>% add_surface()%>% layout(  
  title = "Without Initialization", scene = list(  
    xaxis = list(title = "S/100"),  
    yaxis = list(title = "Latitude"),  
    zaxis = list(title = "T")    ))
```

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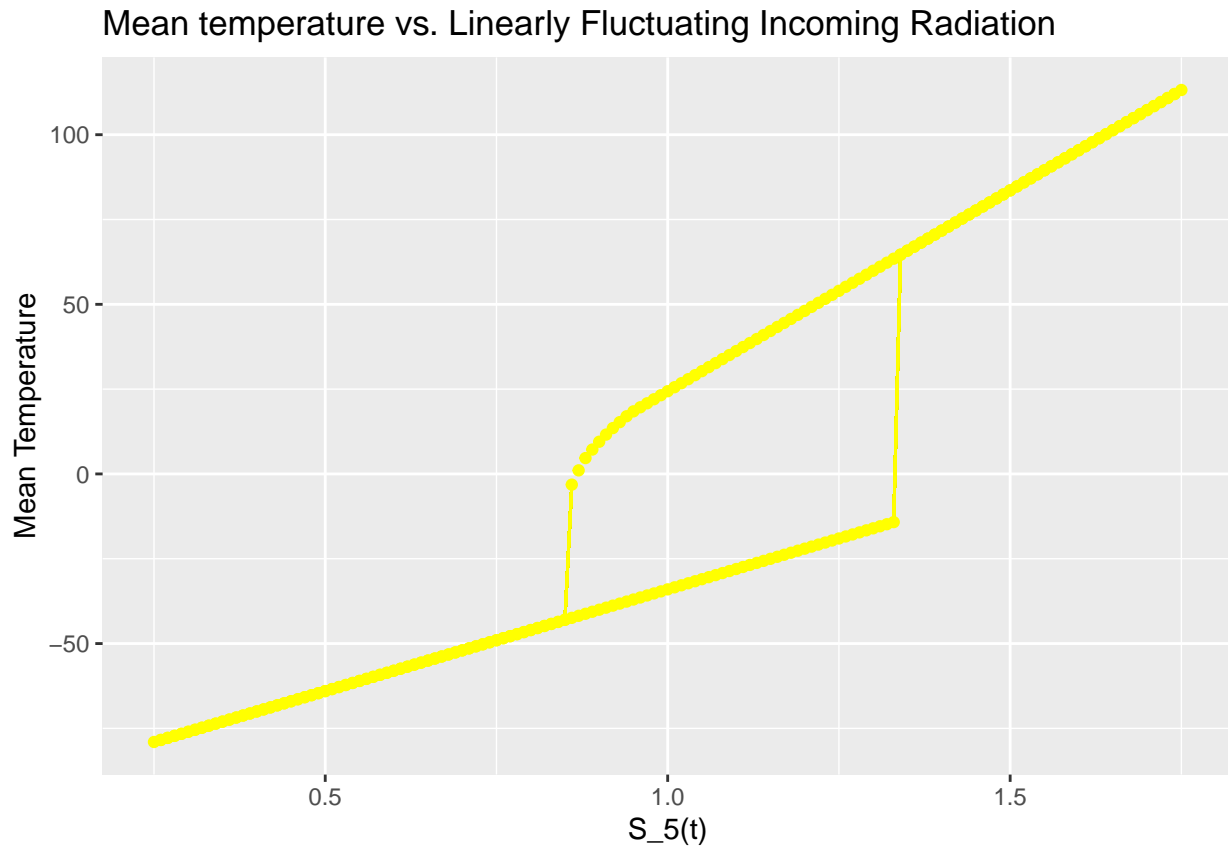

```
data23 <- ebm23(180,300,A,B,K,ai,ab,gamma,delta )
```

```
plot23 <- ggplot(data23,aes(Sarr,Temp2))+geom_point(aes(Sarr, Temp2),colour = 'yellow')+ylab("Mean Temp")
plot23
```



```
data51 <- ebm51(300,60,A,B,K,ai,ab,gamma,delta )
```

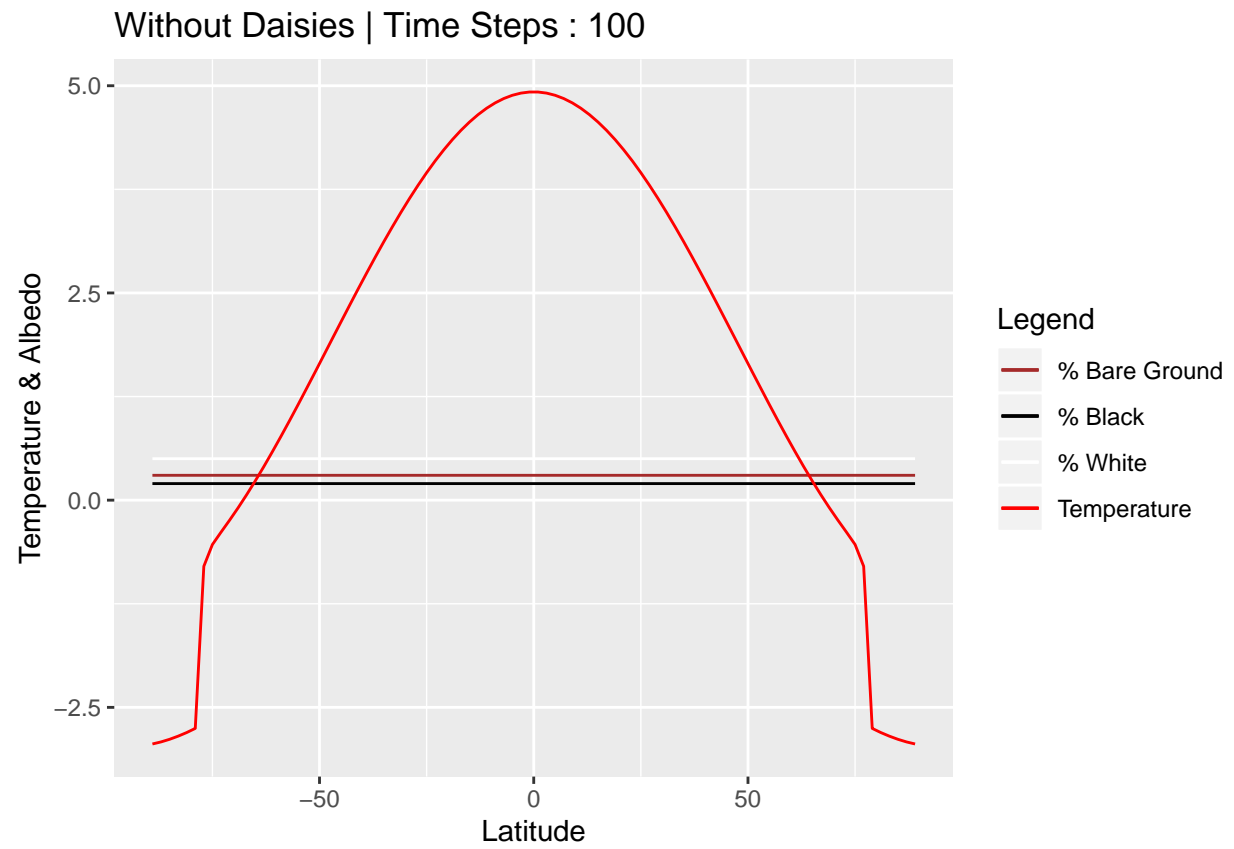
```
plot51 <- ggplot(data51,aes(Sarr,Temp5,group=1))+geom_point(aes(Sarr, Temp5),colour = 'yellow')+geom_se
plot51
```



Embedding Daisies in EBM

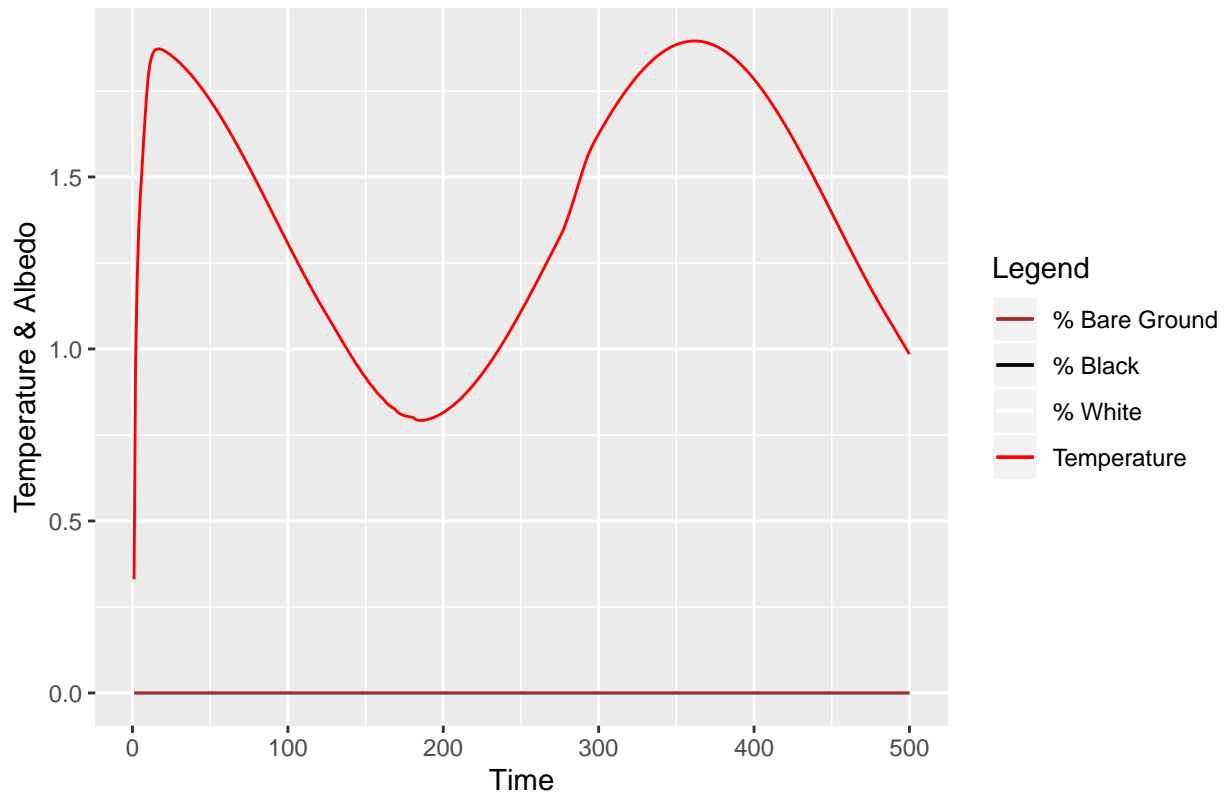
```
# WITHOUT DAISIES
data_ND1 <- ebm_ND1(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta) #from 500
data_ND2 <- ebm_ND2(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta)
data_ND4 <- ebm_ND4(300,1370/920,A,B,K,ai,ab,gamma,delta) #from 300
TEMP <- ebm_ND3(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta)

plot_ND1 <- ggplot(data_ND1,aes(Zones))+geom_line(aes(y=w, colour = "% White"))+geom_line(aes(y=b, colour = "% Black"))
plot_ND2 <- ggplot(data_ND2,aes(I))+geom_line(aes(y=Barr,colour="% Black"))+ geom_line(aes(y=Warr,colour="% White"))
plot_ND1
```



plot_ND2

Without Daisies | Time Steps : 100



```
plot_ly(z=~TEMP)%>% add_surface() %>% layout( title="Temperature Without Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "T")  ))
```

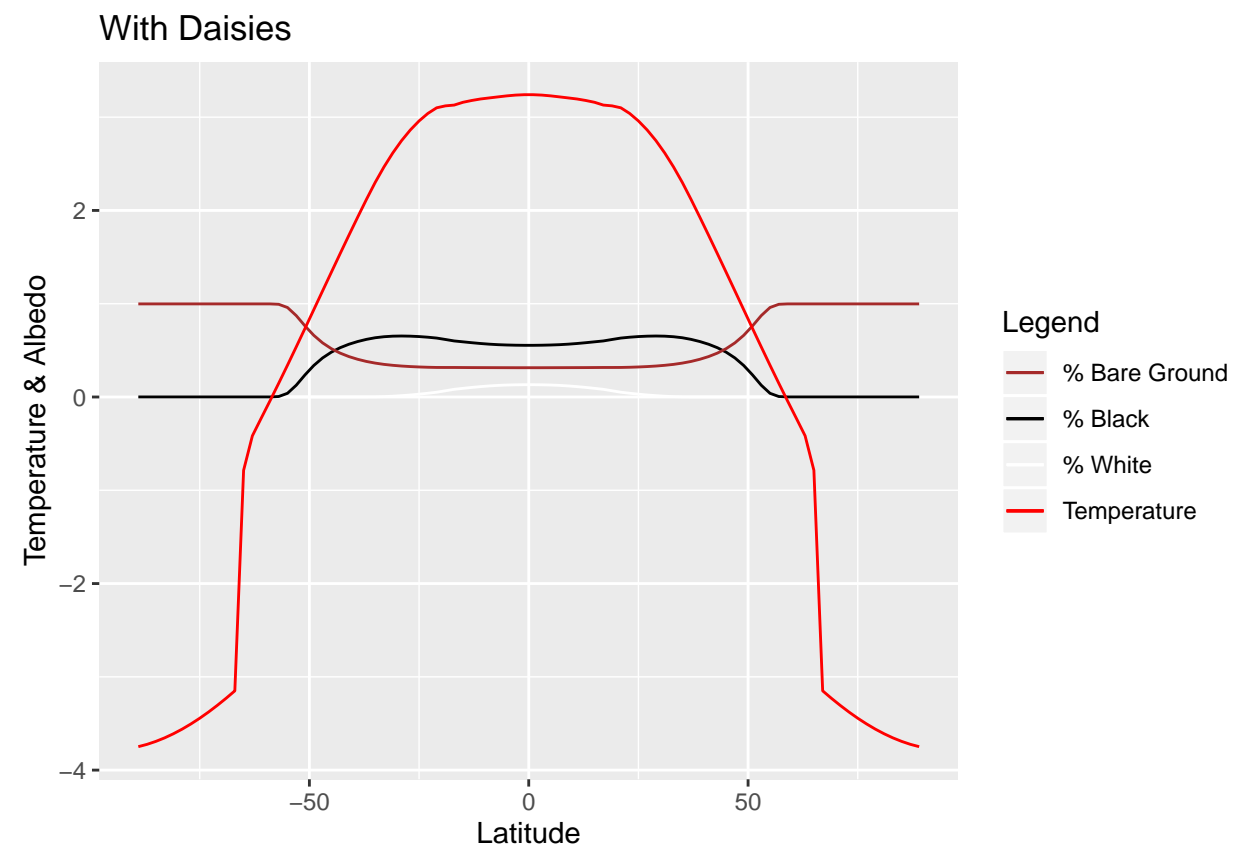
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#WITH DAISIES

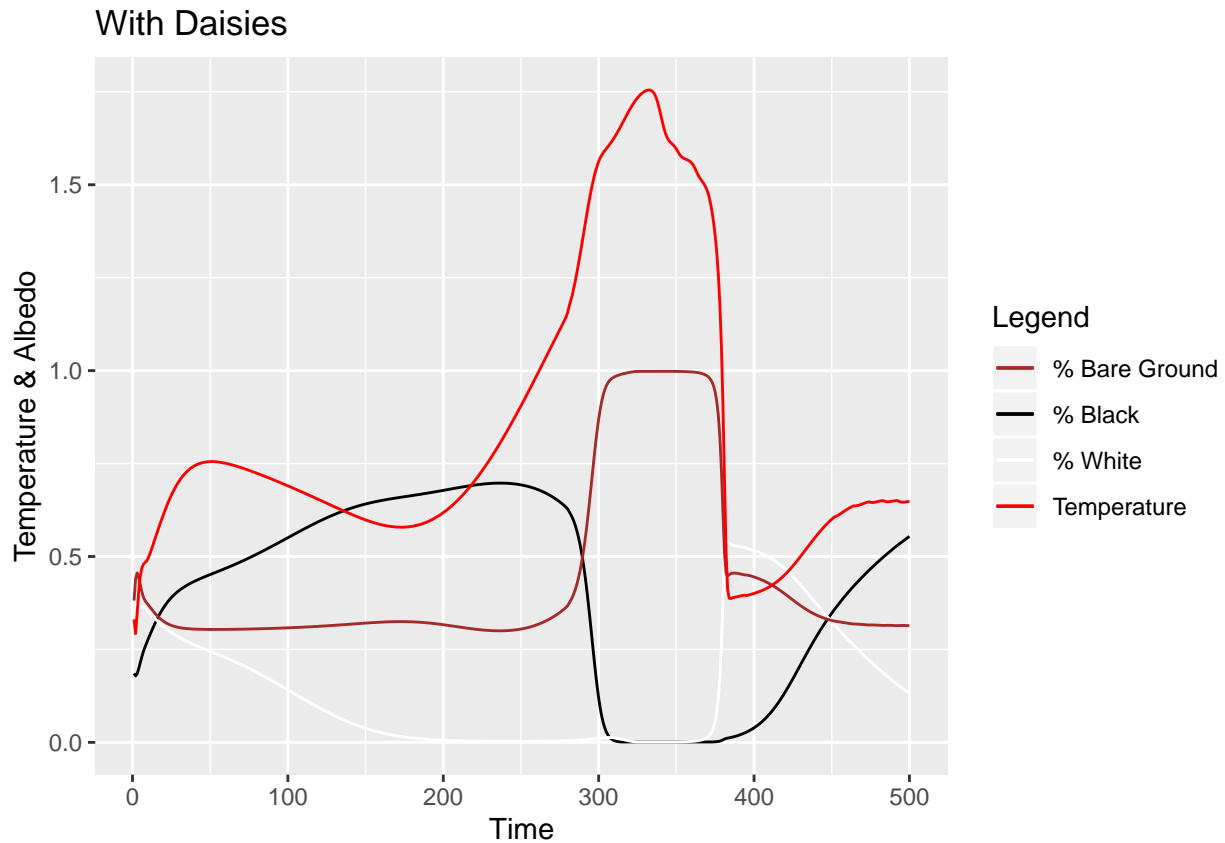
```
data_D1 <- ebm_D1(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
data_D2 <- ebm_D2(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
data_D4 <- ebm_D4(2,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta) #from 300
TEMP <- ebm_D3(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
BLACK <- ebm_Db2(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
WHITE <- ebm_Dw2(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
```

```
plot_D1 <- ggplot(data_D1 ,aes(Zones))+geom_line(aes(y=w, colour = "% White"))+geom_line(aes(y=b, colour=
plot_D2 <- ggplot(data_D2,aes(I))+geom_line(aes(y=Barr,colour="% Black"))+ geom_line(aes(y=Warr,colour=
plot_D4 <- ggplot(data_D4,aes(Sarr,Tarr))+ylab("Temperature")+xlab("Solar Luminosity")+ggtitle("Solar L
```

plot_D1



plot_D2



```
plot_ly(z=~TEMP)%>% add_surface() %>% layout(title="Temperature With Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "T") ))
```

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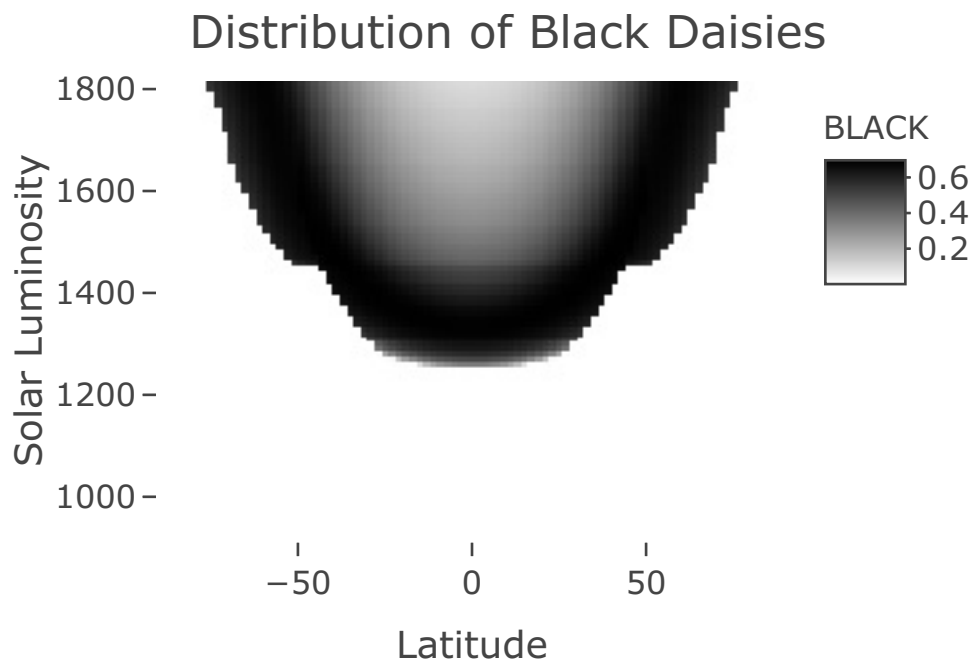
```
plot_ly(z=~BLACK)%>% add_surface() %>% layout(title="Distribution of Black Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "Black" ) )
```

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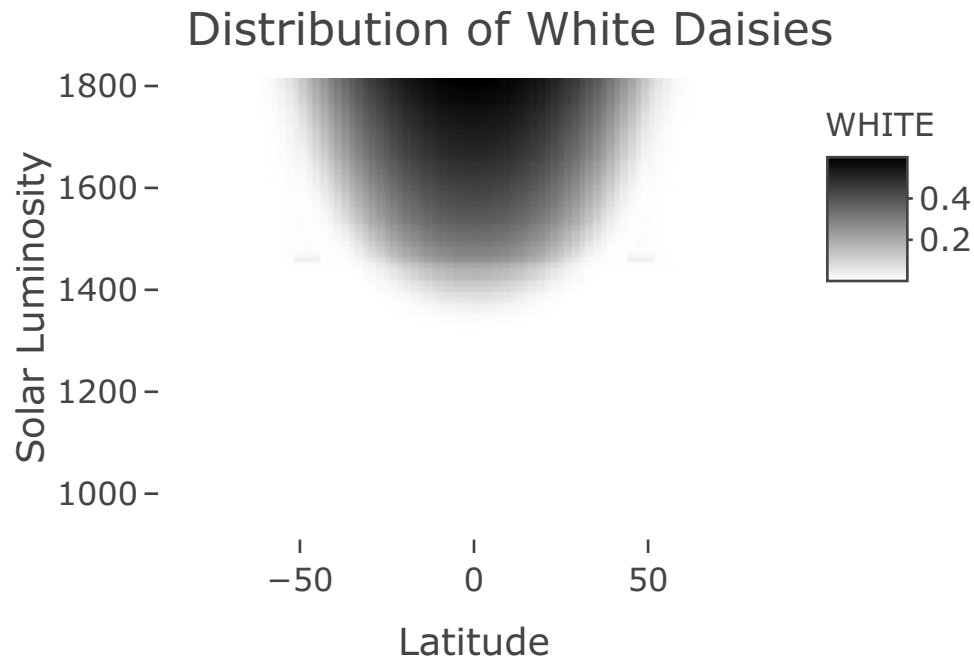
```
plot_ly(z=~WHITE)%>% add_surface() %>% layout(title="Distribution of White Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Latitude"),
    zaxis = list(title = "White" ) )
```

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```
ebm_Db1(150,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)%>% layout(title="Distribution of Black Daisies",
axis = list(title = "Latitude"),
yaxis = list(title = "Solar Luminosity") )
```



```
ebm_Dw1(150,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta) %>% layout(title="Distribution of White Daisies",
axis = list(title = "Latitude"),
yaxis = list(title = "Solar Luminosity") )
```

```
WHITE <- ebm_D4(0,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
BLACK  <- ebm_D4(1,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)

plot_ly(z=~BLACK)%>% add_surface() %>% layout(title="Distribution of Black Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Solar Luminosity"),
    zaxis = list(title = "Black")  ))
```

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```
plot_ly(z=~WHITE)%>% add_surface() %>% layout(title="Distribution of White Daisies",
  scene = list(
    xaxis = list(title = "Time"),
    yaxis = list(title = "Solar Luminosity"),
    zaxis = list(title = "White" ) )
```

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```
data_ND4_D4 <- data.frame(data_ND4,data_D4)
plot_ND4_D4 <- ggplot(data_ND4_D4,aes(Sarr))+ylab("Temperature")+xlab("Solar Luminosity")+ggtitle("Solar Luminosity vs Temperature")
plot_ND4_D4
```

