Climate Modelling

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Contents

Introduction

Packages

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

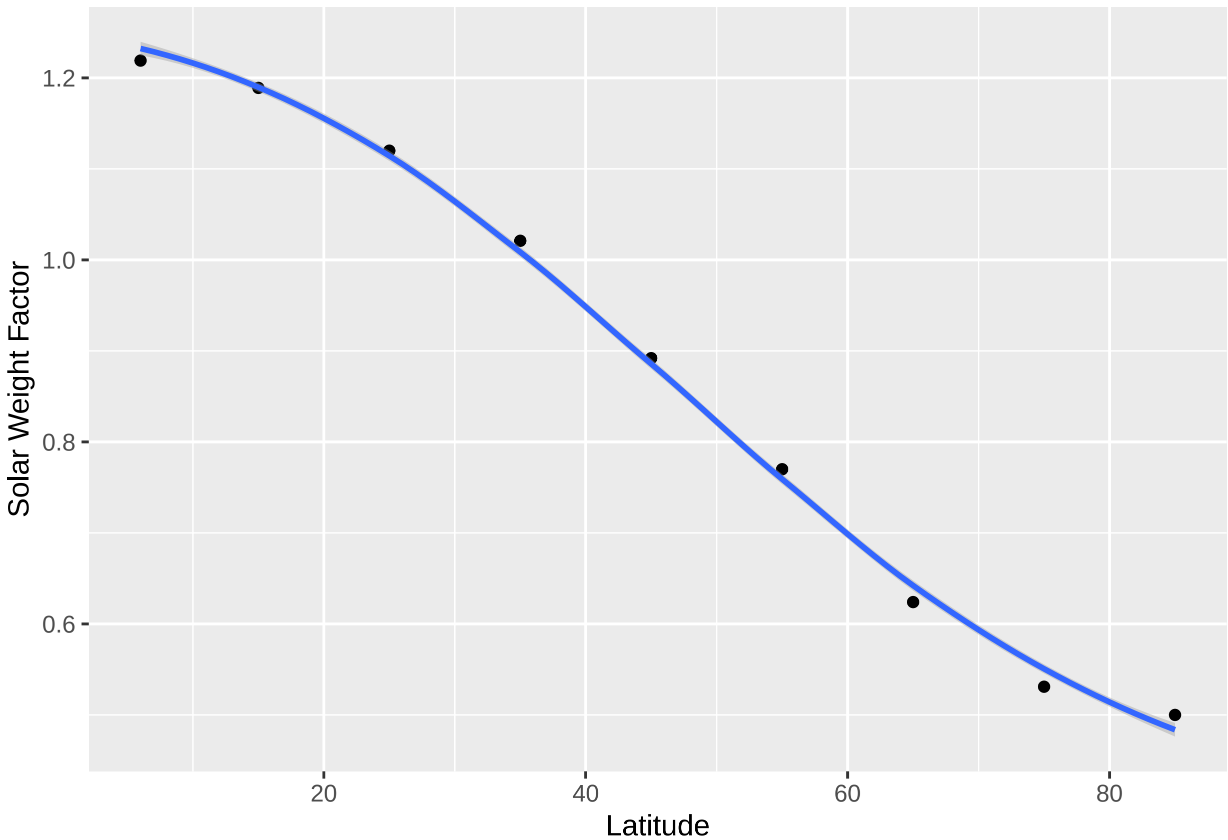
Input Parameters

```
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)))+xla
```



Functional Forms

```r
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)
```

```r
  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)) {
```

```r
  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)
```

```r
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
```

```r
  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}
```

```r
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

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

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

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

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

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

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

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

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

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

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

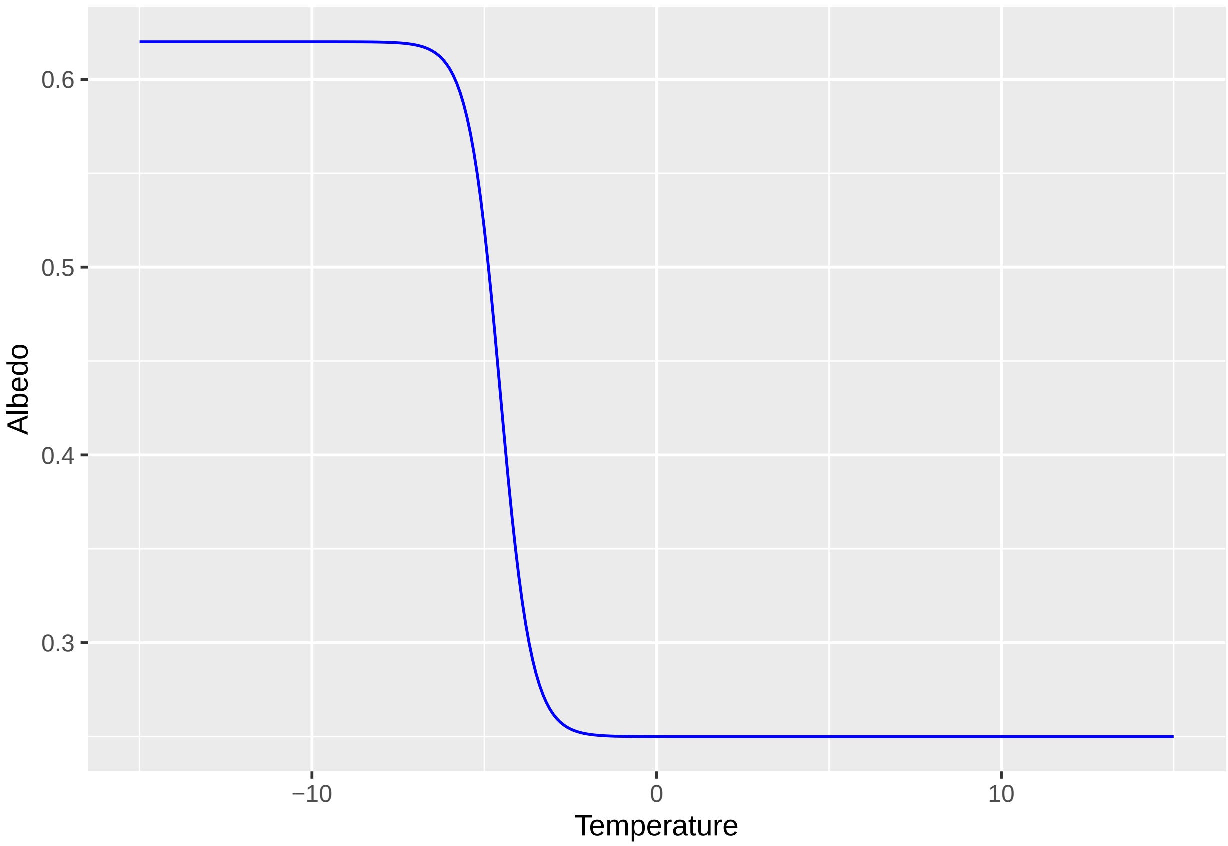
$$F_w = 1 - k(T_0 - T_w)^2$$

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

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

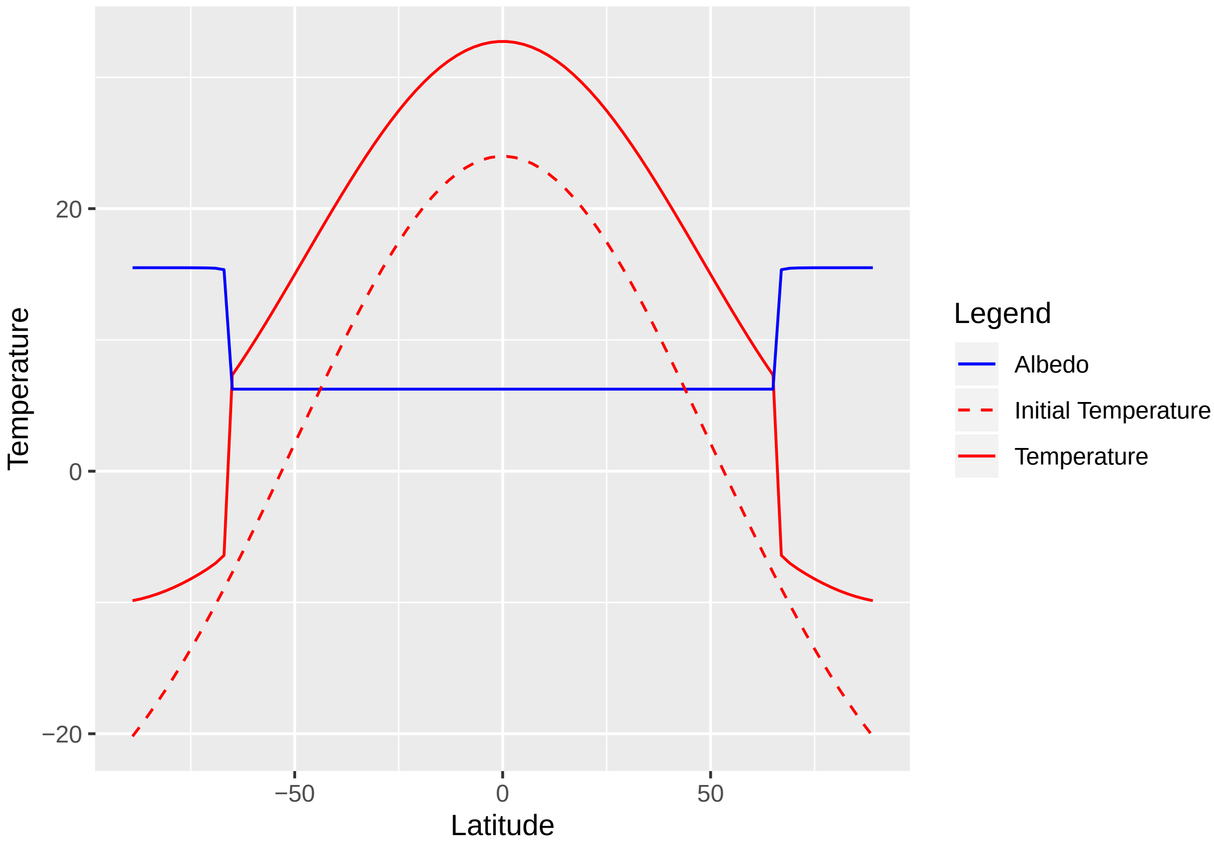
$$b' = b + b(uF_b - D)$$

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



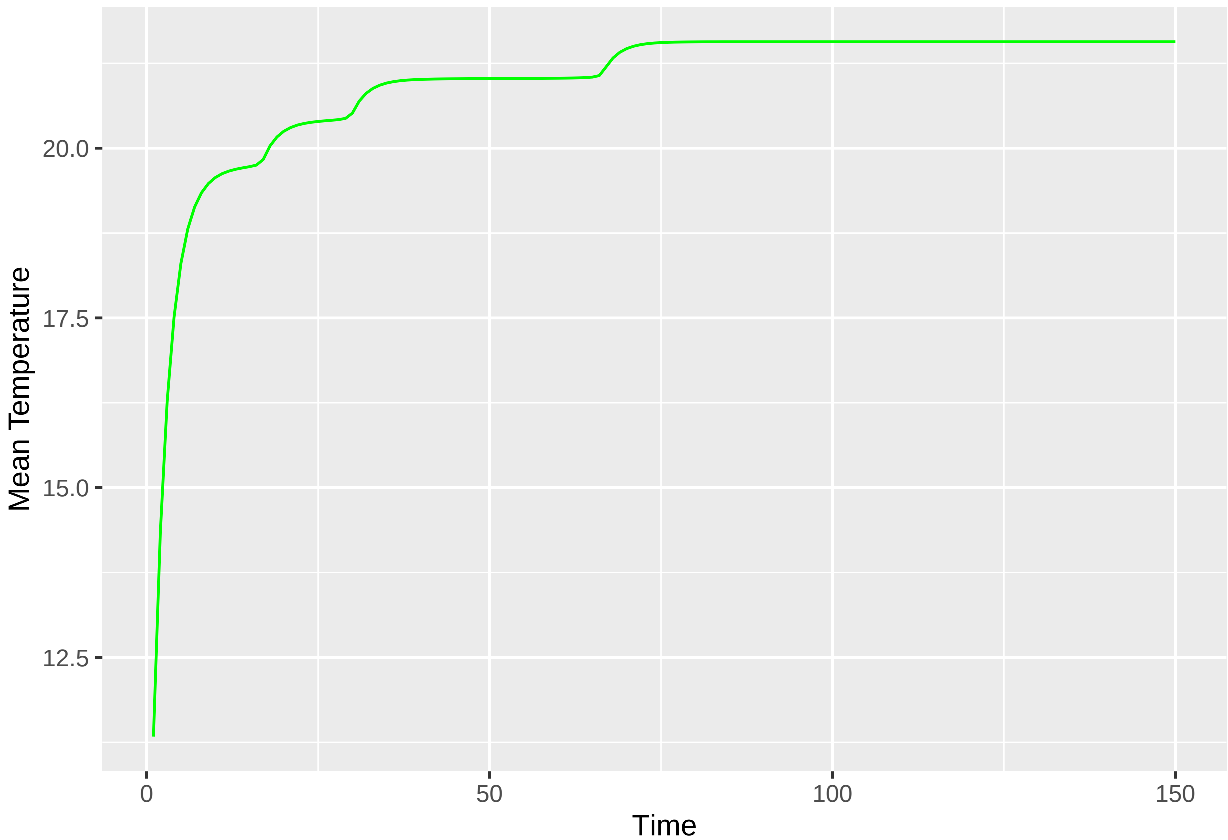
Run 0

```
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")+y

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

plot01
```



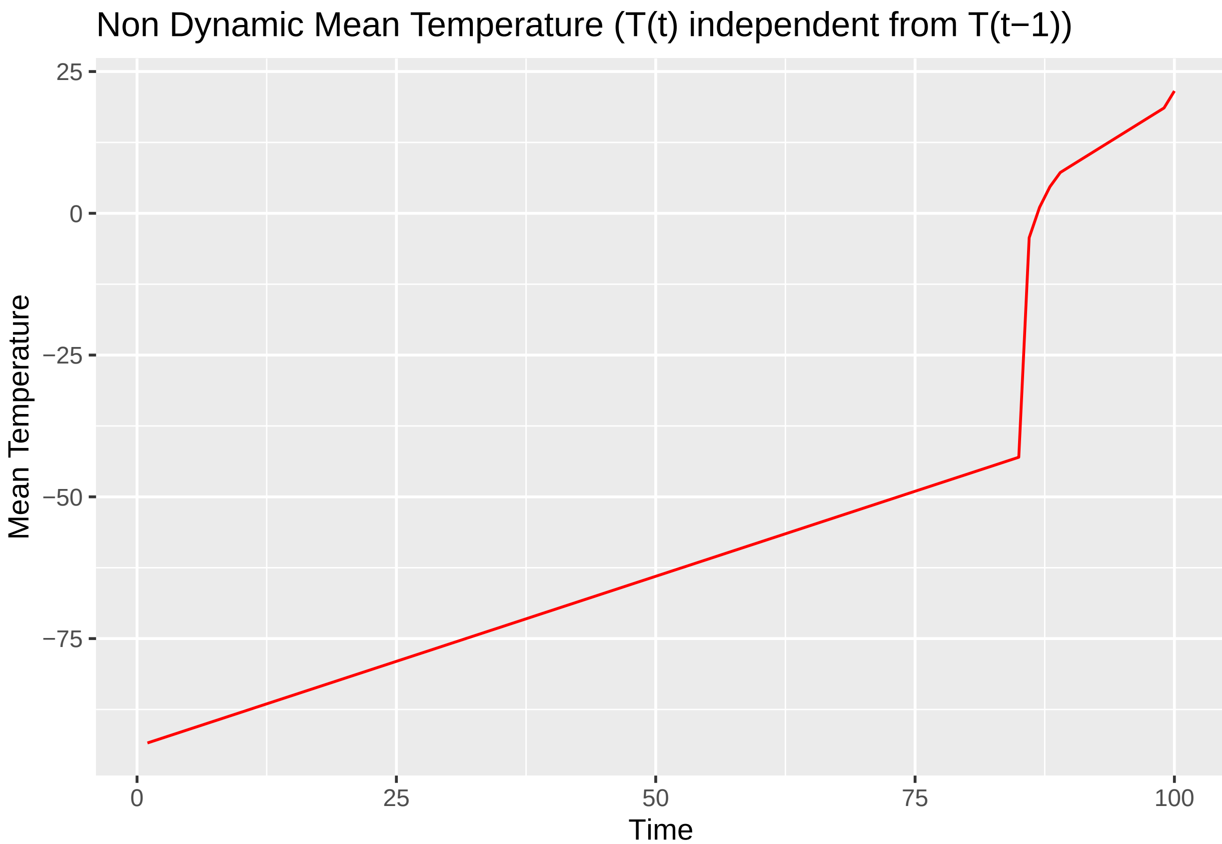
Temperature
20
0
−20
−50
0
50
Latitude
Legend
Albedo
Initial Temperature
Temperature


```
plot02
```



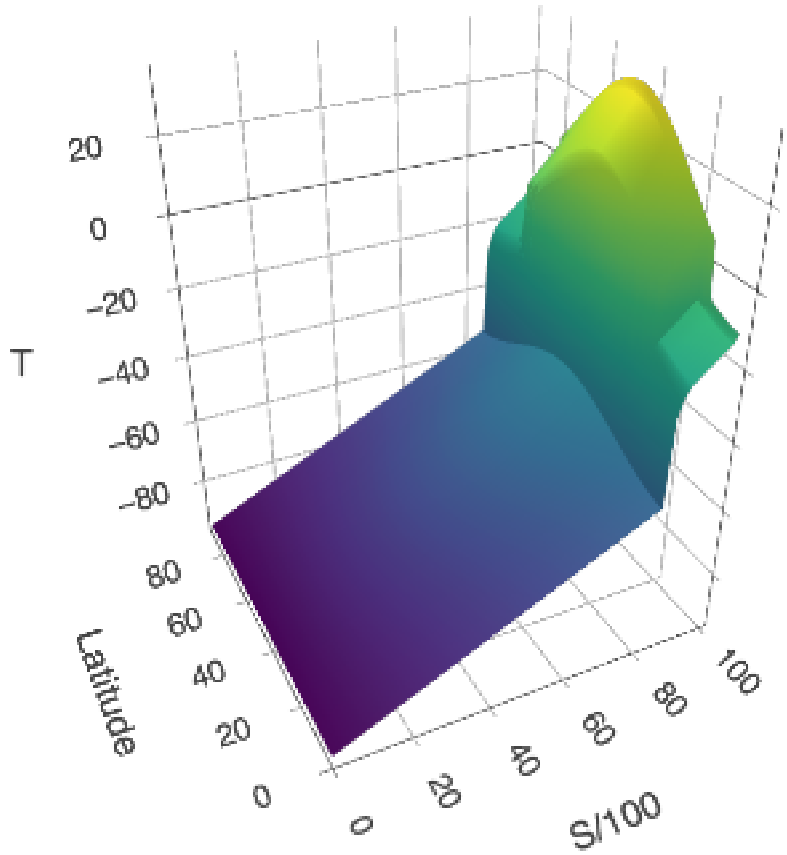
Run 1

```
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
```



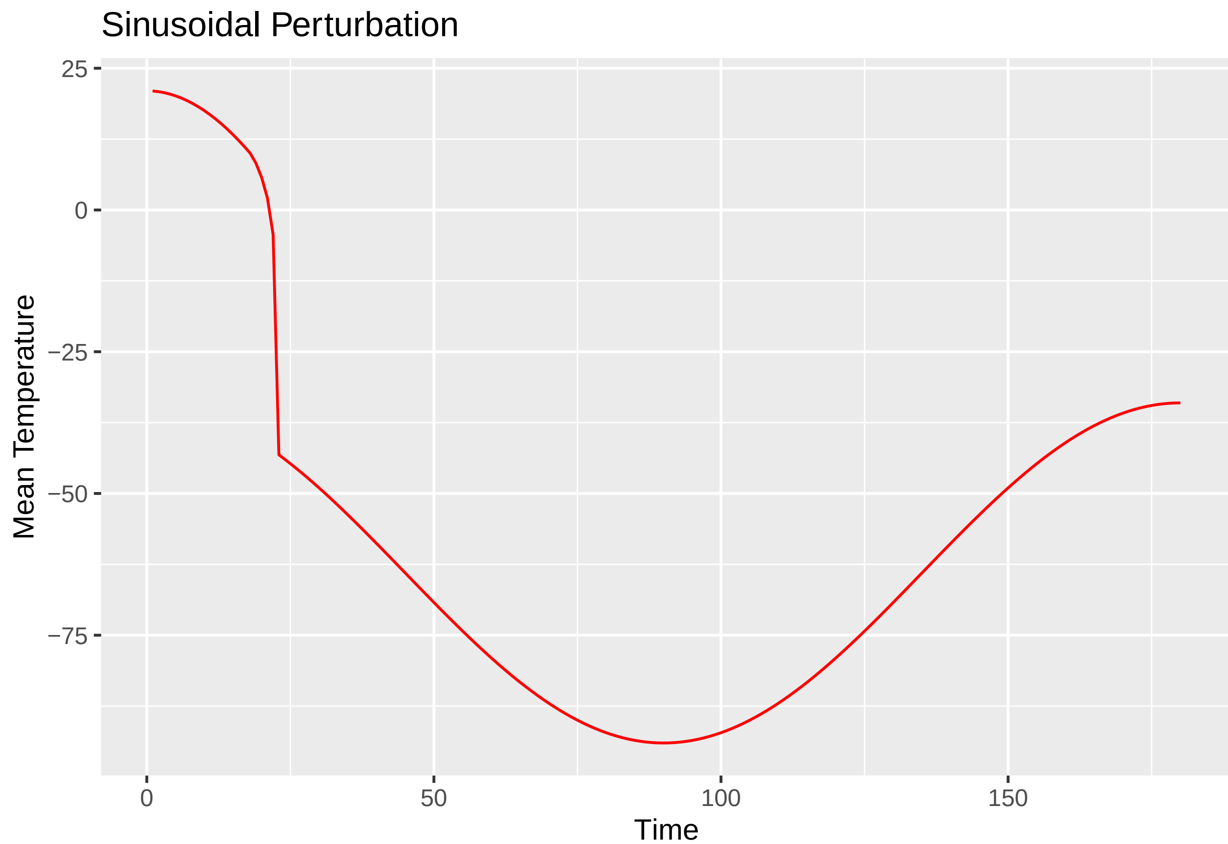

```
TEMP1 <- ebm12(100,300,A,B,K,ai,ab,gamma,delta)

include_graphics("plotly/TEMP1.png")
```

With Initialization

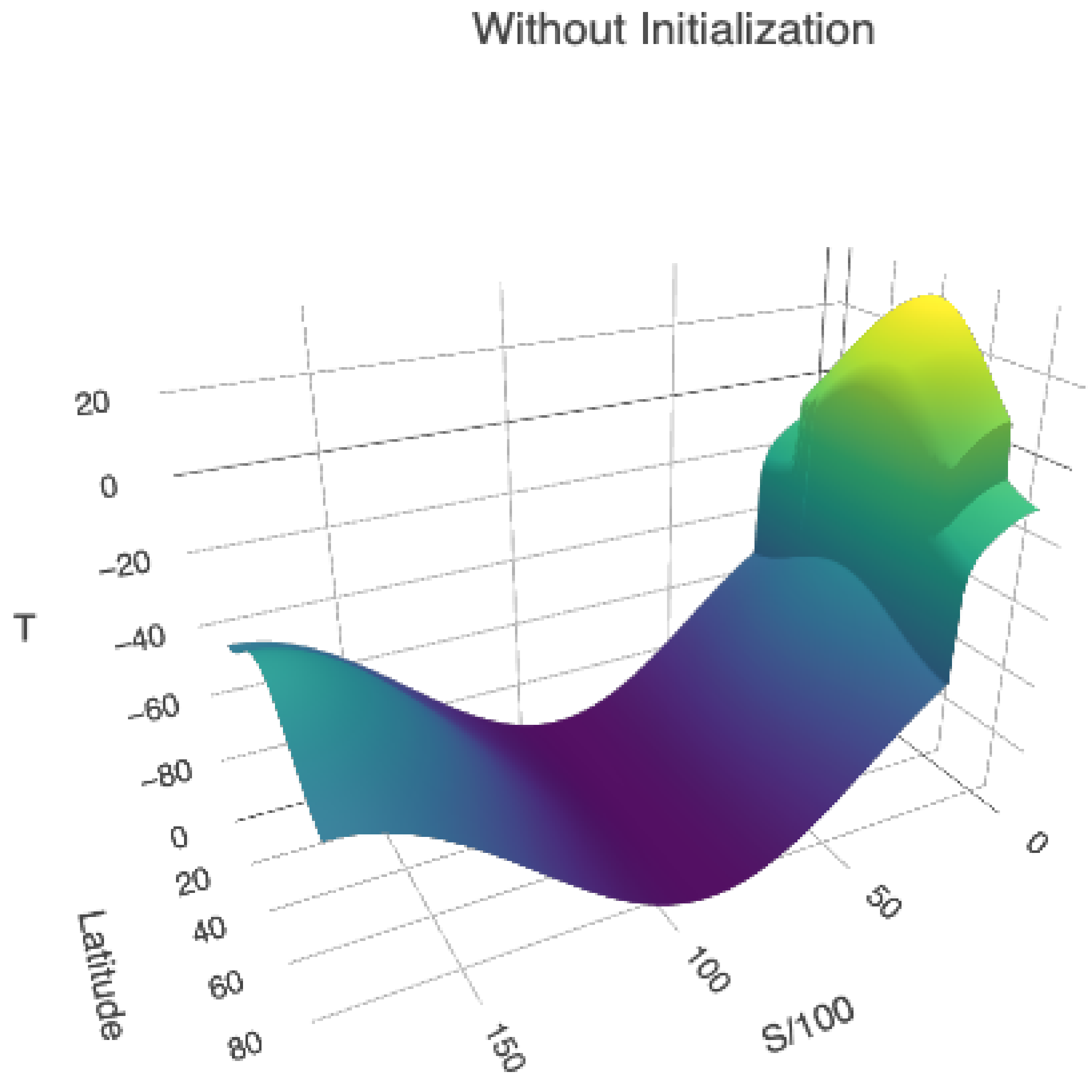


Run 2

```
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 Te

plot21
```

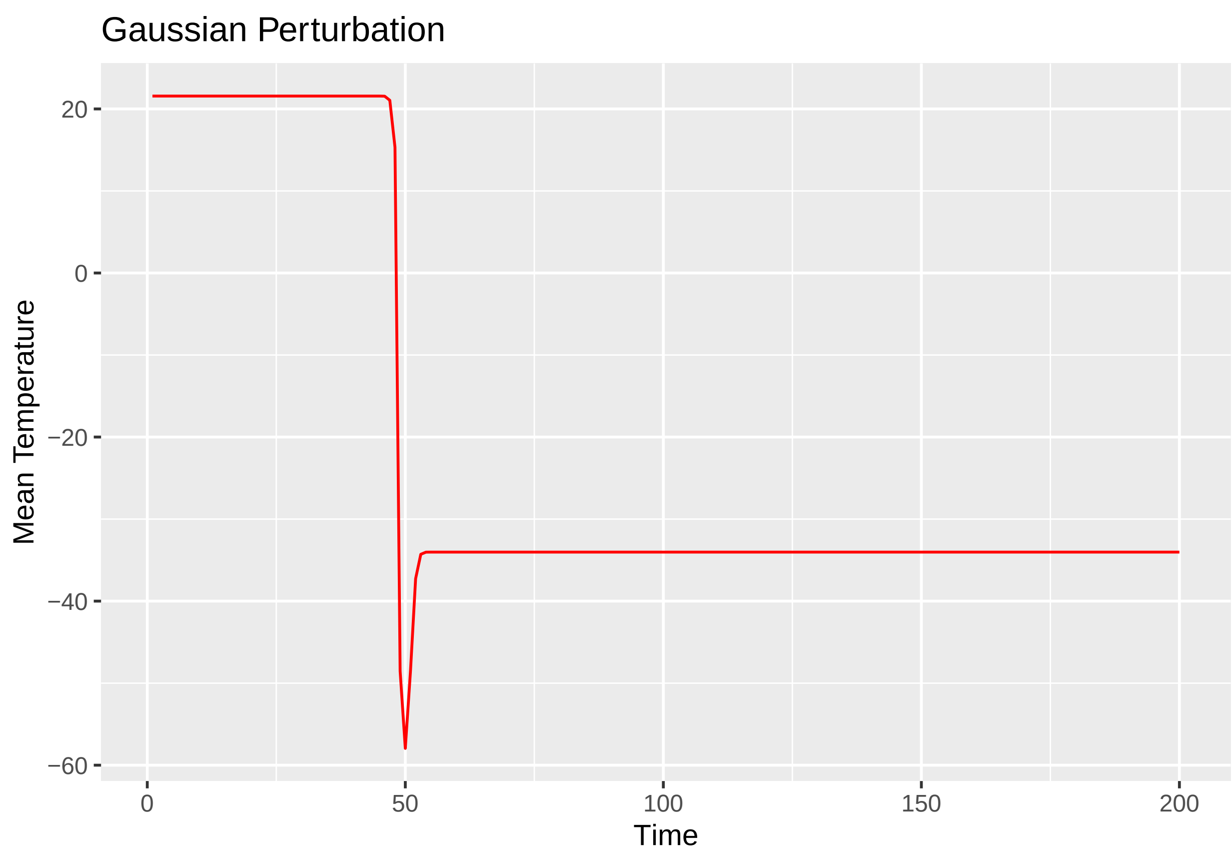



```
TEMP2 <- ebm22(180,300,A,B,K,ai,ab,gamma,delta )
include_graphics("plotly/TEMP2.png")
```



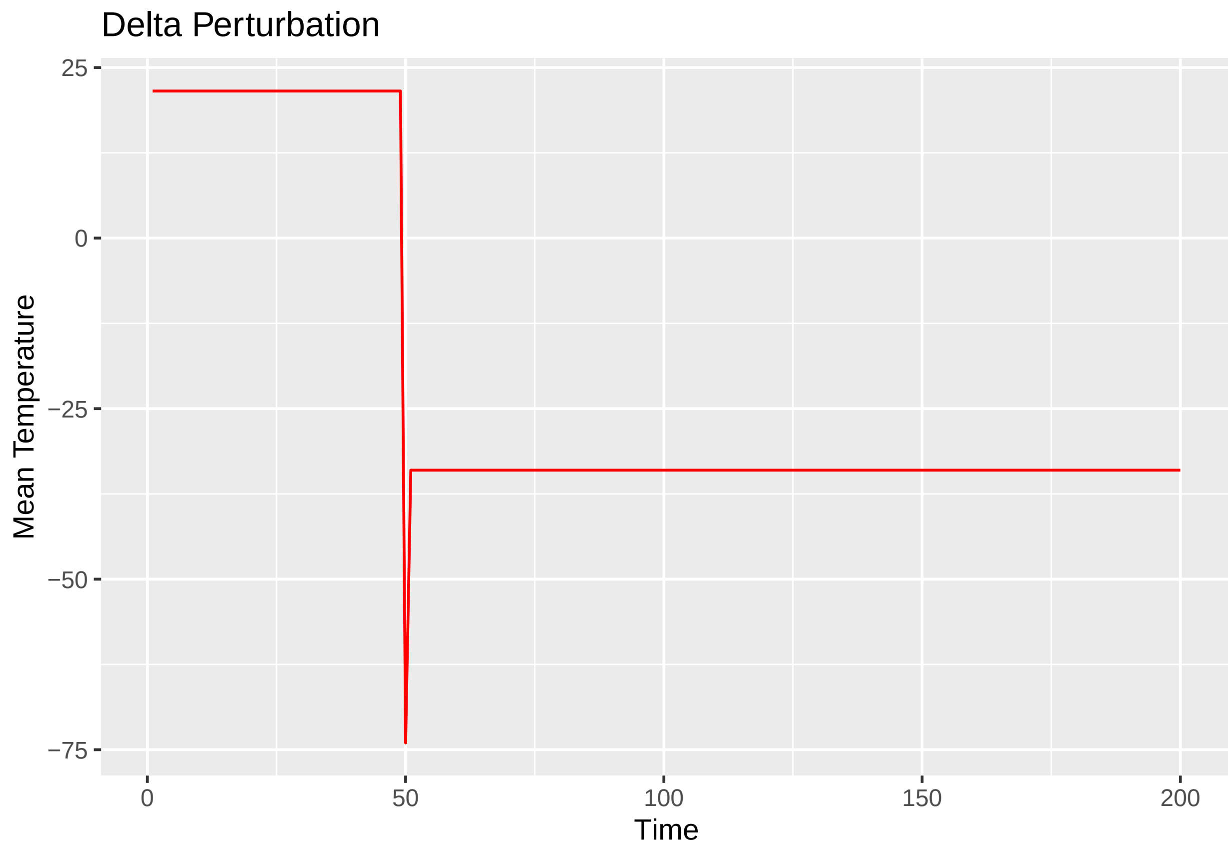
Run 3 & 4

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

plot31
```

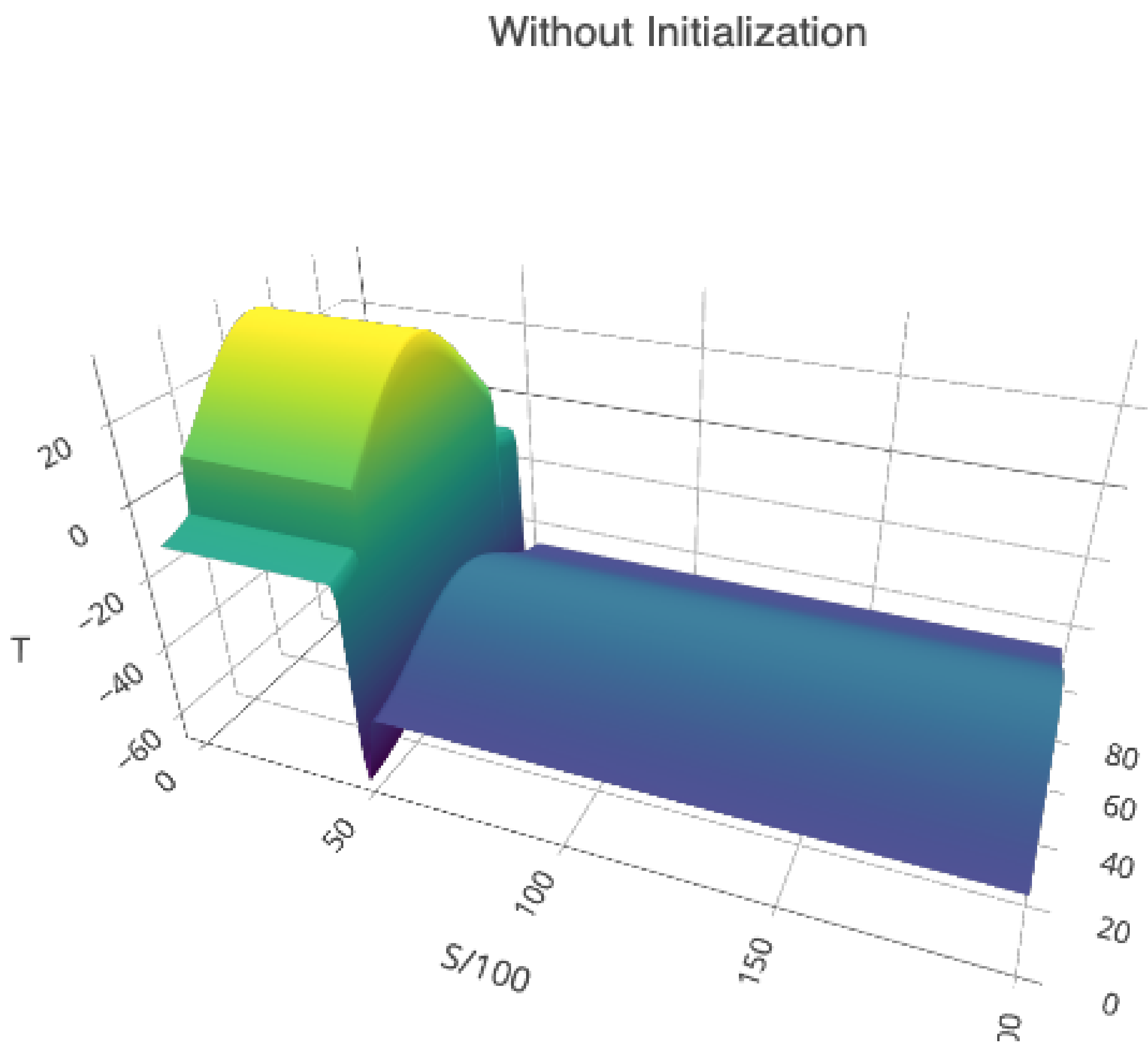


Gaussian Perturbation
Mean Temperature
20
0
−20
−40
−60
0
50
100
150
200
Time

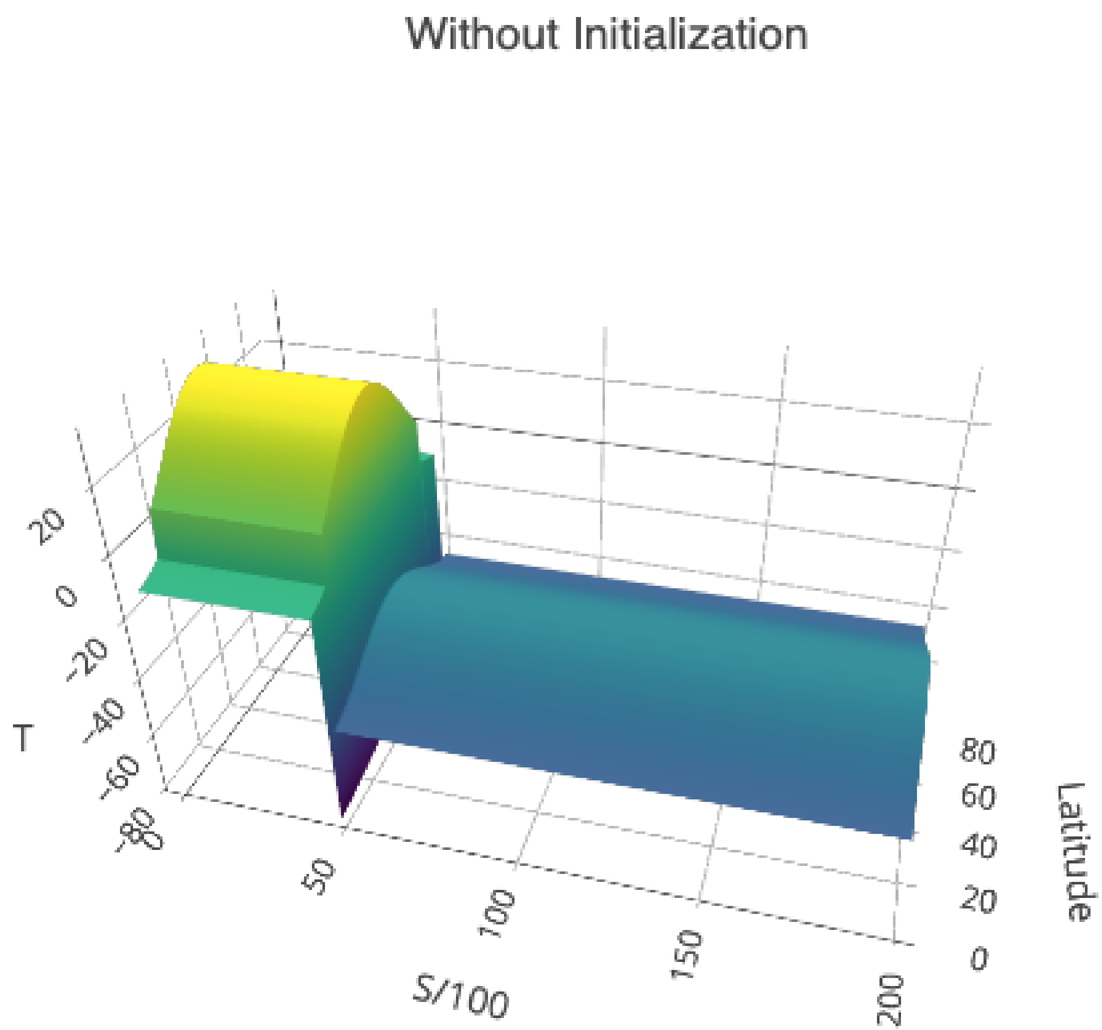

```
plot41
```




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

include_graphics("plotly/TEMP3.png")
```

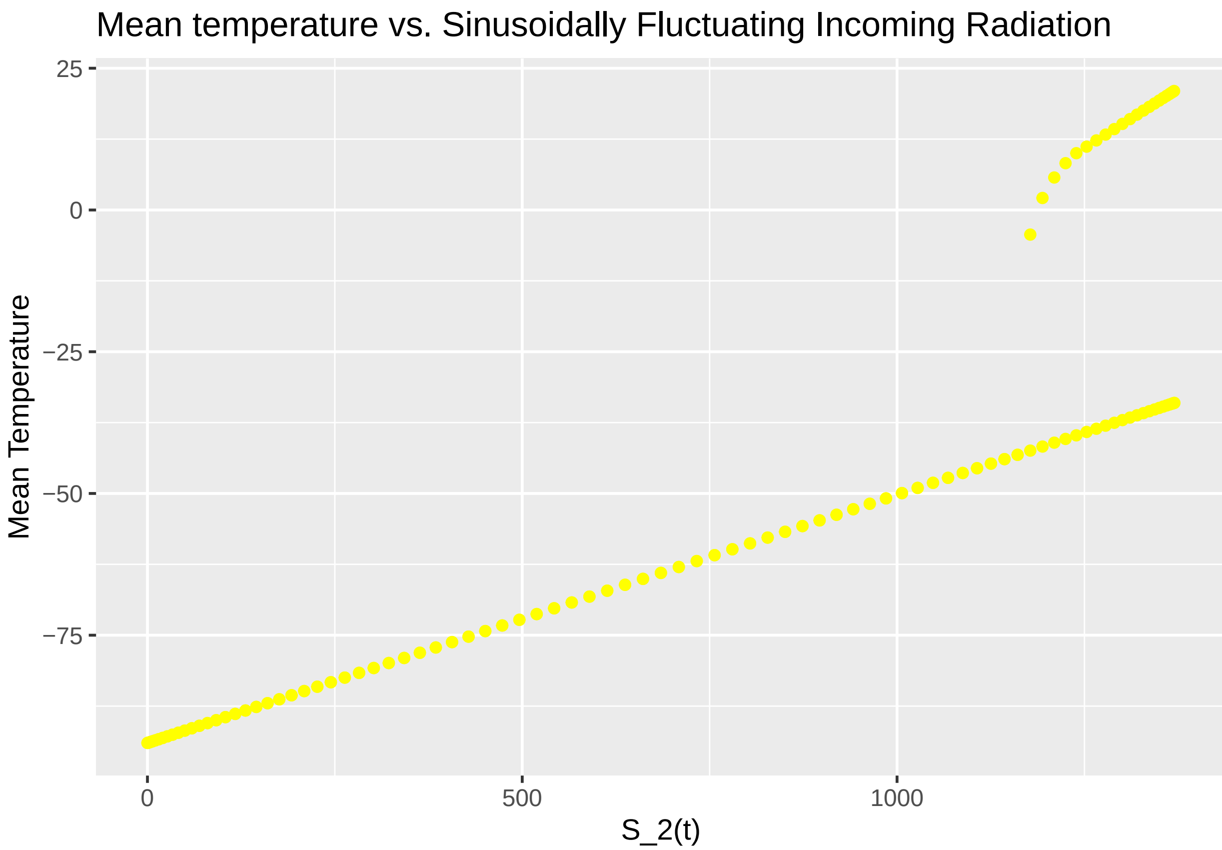



```
include_graphics("plotly/TEMP4.png")
```

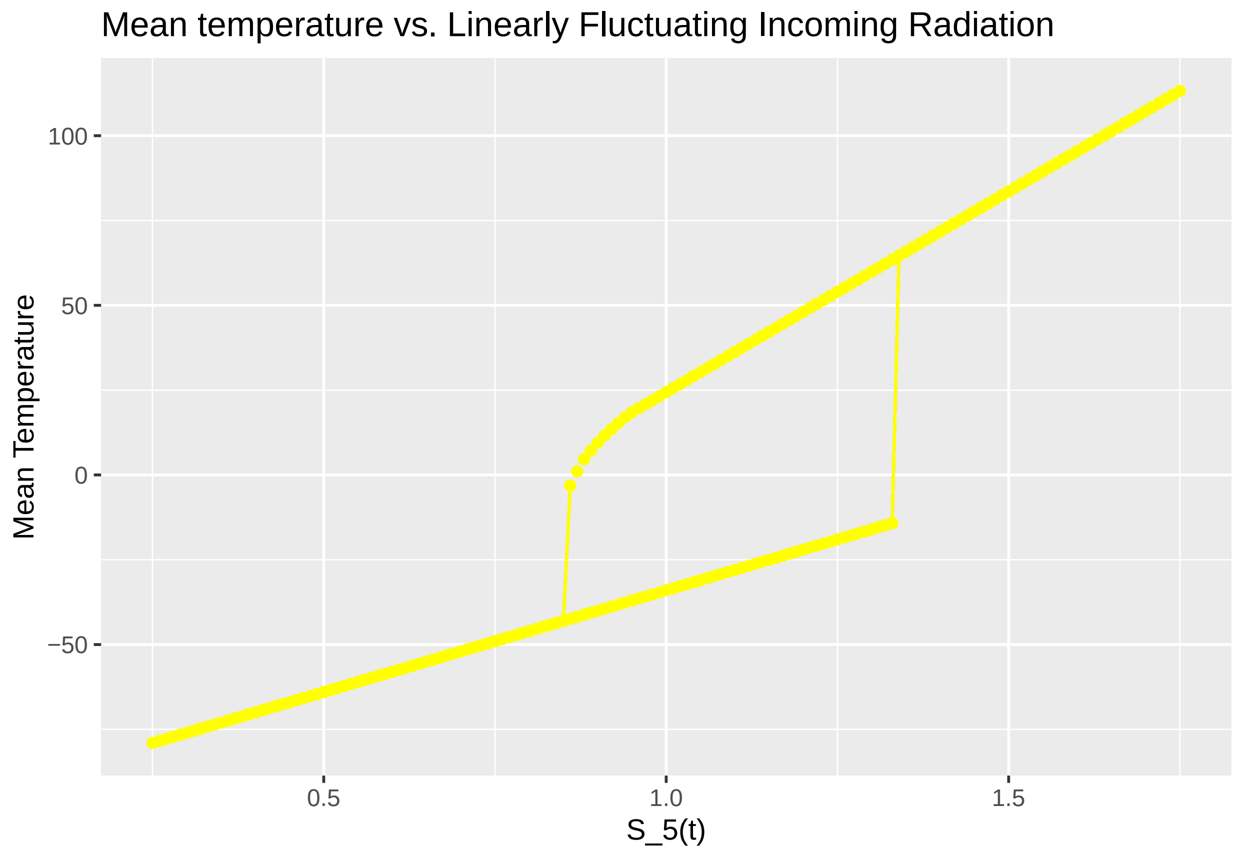


Hysteresis Cycles

```
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 Tempe
plot23
```

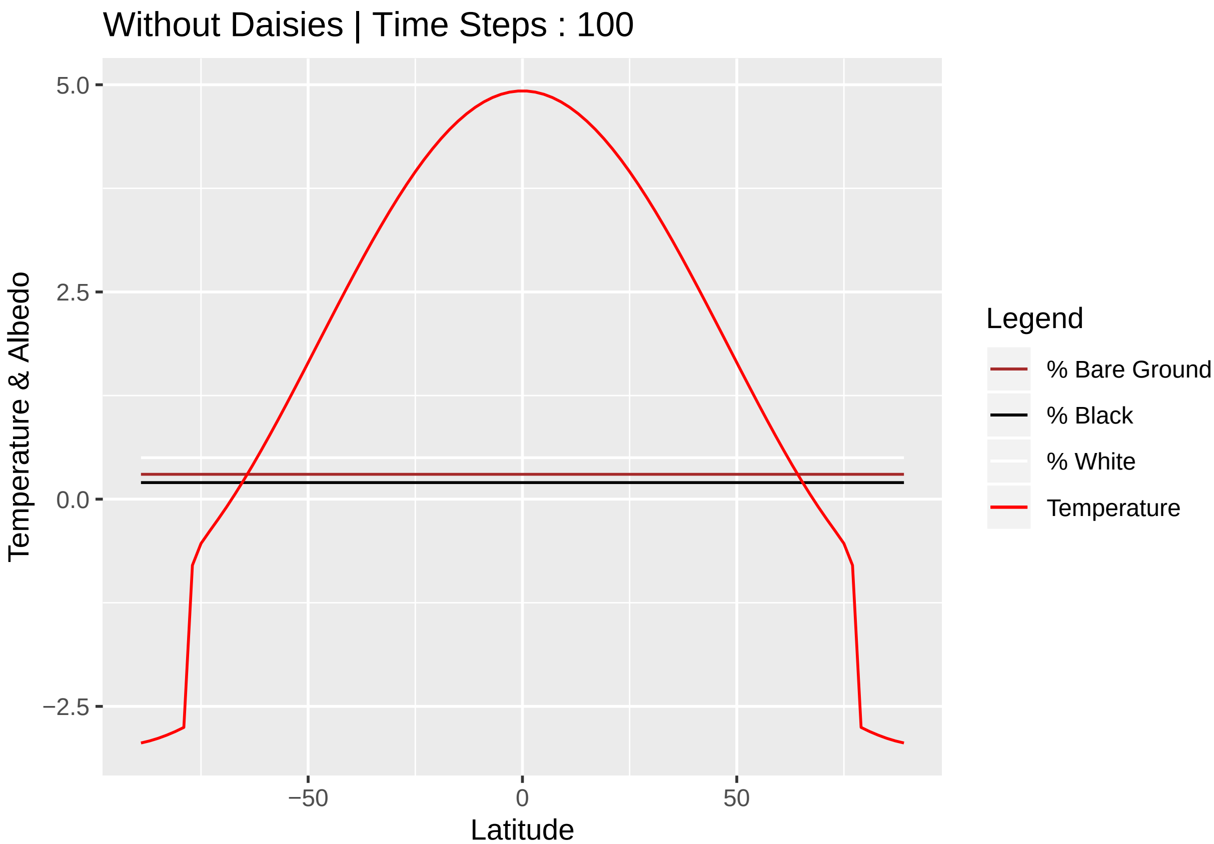



```
data51 <- ebm51(300,60,A,B,K,ai,ab,gamma,delta )

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

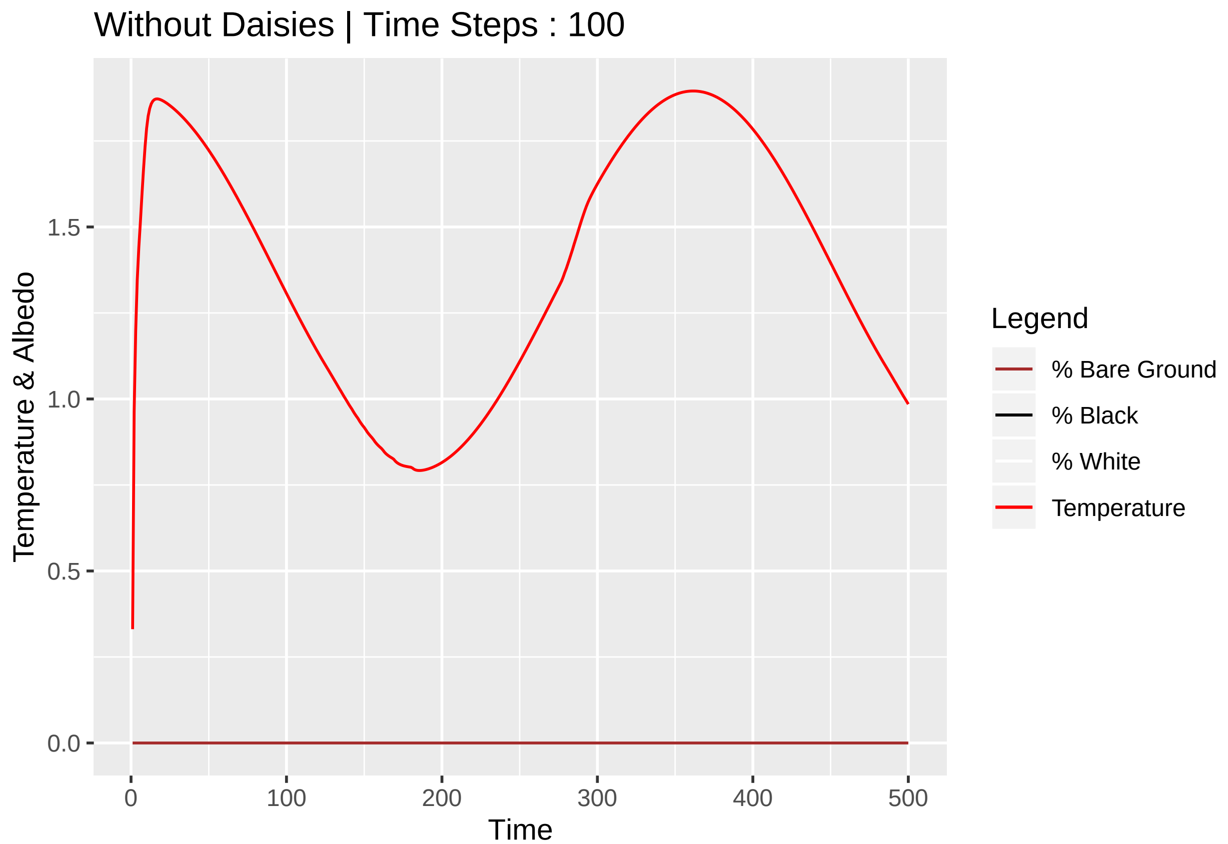


Embedding Daisies in EBM

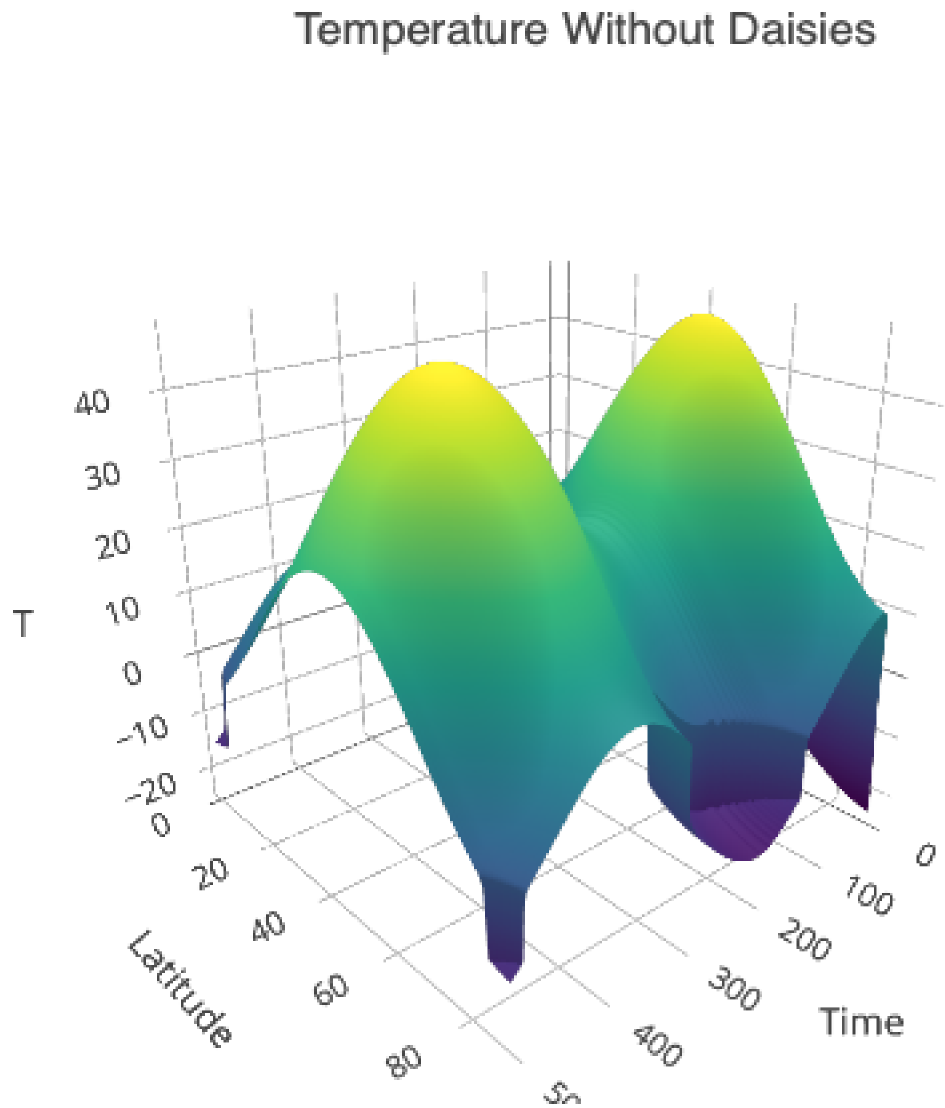
```
# WITHOUT DAISIES
data_ND1 <- ebm_ND1(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta) #from 500
data_ND2 <- ebm_ND2(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta)
data_ND4 <- ebm_ND4(300,1370/920,A,B,K,ai,ab,gamma,delta) #from 300
TEMP <- ebm_ND3(500,w0,b0,A,B,K,ai,ab,aW,aB,gamma,delta)

plot_ND1 <- ggplot(data_ND1,aes(Zones))+geom_line(aes(y=w, colour = "% White"))+geom_line(aes(y=b, colou

plot_ND2 <- ggplot(data_ND2,aes(I))+geom_line(aes(y=Barr,colour="% Black"))+ geom_line(aes(y=Warr,colou

plot_ND1
```


Without Daisies | Time Steps : 100
Temperature & Albedo
5.0
2.5
0.0
−2.5
−50
0
50
Latitude
Legend
% Bare Ground
% Black
% White
Temperature

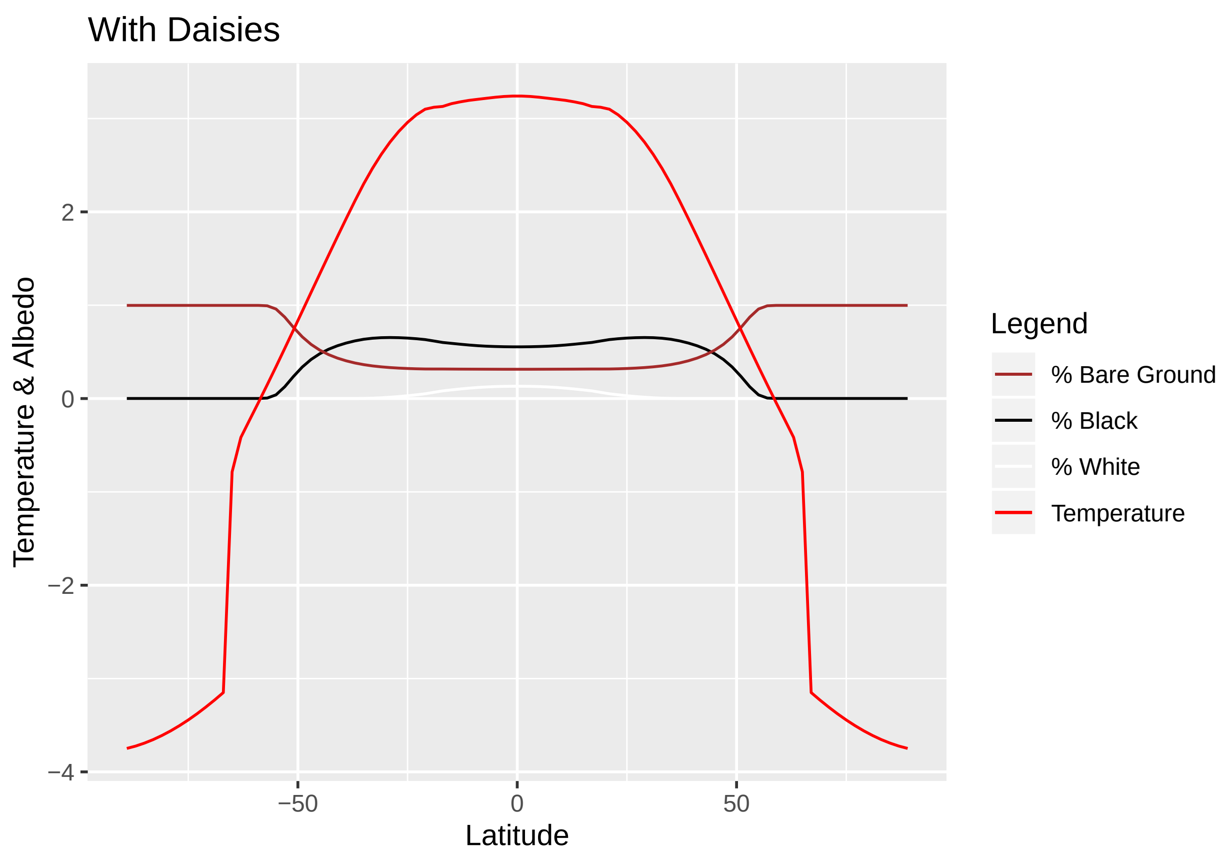
```
plot_ND2
```



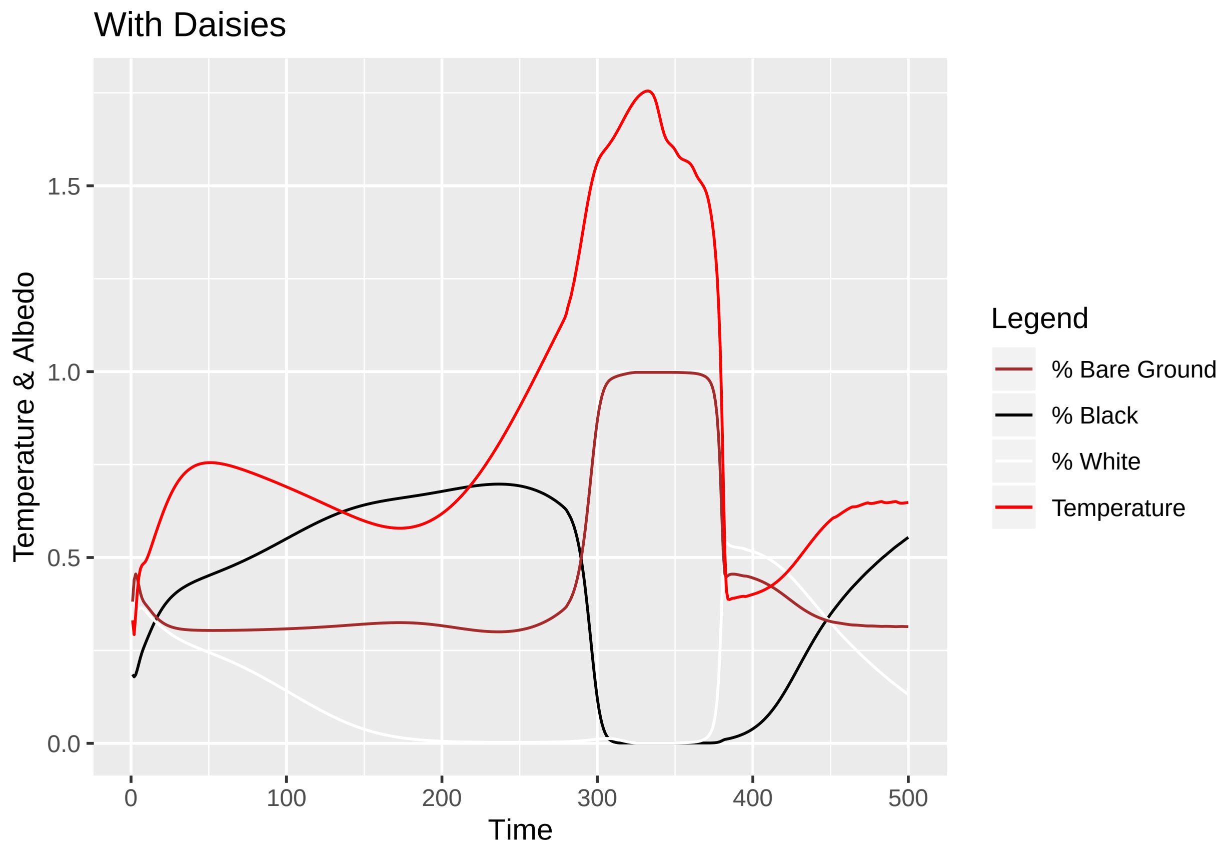

```
include_graphics("plotly/ND1.png")
```



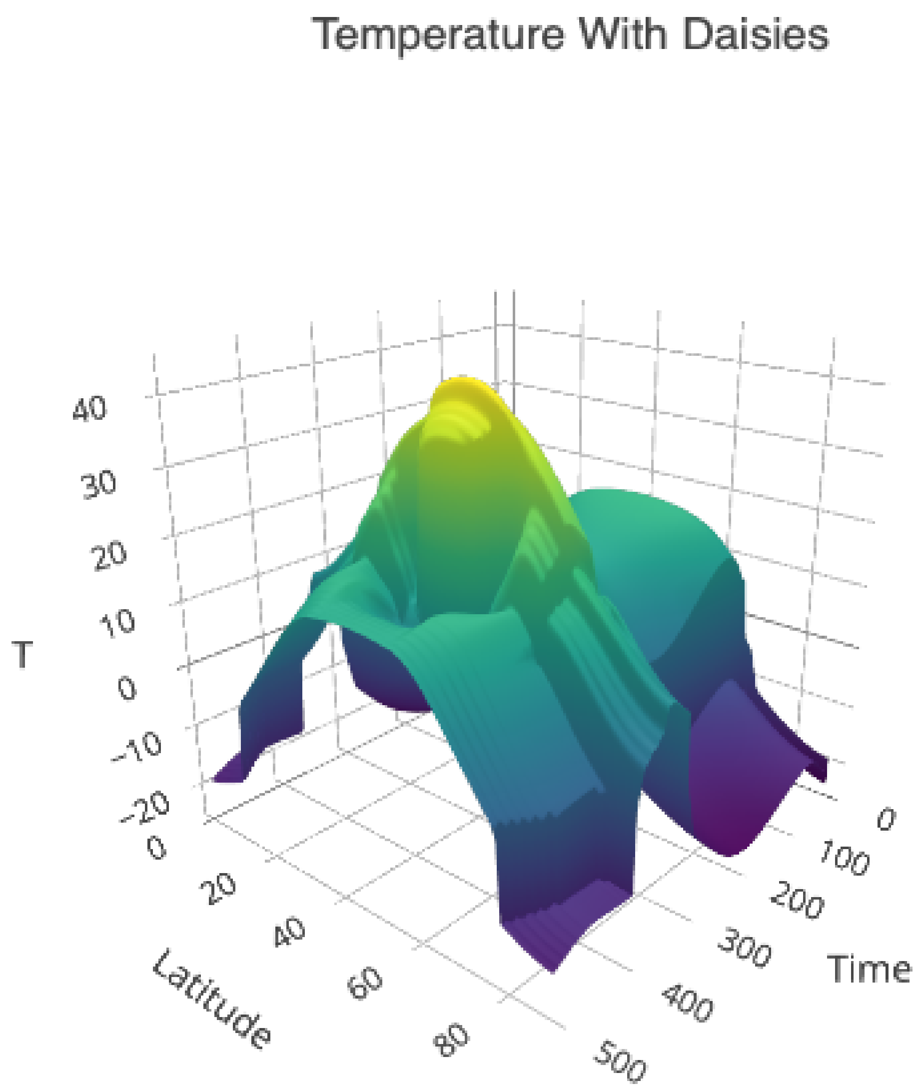

```
#WITH DAISIES
data_D1 <- ebm_D1(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
data_D2 <- ebm_D2(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
data_D4 <- ebm_D4(2,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta) #from 300
TEMP    <- ebm_D3(500,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
BLACK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


With Daisies
Temperature & Albedo
2
0
−2
−4
−50
0
50
Latitude
Legend
% Bare Ground
% Black
% White
Temperature

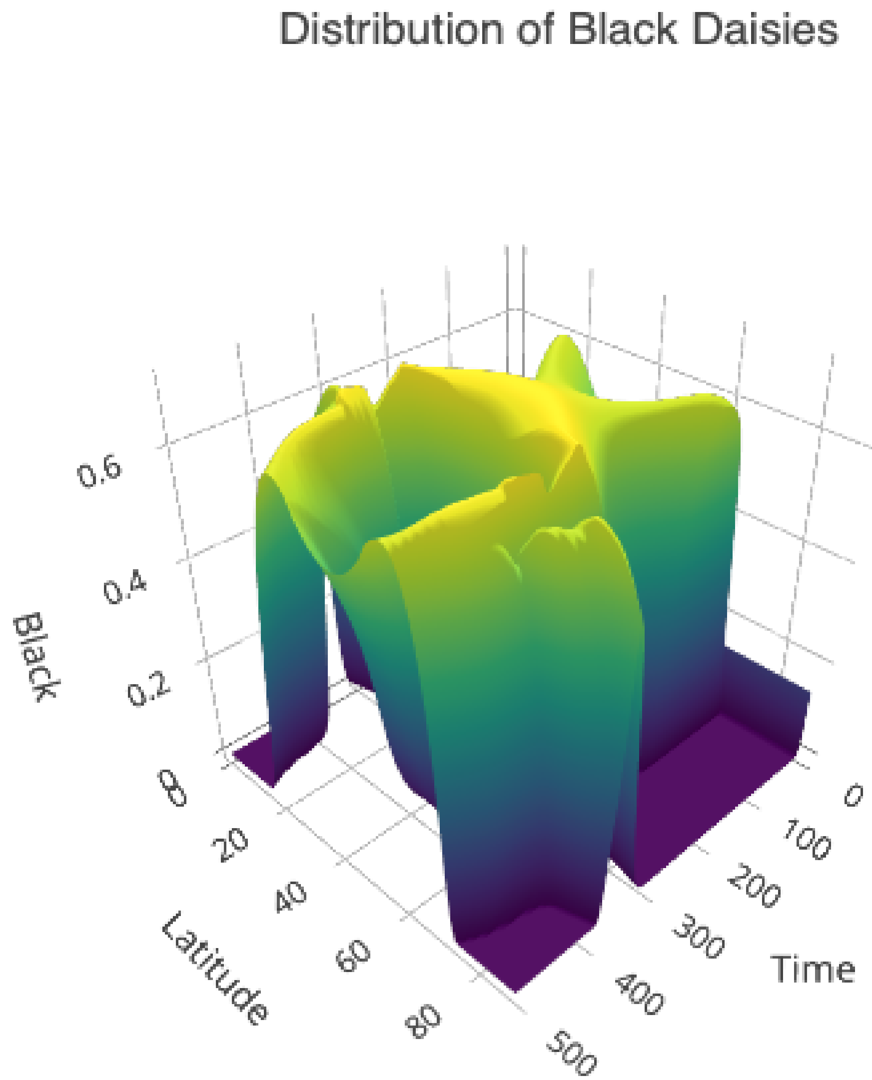
```
plot_D2
```



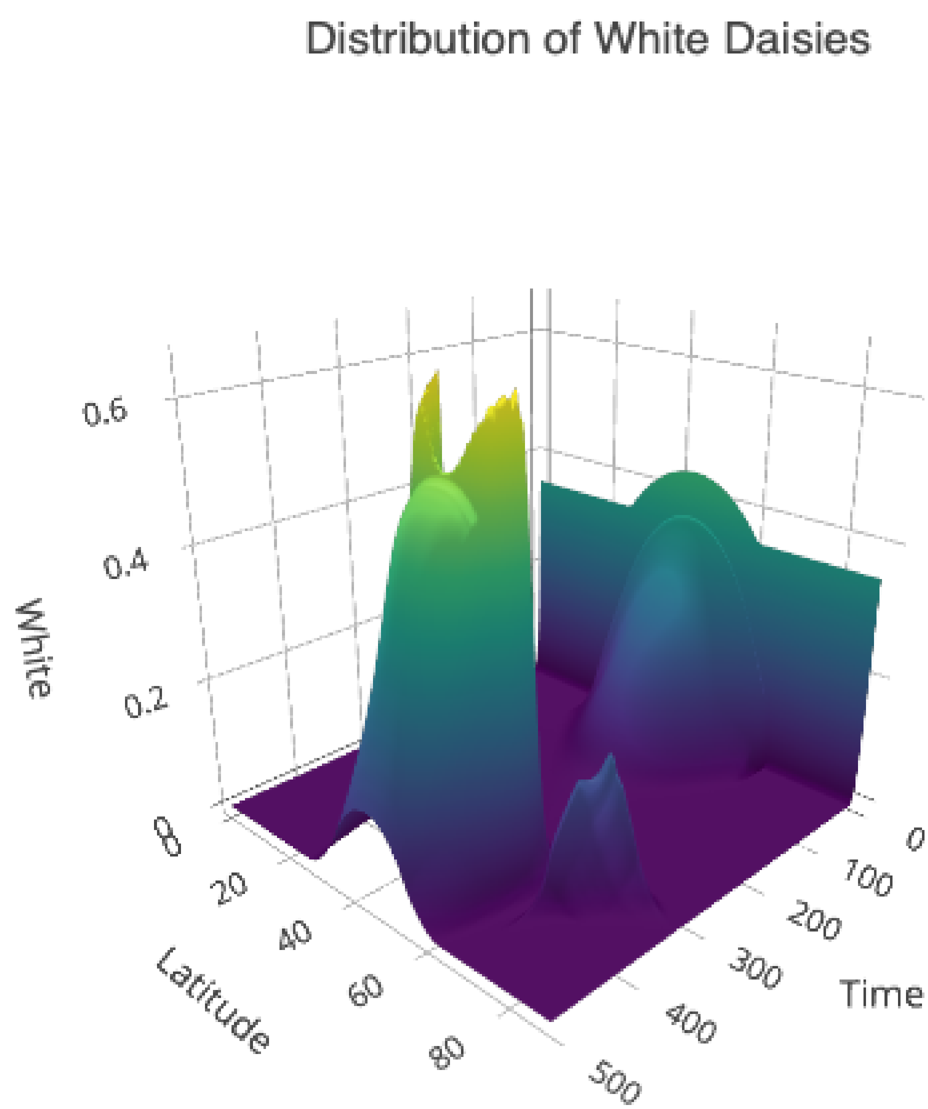

```r
include_graphics("plotly/D1.png")
```



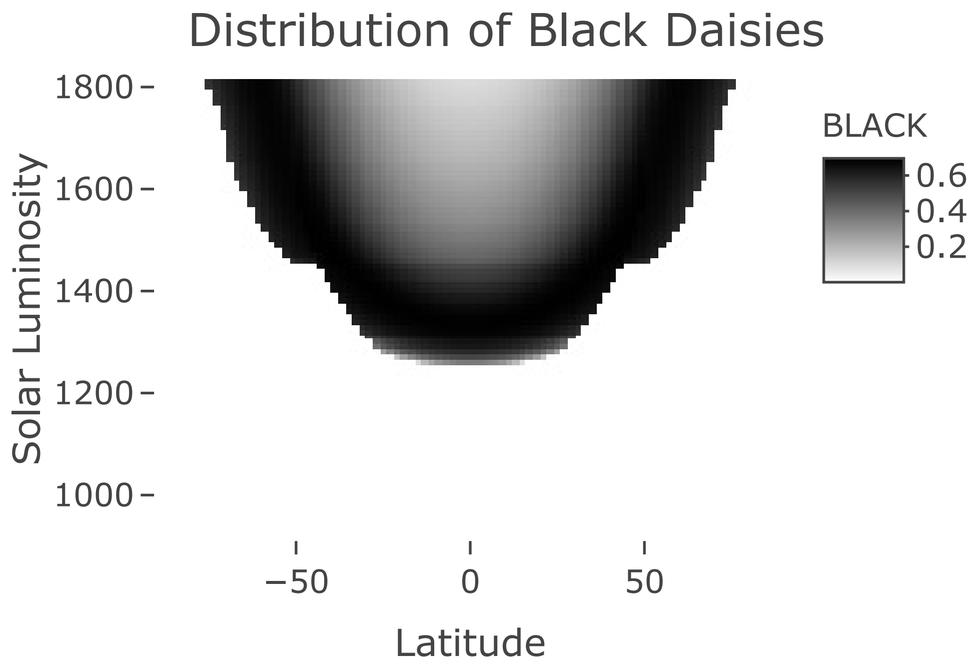

```r
include_graphics("plotly/DB1.png")
```



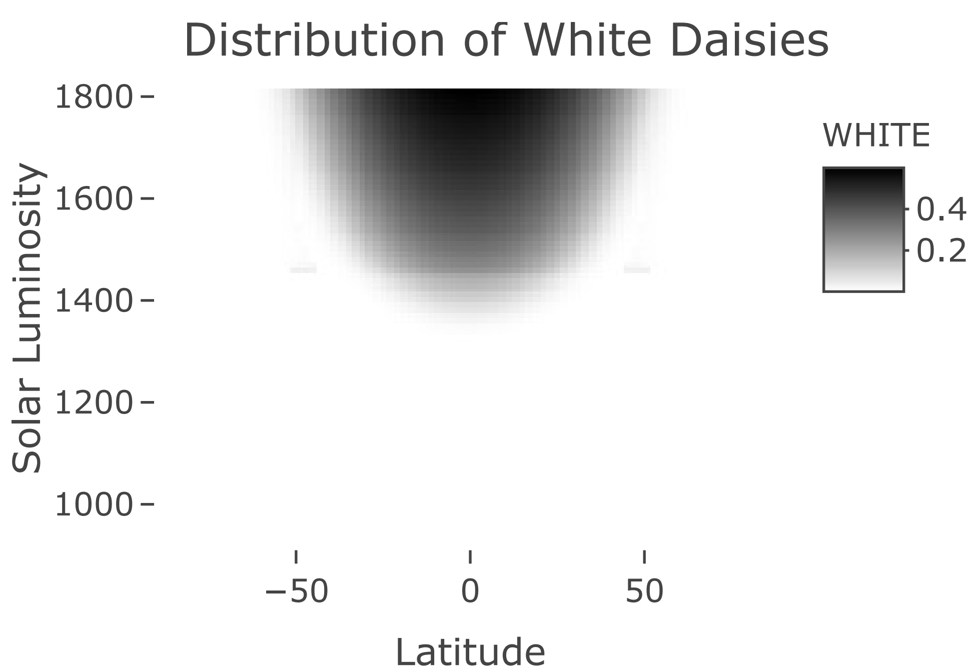

```r
include_graphics("plotly/DW1.png")
```



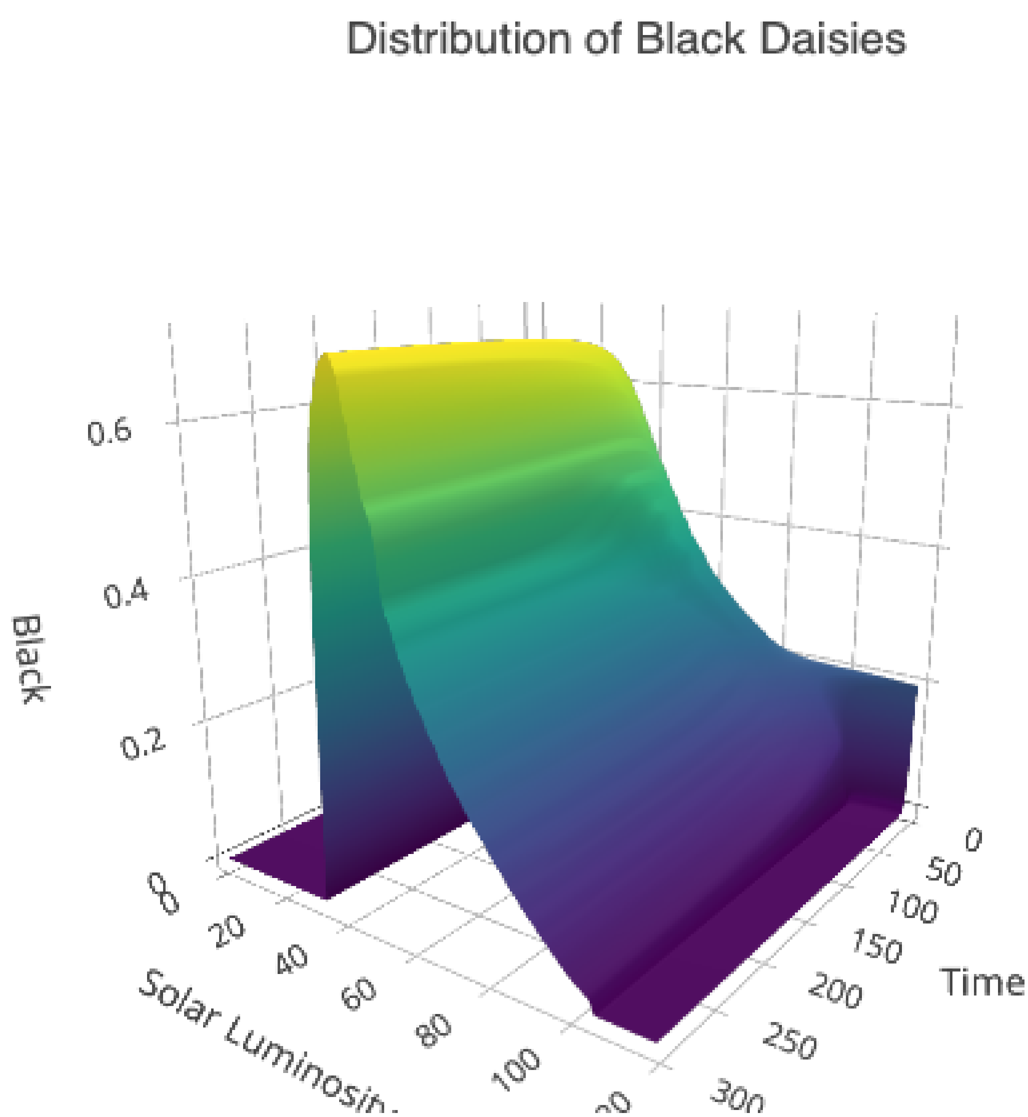

```
ebm_Db1(150,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)%>% layout(title="Distribution of Black I
                                                    xaxis = list(title = "Latitude"),
                                                    yaxis = list(title = "Solar Luminosity") )
```




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

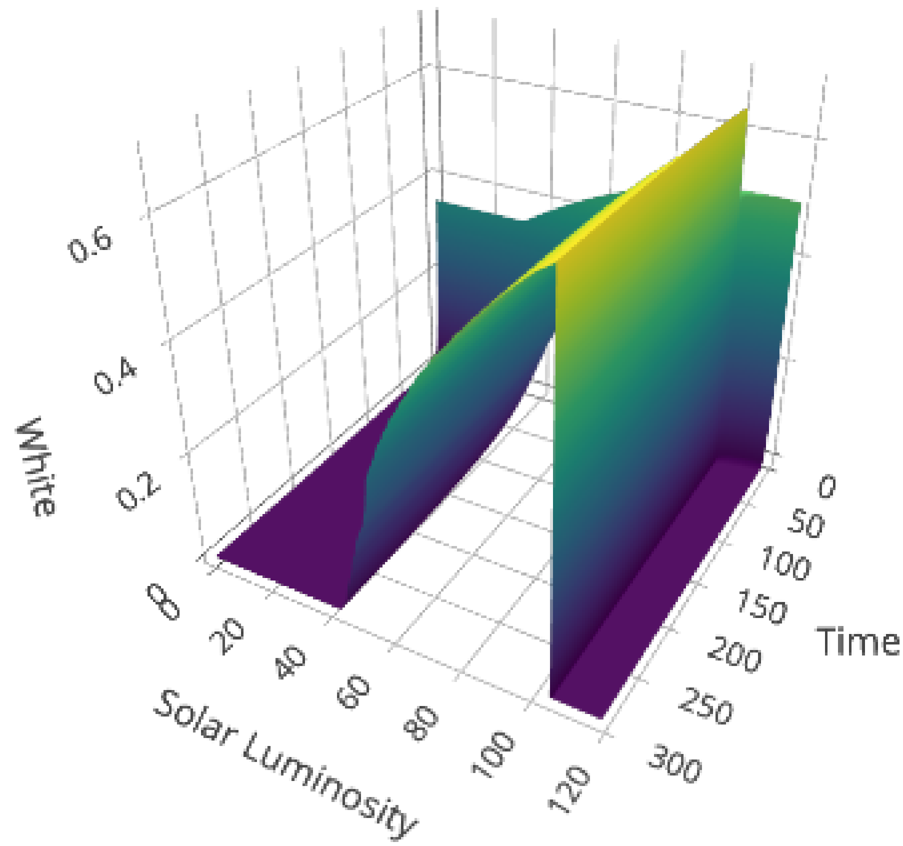



```
WHITE  <- ebm_D4(0,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)
BLACK  <- ebm_D4(1,300,1370/920,w0,b0,c,k,D,A,B,K,ai,ab,aW,aB,gamma,delta)


include_graphics("plotly/DB2.png")
```

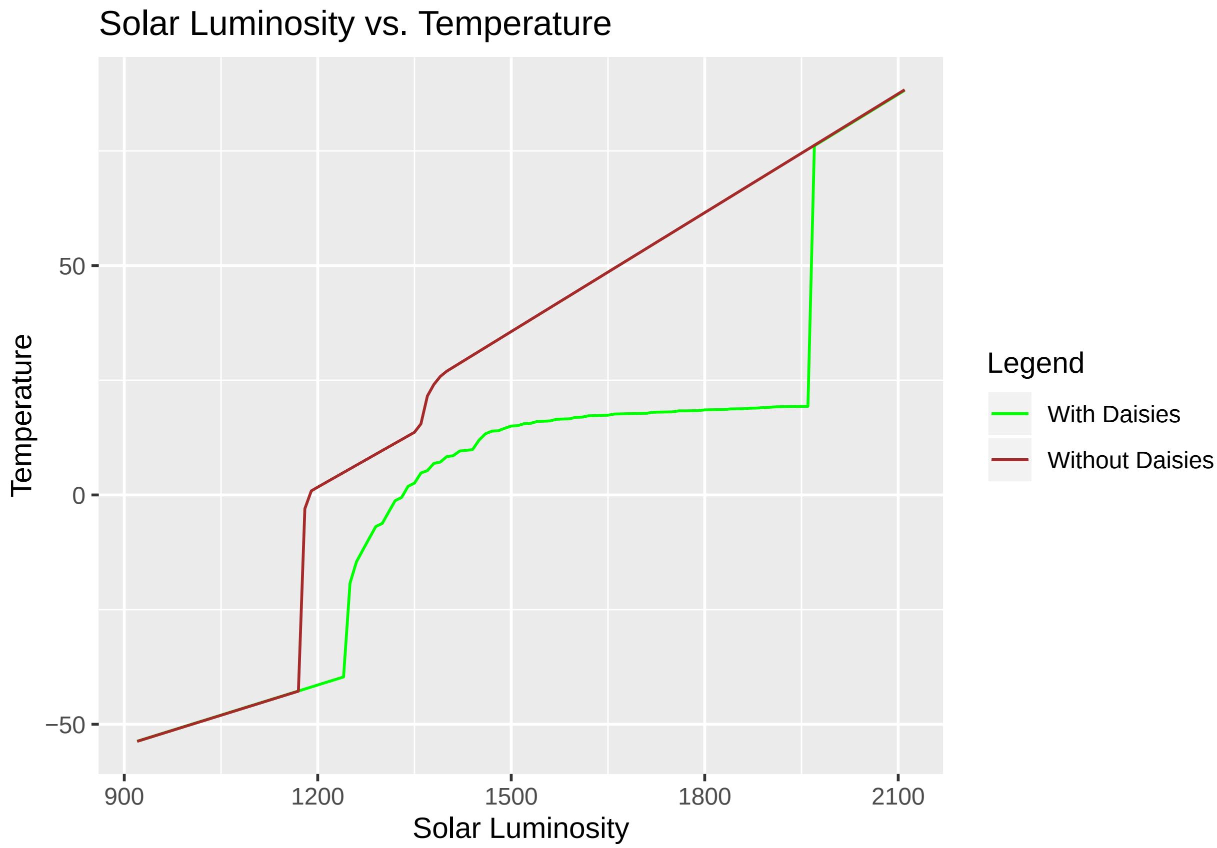



```r
include_graphics("plotly/DW2.png")
```

Distribution of White Daisies




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


Solar Luminosity vs. Temperature
Temperature
50
0
−50
900
1200
1500
1800
2100
Solar Luminosity
Legend
With Daisies
Without Daisies