Midterm-2

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```
library(readr)
EVI_Data <- read_csv("EVI_Data.csv")
```

```
## Rows: 802 Columns: 5
```

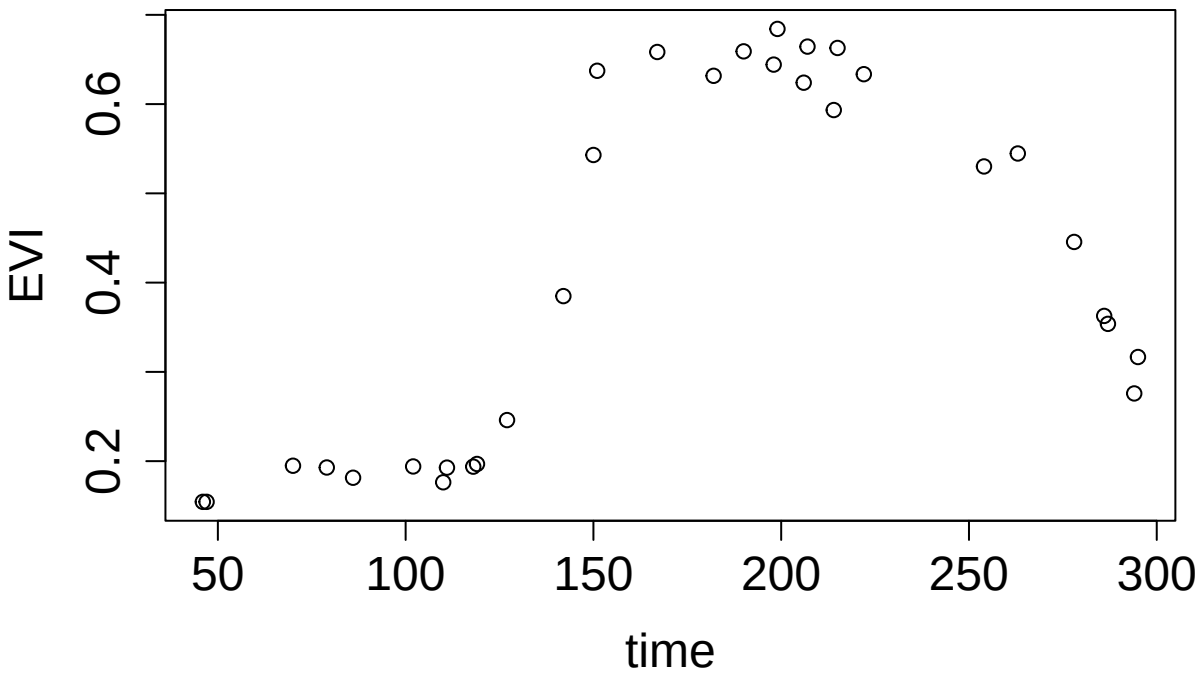
```
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## dbl (5): Year, Month, Day, DOY, EVI
```

```
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
EVI_Data$Date<-as.Date(with(EVI_Data,paste(Year,Month,Day,sep="-")),"%Y-%m-%d")
```

```
Y = EVI_Data[EVI_Data$Year == 2006,]$EVI; time = EVI_Data[EVI_Data$Year == 2006,]$DOY; years = EVI_Data$
ind = order(time)
time = time[ind]
Y = Y[ind]
```

```
plot(time,Y,xlab="time",ylab="EVI",cex.lab=1.5,cex.axis=1.5)
```




```
evi_model <- "model{
```

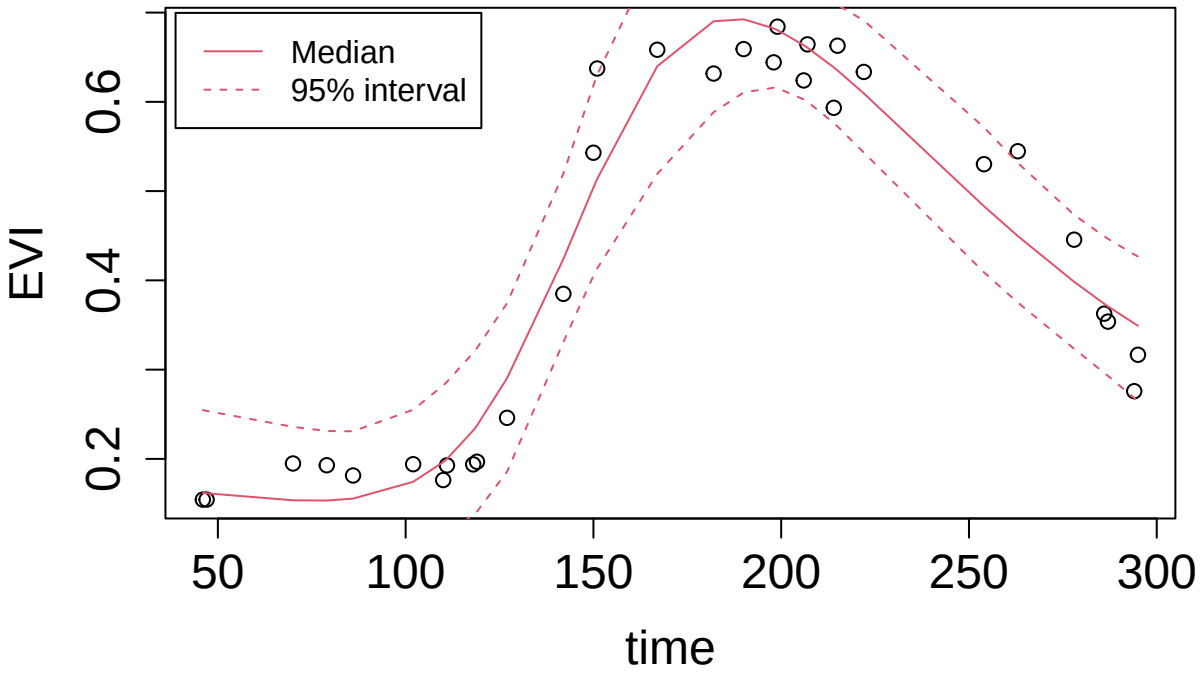
```
  # Likelihood
  for(i in 1:n){
     Y[i] ~ dnorm(mean[i],taum)
     mean[i] <- beta0 + 1/(1+exp(-beta2*(t[i]-beta1))) - 1/(1+exp(-beta4*(t[i]-beta3)))
  }

  # Prior
  beta1  ~ dnorm(mu1,tau1)T(0,)
  beta2 ~ dnorm(mu2,tau2)T(0,)
  beta3 ~ dnorm(mu3,tau3)T(0,)
  beta4 ~ dnorm(mu4,tau4)T(0,)
  mu1 ~ dunif(0, 183)
  mu3 ~ dunif(182, 360)
  mu2 ~ dunif(0.1, 20)
  mu4 ~ dunif(0.1, 20)
  beta0 ~dnorm(0,0.01)T(0,)
  taum ~ dgamma(0.1,0.1)
  tau1 ~ dgamma(0.1,0.1)
  tau2 ~ dgamma(0.1,0.1)
  tau3 ~ dgamma(0.1,0.1)
  tau4 ~ dgamma(0.1,0.1)
 }"
  library(rjags)
```

```
## Loading required package: coda
```

```
## Linked to JAGS 4.3.0
```

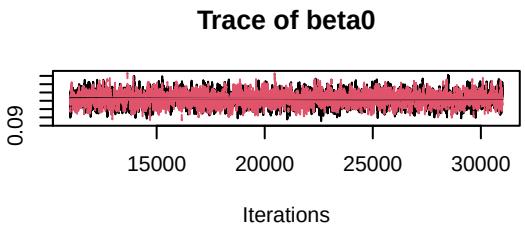
```
## Loaded modules: basemod,bugs
```

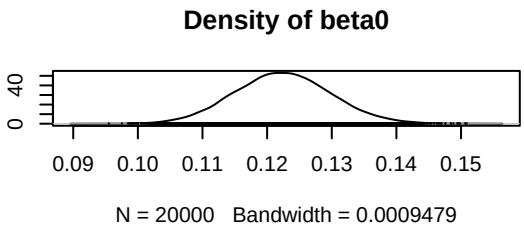
```
  dat    <- list(Y=Y,n=N,t =time)
  init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
  model  <- jags.model(textConnection(evi_model),
                       inits=init,data = dat,n.chains=2,quiet=TRUE)

  update(model, 10000, progress.bar="none")

  samp   <- coda.samples(model,
            variable.names=c("mean","beta0","beta1","beta2","beta3","beta4"),
            n.iter=20000, progress.bar="none")
  sum <- summary(samp)
  q <- sum$quantiles

  plot(time,Y,xlab="time",ylab="EVI",
       cex.lab=1.5,cex.axis=1.5)

  lines(time,q[6:dim(q)[1],1],col=2,lty=2) # 0.025 quantile (lower bound)
  lines(time,q[6:dim(q)[1],3],col=2,lty=1) # 0.500 quantile (median)
  lines(time,q[6:dim(q)[1],5],col=2,lty=2) # 0.975 quantile (upper bound)

  legend("topleft",c("Median","95% interval"),
         lty=1:2,col=2,bg=gray(1),inset=0.01,cex=1)
```

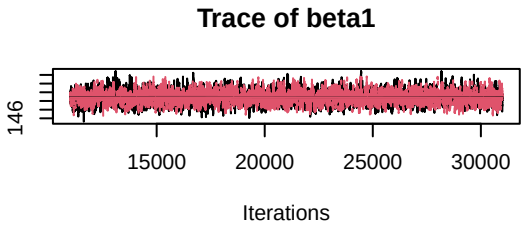


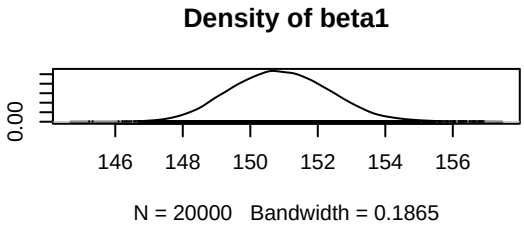

```
Y = EVI_Data$EVI; time = EVI_Data$DOY; years = EVI_Data$Year;  yrs = years - years[1] + 1; uniq_years =
ind = order(time)
time = time[ind]
Y = Y[ind]
   dat    <- list(Y=Y,n=N,t =time)
   init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
   model  <- jags.model(textConnection(evi_model), inits=init,data = dat,n.chains=2,quiet=TRUE)
   update(model, 10000, progress.bar="none")
   samp   <- coda.samples(model,
              variable.names=c("beta0","beta1","beta2","beta3","beta4"),
              n.iter=20000, progress.bar="none")
```

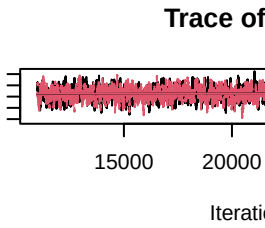
```
plot(samp)
```

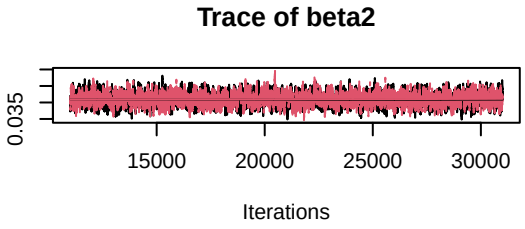


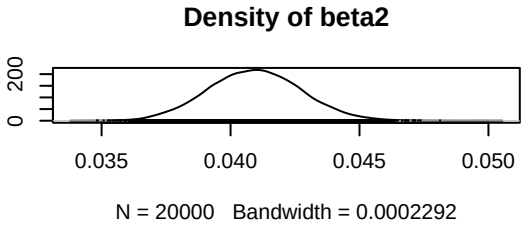


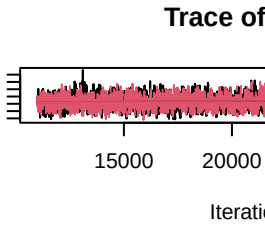













```
effectiveSize(samp)
```

```
##    beta0    beta1    beta2    beta3    beta4
## 1818.457 1912.192 1366.232 1127.135 1613.982
```

```
gelman.diag(samp)
```

```
## Potential scale reduction factors:
##
##       Point est. Upper C.I.
## beta0          1       1.01
## beta1          1       1.01
## beta2          1       1.01
## beta3          1       1.01
## beta4          1       1.01
##
## Multivariate psrf
##
## 1
```

```
geweke.diag(samp[[1]])
```

```
##
## Fraction in 1st window = 0.1
## Fraction in 2nd window = 0.5
##
##   beta0   beta1   beta2   beta3   beta4
##  1.7896 -0.4989  1.1287 -1.4490 -0.8184
```

```
evi_model <- "model{

   # Likelihood
   for(i in 1:n){
      Y[i] ~ dnorm(mean[i],taum)
      mean[i] <- beta0 + 1/(1+exp(-beta2*(t[i]-beta1))) - 1/(1+exp(-beta4*(t[i]-beta3)))
   }

   # Prior
   beta1  ~ dnorm(mu1,tau1)T(0,)
   beta2 ~ dnorm(mu2,tau2)T(0,)
   beta3 ~ dnorm(mu3,tau3)T(0,)
   beta4 ~ dnorm(mu4,tau4)T(0,)
   mu1 ~ dunif(0, 183)
   mu3 ~ dunif(182, 360)
   mu2 ~ dunif(0.1, 20)
   mu4 ~ dunif(0.1, 20)
   beta0 ~dnorm(0,0.01)T(0,)
   taum ~ dgamma(0.1,0.1)
   tau1 ~ dgamma(0.1,0.1)
   tau2 ~ dgamma(0.1,0.1)
   tau3 ~ dgamma(0.1,0.1)
   tau4 ~ dgamma(0.1,0.1)
   # WAIC calculations
   for(i in 1:n){
     like[i] = dnorm(Y[i],mean[i],taum)
   }
  }"
   dat    <- list(Y=Y,n=N,t =time)
   init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
   model  <- jags.model(textConnection(evi_model),
                        inits=init,data = dat,n.chains=2,quiet=TRUE)

   update(model, 10000, progress.bar="none")

   samp   <- coda.samples(model,
             variable.names=c("like"),
             n.iter=20000, progress.bar="none")
   # Compute DIC
DIC_logit  <- dic.samples(model,n.iter=20000,progress.bar="none")

# Compute WAIC
like       <- rbind(samp[[1]],samp[[2]]) # Combine the two chains
fbar       <- colMeans(like)
Pw         <- sum(apply(log(like),2,var))
WAIC_logit <- -2*sum(log(fbar))+2*Pw
DIC_logit
```

```
## Mean deviance:  -1797
## penalty 6.613
## Penalized deviance: -1790
```

```
WAIC_logit
```

```
## [1] -1787.302
```

```
evi_model2 <- "model{

   # Likelihood
   for(i in 1:n){
      Y[i] ~ dnorm(mean[i],taum)
      mean[i] <-beta0 + 1/(1+exp(-beta2*(t[i]-beta1))) - 1/(1+exp(-beta4*(t[i]-beta3)))
   }

   # Prior
   beta0 ~ dlnorm(0,0.01)
   beta1  ~ dnorm(mu1,tau1)T(0,)
   beta2 ~ dnorm(mu2,tau2)T(0,)
   beta3 ~ dnorm(mu3,tau3)T(0,)
   beta4 ~ dnorm(mu4,tau4)T(0,)
   mu1 ~ dunif(0, 183)
   mu3 ~ dunif(182, 360)
   mu2 ~ dunif(0.1, 20)
   mu4 ~ dunif(0.1, 20)
   taum ~ dgamma(0.1,0.1)
   tau1 ~ dgamma(0.1,0.1)
   tau2 ~ dgamma(0.1,0.1)
   tau3 ~ dgamma(0.1,0.1)
   tau4 ~ dgamma(0.1,0.1)
   # WAIC calculations
   for(i in 1:n){
     like[i]  = dnorm(Y[i],mean[i],taum)
   }
  }"
   library(rjags)
   dat    <- list(Y=Y,n=N,t =time)
   init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
   model  <- jags.model(textConnection(evi_model),
                        inits=init,data = dat,n.chains=2,quiet=TRUE)

   update(model, 10000, progress.bar="none")

   samp1   <- coda.samples(model,
             variable.names=c("like"),
             n.iter=20000, progress.bar="none")
   # Compute DIC
DIC_logit  <- dic.samples(model,n.iter=20000,progress.bar="none")

# Compute WAIC
like       <- rbind(samp1[[1]],samp1[[2]]) # Combine the two chains
fbar       <- colMeans(like)
Pw         <- sum(apply(log(like),2,var))
WAIC_logit <- -2*sum(log(fbar))+2*Pw
DIC_logit
```

```
## Mean deviance:  -1797
```

```
## penalty 6.574
## Penalized deviance: -1790
```

```
WAIC_logit
```

```
## [1] -1786.961
```

```
Y = EVI_Data[EVI_Data$Year == 2006,]$EVI; time = EVI_Data[EVI_Data$Year == 2006,]$DOY;
N = length(Y)
evi_model <- "model{

   # Likelihood
   for(i in 1:n){
      Y[i] ~ dnorm(mean[i],taum)
      mean[i] <- beta0 + 1/(1+exp(-beta2*(t[i]-beta1))) - 1/(1+exp(-beta4*(t[i]-beta3)))
   }

   # Prior
   beta1  ~ dnorm(mu1,tau1)T(0,250)
   beta2 ~ dnorm(mu2,tau2)T(0,)
   beta3 ~ dnorm(mu3,tau3)T(0,)
   beta4 ~ dnorm(mu4,tau4)T(0,)
   mu1 ~ dunif(0, 183)
   mu3 ~ dunif(182, 360)
   mu2 ~ dunif(0.1, 20)
   mu4 ~ dunif(0.1, 20)
   beta0 ~dnorm(0,0.01)T(0,)
   taum ~ dgamma(0.1,0.1)
   tau1 ~ dgamma(0.1,0.1)
   tau2 ~ dgamma(0.1,0.1)
   tau3 ~ dgamma(0.1,0.1)
   tau4 ~ dgamma(0.1,0.1)
  }"
   library(rjags)
   dat    <- list(Y=Y,n=N,t =time)
   init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
   model  <- jags.model(textConnection(evi_model),
                        inits=init,data = dat,n.chains=2,quiet=TRUE)

   update(model, 10000, progress.bar="none")

   samp   <- coda.samples(model,
             variable.names=c("beta1"),
             n.iter=20000, progress.bar="none")
   sum <- summary(samp)
   q <- sum$quantiles
   names(q)= NULL
   Table = data.frame(q)
```

```
for(yr in 1:num_years){
  year = uniq_years[yr]

Y = EVI_Data[EVI_Data$Year == year,]$EVI; time = EVI_Data[EVI_Data$Year == year,]$DOY;
N = length(Y)
evi_model <- "model{
```

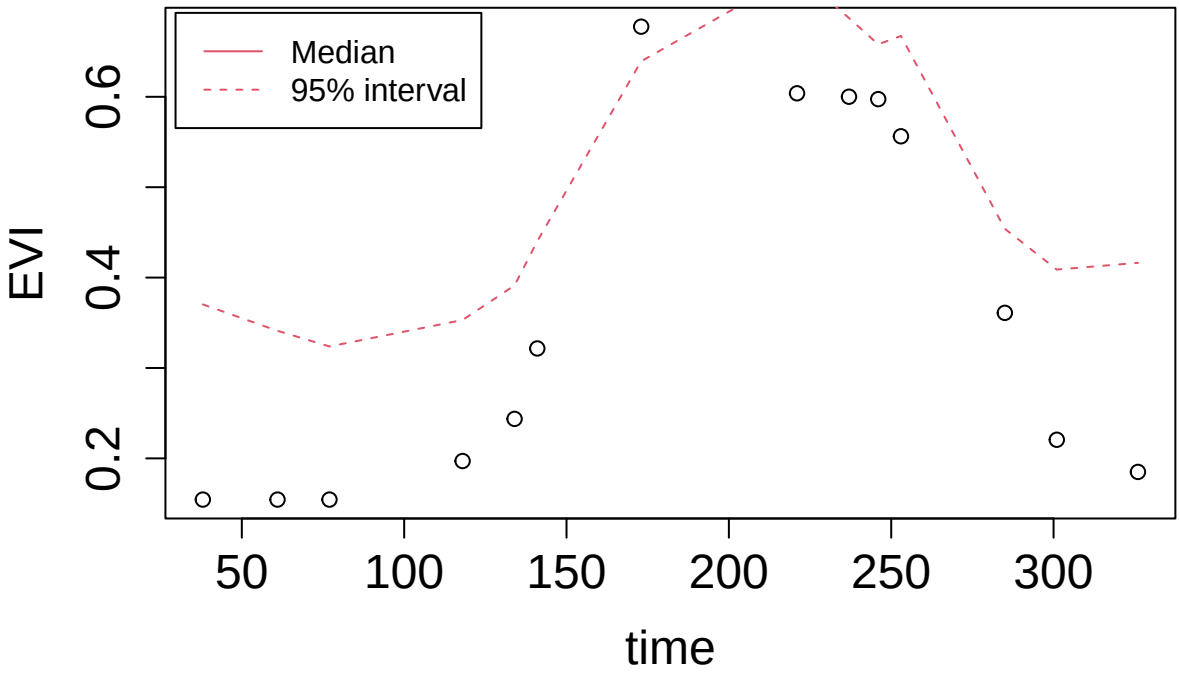
```
  # Likelihood
  for(i in 1:n){
     Y[i] ~ dnorm(mean[i],taum)
     mean[i] <- beta0 + 1/(1+exp(-beta2*(t[i]-beta1))) - 1/(1+exp(-beta4*(t[i]-beta3)))
  }

  # Prior
  beta1  ~ dnorm(mu1,tau1)T(0,)
  beta2 ~ dnorm(mu2,tau2)T(0,)
  beta3 ~ dnorm(mu3,tau3)T(0,)
  beta4 ~ dnorm(mu4,tau4)T(0,)
  mu1 ~ dunif(0, 150)
  mu3 ~ dunif(182, 360)
  mu2 ~ dunif(0.1, 20)
  mu4 ~ dunif(0.1, 20)
  beta0 ~dnorm(0,0.1)T(0,)
  taum ~ dgamma(0.1,0.1)
  tau1 ~ dgamma(0.01,0.01)
  tau2 ~ dgamma(0.1,0.1)
  tau3 ~ dgamma(0.1,0.1)
  tau4 ~ dgamma(0.1,0.1)
 }"
  library(rjags)
  dat    <- list(Y=Y,n=N,t =time)
  init   <- list(mu1=96, mu3 = 271, mu2 = 5, mu4 = 5)
  model  <- jags.model(textConnection(evi_model),
                       inits=init,data = dat,n.chains=2,quiet=TRUE)

  update(model, 10000, progress.bar="none")

  samp   <- coda.samples(model,
            variable.names=c("beta1"),
            n.iter=20000, progress.bar="none")
  sum <- summary(samp)
  q <- sum$quantiles
  names(q)= NULL
  Table[as.character(year)] = q}
 Table
```

```
##          q       1984       1985      1986      1987      1988     1989
## 1 134.5705   237.2506   314.7239  20.52423  138.7435  11.36236 127.6686
## 2 141.5961  1717.4158   529.3145  66.65691  152.9391 104.97913 133.7331
## 3 145.1283  4612.9693  1060.3400 137.15590  223.3134 141.99196 140.4947
## 4 149.0620  5812.3913  2211.4595 210.78227 1115.6396 151.19329 147.1380
## 5 161.7551 13537.3629 10767.6237 258.46734 5474.1337 180.60633 177.9979
##         1990     1991      1992     1993      1994      1995       1996
## 1   14.89776 119.6104  193.0178 110.5280  144.6186  65.85811   8.322951
## 2  125.71539 132.2117  338.9178 139.8280  276.0166 132.45476  64.844377
## 3  149.04573 135.5827  522.5903 147.2145  600.9933 137.98868  93.876436
## 4  701.66836 140.1196  897.0708 171.1300 1596.5972 147.36111 119.069579
## 5 4160.53347 153.0828 3017.4269 262.4950 3645.0220 210.77783 202.599638
##          1997      1998     1999     2000     2001     2002     2003     2004
## 1    70.04722  141.9441 130.5743 128.2403 133.0310 131.1497 131.2503 123.2732
```

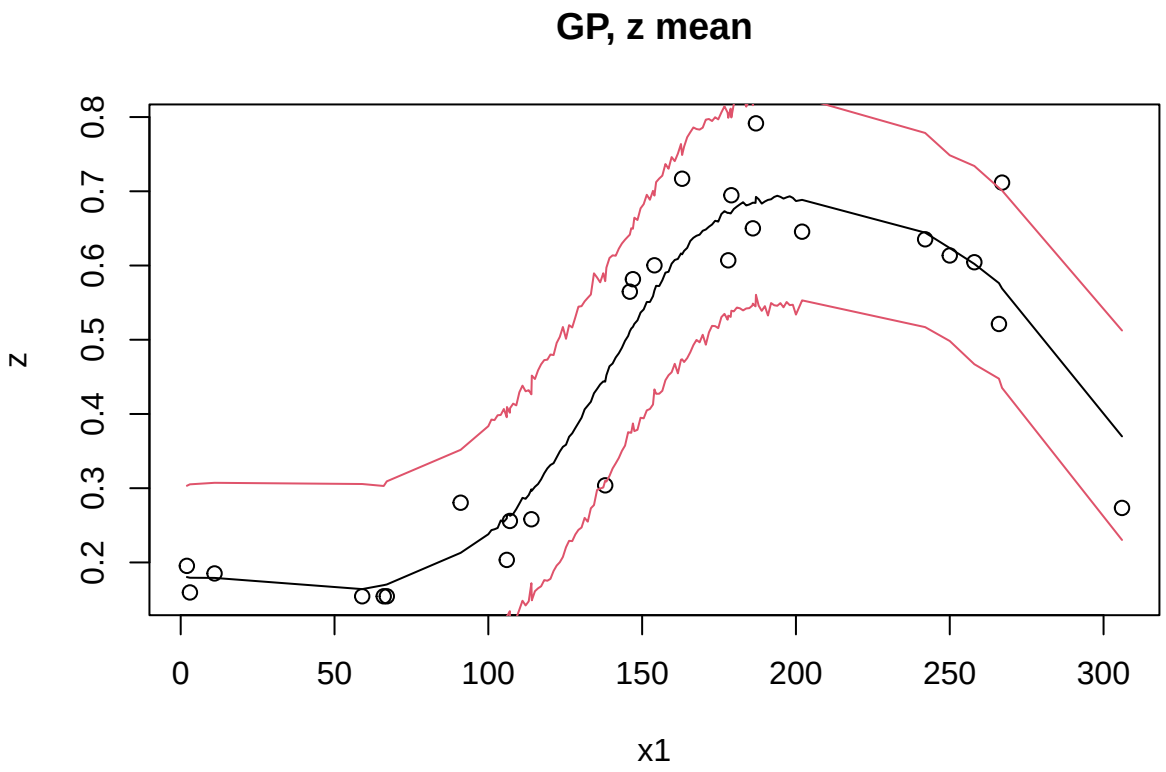
```
## 2   361.53539  308.3324 141.1157 142.9109 140.2244 141.9487 149.1076 136.1014
## 3  1217.94991 1158.7701 145.7367 149.9245 144.0606 146.5809 157.8408 141.1635
## 4  3613.06896 4171.2576 151.1931 163.0630 147.9618 150.6853 165.3946 149.3749
## 5 29395.60343 5205.7952 178.4774 223.5297 157.9819 176.4259 181.5005 174.6998
##       2005     2006     2007     2008     2009     2010     2011       2012
## 1 134.4305 133.5539 127.1328 131.2272 129.2808 115.3705 134.9418   84.15718
## 2 146.0081 141.2492 137.3436 139.4699 137.0203 124.1429 148.9345  129.81713
## 3 151.5514 144.8152 142.4686 143.6323 140.8703 128.4159 195.9793  327.05718
## 4 157.9814 148.4668 146.8249 147.3381 145.1561 133.2765 303.8640 1001.91048
## 5 176.4254 161.1841 160.4919 155.3925 161.3010 145.9289 594.3959 3855.32975
##       2013     2014     2015     2016     2017     2018     2019
## 1 126.6454 129.9469 127.5449 119.0750 129.5810 130.8379 122.5286
## 2 138.2725 141.1049 133.4507 138.8460 140.0642 137.9811 136.7467
## 3 144.8949 145.8455 139.7423 144.8556 144.9858 141.7355 143.1332
## 4 152.8982 152.3309 148.2189 151.0077 149.6603 145.5333 149.4040
## 5 188.5688 179.4931 178.1445 180.1952 162.0285 156.5803 171.5035
```

```
Y = EVI_Data[EVI_Data$Year == 1994,]$EVI; time = EVI_Data[EVI_Data$Year == 1994,]$DOY;
N = length(Y)
 library(splines)

 J <- 10       # Number of basis functions
 B <- bs(time,J)  # Specify the basis functions
evi_model <- "model{


   # Likelihood
   for(i in 1:n){
      Y[i]    ~ dnorm(mean[i],taue)T(0,)
      mean[i] <- mu + inprod(B[i,],beta[])
   }

   # Prior
   mu   ~ dnorm(0,0.01)
   taue ~ dgamma(0.1,0.1)
   for(j in 1:J){
    beta[j] ~ dnorm(0,taue*taub)
   }
   taub ~ dgamma(0.1,0.1)

  }"
   library(rjags)
   dat    <- list(Y=Y,n=N,B=B, J=J)
   init   <- list(mu=mean(Y),beta=rep(0,J),taue=1/var(Y))
   model  <- jags.model(textConnection(evi_model),
                        inits=init,data = dat,n.chains=2,quiet=TRUE)

   update(model, 10000, progress.bar="none")

   samp   <- coda.samples(model,
             variable.names=c("beta","mean"),
             n.iter=20000, progress.bar="none")
   sum <- summary(samp)
   q <- sum$quantiles
```

```
plot(time,Y,xlab="time",ylab="EVI",
     cex.lab=1.5,cex.axis=1.5)

lines(time,q[11:dim(q)[1],1],col=2,lty=2) # 0.025 quantile (lower bound)
lines(time,q[11:dim(q)[1],3],col=2,lty=1) # 0.500 quantile (median)
lines(time,q[11:dim(q)[1],5],col=2,lty=2) # 0.975 quantile (upper bound)

legend("topleft",c("Median","95% interval"),
       lty=1:2,col=2,bg=gray(1),inset=0.01,cex=1)
```




```
library(tgp)
Y = EVI_Data[EVI_Data$Year == 2019,]$EVI; time = EVI_Data[EVI_Data$Year == 2019,]$DOY;
N = length(Y)
xx=seq(100,200,length=100)
sin.bgp <- bgp(X=time, Z=Y, XX=xx, verb=0)
plot(sin.bgp, main='GP,', layout='surf')
```


GP, z mean
z
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
300
x1