

Testing examples in saemix 3.0 - continuous models

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Objective

Check saemix for continuous data models

Setup

- set up work directories
- two versions toggled by testMode
 - if testMode is FALSE, load the functions in R
 - if testMode is TRUE, load the library in a dev_mode environment
- aim: check the examples used in the online documentation
 - all examples must run without error

Testing library

```
if(testMode) cat("Testing package\n") else cat("Loading libraries\n")
```

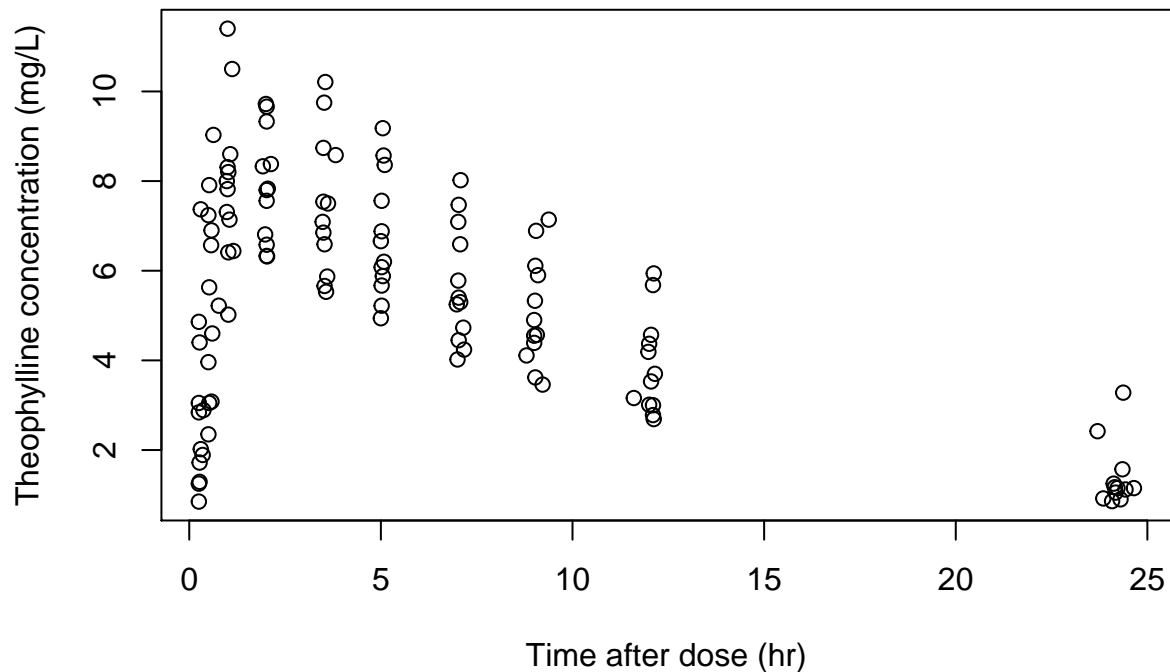
```
## Testing package
```

Continuous response model

Theophylline

```
if(testMode)
  data(theo.saemix) else
  theo.saemix<-read.table(file.path(datDir, "theo.saemix.tab"), header=TRUE)

#Plotting the theophylline data
plot(Concentration~Time,data=theo.saemix,xlab="Time after dose (hr)",
ylab="Theophylline concentration (mg/L)")
```



```
saemix.data<-saemixData(name.data=theo.saemix,header=TRUE,sep=" ",na=NA,
  name.group=c("Id"),name.predictors=c("Dose","Time"),
  name.response=c("Concentration"),name.covariates=c("Weight","Sex"),
  units=list(x="hr",y="mg/L",covariates=c("kg","-")), name.X="Time")
```

```
##
##
## The following SaemixData object was successfully created:
##
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset theo.saemix
##   Structured data: Concentration ~ Dose + Time | Id
##   X variable for graphs: Time (hr)
##   covariates: Weight (kg), Sex (-)
##   reference class for covariate Sex : 0
```

```
model1cpt<-function(psi,id,xidep) {
  dose<-xidep[,1]
  tim<-xidep[,2]
  ka<-psi[id,1]
  V<-psi[id,2]
  CL<-psi[id,3]
  k<-CL/V
  ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
  return(ypred)
}
# Default model, no covariate
saemix.model<-saemixModel(model=model1cpt,
  description="One-compartment model with first-order absorption",
  psi0=matrix(c(1.,20,0.5,0.1,0,-0.01),ncol=3,byrow=TRUE,
  dimnames=list(NULL, c("ka","V","CL"))),transform.par=c(1,1,1))
```

```

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
##   Model function: One-compartment model with first-order absorption
##   Model type: structural
## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-psi[id,2]
##   CL<-psi[id,3]
##   k<-CL/V
##   ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##   return(ypred)
## }
##   Nb of parameters: 3
##     parameter names: ka V CL
##     distribution:
##       Parameter Distribution Estimated
## [1,] ka      log-normal Estimated
## [2,] V      log-normal Estimated
## [3,] CL      log-normal Estimated
##   Variance-covariance matrix:
##     ka V CL
## ka  1 0 0
## V   0 1 0
## CL  0 0 1
##   Error model: constant , initial values: a.1=1
##   No covariate in the model.
##   Initial values
##           ka V CL
## Pop.CondInit 1.0 20 0.50
## Cov.CondInit 0.1 0 -0.01

# Note: remove the options save=FALSE and save.graphs=FALSE
# to save the results and graphs
saemix.options<-list(seed=632545,save=FALSE,save.graphs=FALSE, displayProgress=FALSE)

saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset theo.saemix
##   Structured data: Concentration ~ Dose + Time | Id
##   X variable for graphs: Time (hr)
##   covariates: Weight (kg), Sex (-)
##   reference class for covariate Sex : 0
## Dataset characteristics:
##   number of subjects: 12

```

```

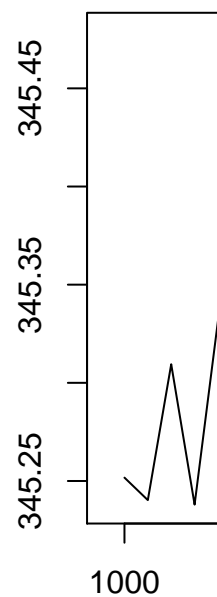
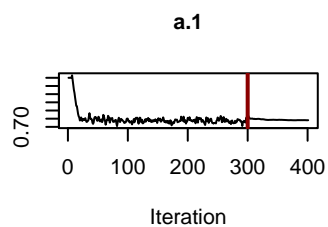
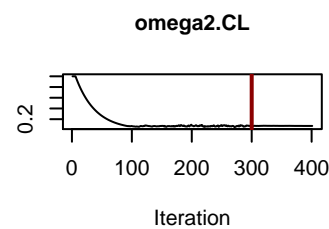
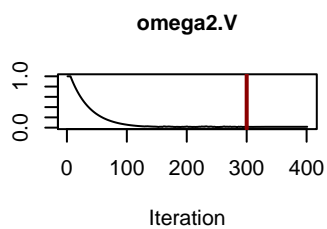
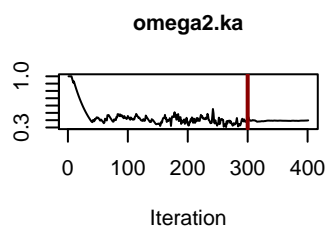
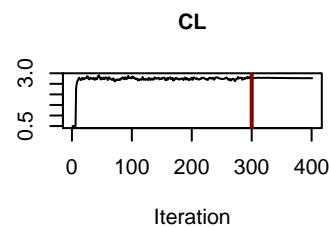
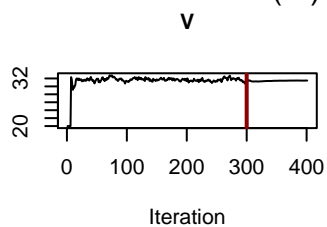
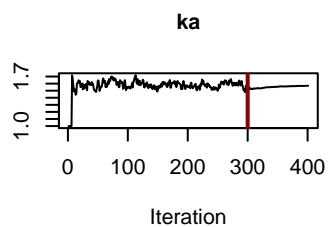
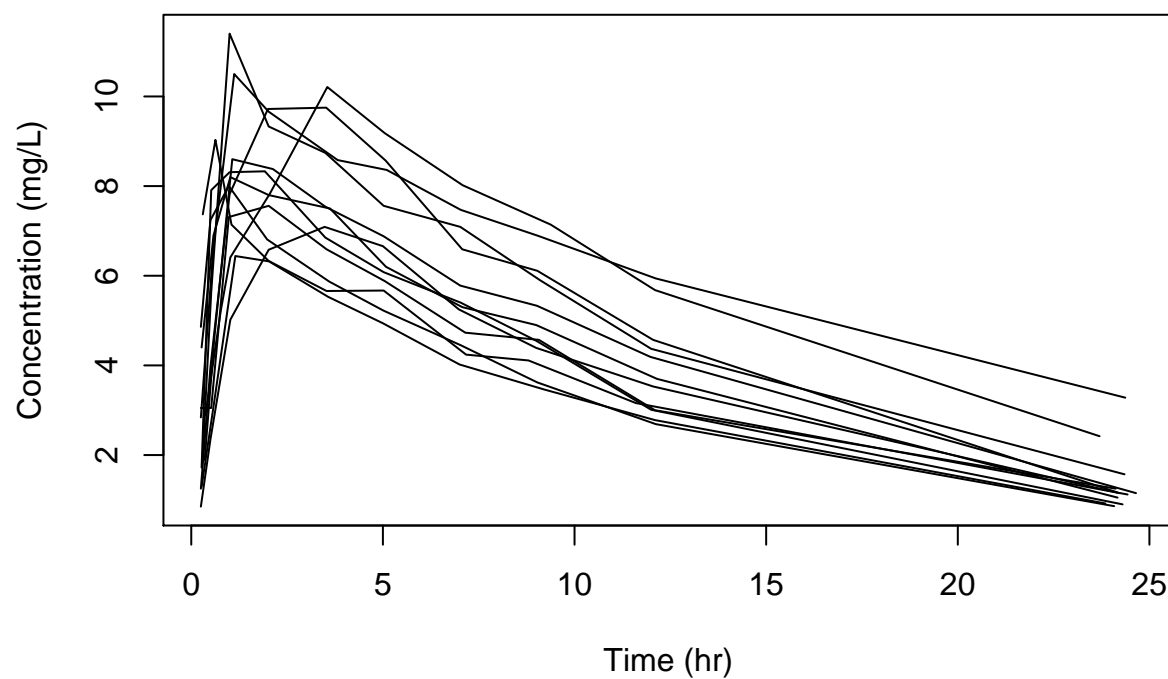
##      number of observations: 120
##      average/min/max nb obs: 10.00 / 10 / 10
## First 10 lines of data:
##      Id      Dose  Time Concentration Weight Sex mdv cens occ ytype
## 1      1 319.992 0.25          2.84   79.6   1  0    0  1    1
## 2      1 319.992 0.57          6.57   79.6   1  0    0  1    1
## 3      1 319.992 1.12         10.50   79.6   1  0    0  1    1
## 4      1 319.992 2.02          9.66   79.6   1  0    0  1    1
## 5      1 319.992 3.82          8.58   79.6   1  0    0  1    1
## 6      1 319.992 5.10          8.36   79.6   1  0    0  1    1
## 7      1 319.992 7.03          7.47   79.6   1  0    0  1    1
## 8      1 319.992 9.05          6.89   79.6   1  0    0  1    1
## 9      1 319.992 12.12         5.94   79.6   1  0    0  1    1
## 10     1 319.992 24.37          3.28   79.6   1  0    0  1    1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
## Model function: One-compartment model with first-order absorption
## Model type: structural
## function(psi,id,xidep) {
##     dose<-xidep[,1]
##     tim<-xidep[,2]
##     ka<-psi[id,1]
##     V<-psi[id,2]
##     CL<-psi[id,3]
##     k<-CL/V
##     ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##     return(ypred)
## }
## <bytecode: 0x5618ef977ba8>
## Nb of parameters: 3
##     parameter names: ka V CL
##     distribution:
##     Parameter Distribution Estimated
## [1,] ka      log-normal Estimated
## [2,] V      log-normal Estimated
## [3,] CL      log-normal Estimated
## Variance-covariance matrix:
##     ka V CL
## ka  1 0 0
## V   0 1 0
## CL  0 0 1
## Error model: constant , initial values: a.1=1
## No covariate in the model.
## Initial values
##     ka V CL
## Pop.CondInit 1 20 0.5
## -----
## ---- Key algorithm options ----
## -----
## Estimation of individual parameters (MAP)
## Estimation of standard errors and linearised log-likelihood
## Estimation of log-likelihood by importance sampling

```

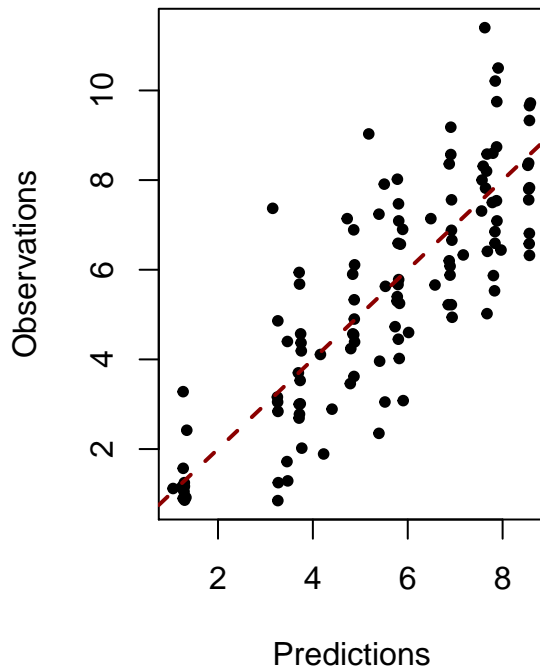
```

##      Number of iterations:  K1=300, K2=100
##      Number of chains:  5
##      Seed:  632545
##      Number of MCMC iterations for IS:  5000
##      Simulations:
##          nb of simulated datasets used for npde:  1000
##          nb of simulated datasets used for VPC:  100
##      Input/output
##          save the results to a file:  FALSE
##          save the graphs to files:  FALSE
## -----
## ----- Results -----
## -----
## ----- Fixed effects -----
## -----
##      Parameter Estimate SE      CV(%)
## [1,] ka          1.57   0.304 19.3
## [2,] V          31.47   1.423  4.5
## [3,] CL          2.77   0.239  8.7
## [4,] a.1         0.74   0.057  7.7
## -----
## ----- Variance of random effects -----
## -----
##      Parameter Estimate SE      CV(%)
## ka omega2.ka 0.397   0.1790 45
## V  omega2.V  0.017   0.0096 58
## CL omega2.CL 0.074   0.0360 49
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.ka omega2.V omega2.CL
## omega2.ka 1          0          0
## omega2.V  0          1          0
## omega2.CL 0          0          1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 344.1136
##      AIC = 358.1136
##      BIC = 361.5079
##
## Likelihood computed by importance sampling
##      -2LL= 345.4329
##      AIC = 359.4329
##      BIC = 362.8273
## -----
plot(saemix.fit)

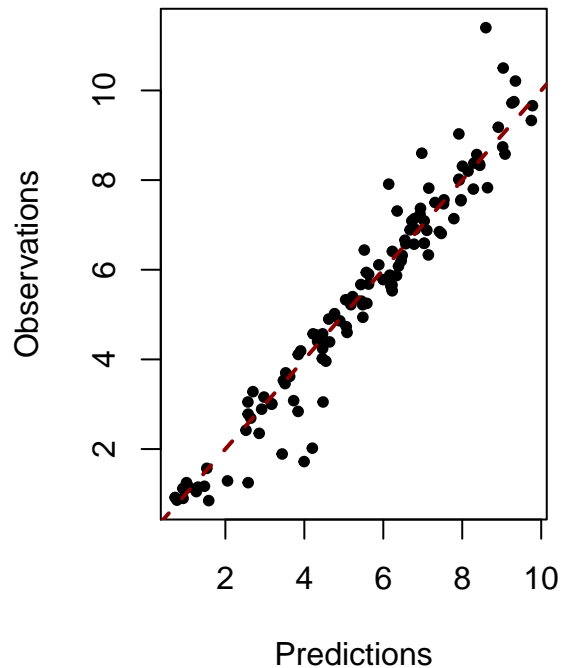
```



Population predictions



Individual predictions, MAP



```
# Model with covariates
saemix.model<-saemixModel(model=model1cpt,
                          description="One-compartment model with first-order absorption",
                          psi0=matrix(c(1.,20,0.5,0.1,0,-0.01),ncol=3,byrow=TRUE,
                                       dimnames=list(NULL, c("ka","V","CL"))),transform.par=c(1,1,1),
                          covariate.model=matrix(c(0,0,1,0,0,0),ncol=3,byrow=TRUE),fixed.estim=c(1,1,1),
                          covariance.model=matrix(c(1,0,0,0,1,1,0,1,1),ncol=3,byrow=TRUE),
                          omega.init=matrix(c(1,0,0,0,1,0,0,0,1),ncol=3,byrow=TRUE),error.model="combination")

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
## Model function: One-compartment model with first-order absorption
## Model type: structural
## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-psi[id,2]
##   CL<-psi[id,3]
##   k<-CL/V
##   ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##   return(ypred)
## }
## <bytecode: 0x5618ef977ba8>
## Nb of parameters: 3
## parameter names: ka V CL
## distribution:
```

```

##      Parameter Distribution Estimated
## [1,] ka      log-normal Estimated
## [2,] V      log-normal Estimated
## [3,] CL      log-normal Estimated
##      Variance-covariance matrix:
##      ka V CL
## ka  1 0 0
## V   0 1 1
## CL  0 1 1
##      Error model: combined , initial values: a.1=1 b.1=1
##      Covariate model:
##      ka V CL
## [1,] 0 0 1
## [2,] 0 0 0
##      Initial values
##      ka V CL
## Pop.CondInit 1.0 20 0.50
## Cov.CondInit 0.1 0 -0.01

saemix.options<-list(seed=39546,save=FALSE,save.graphs=FALSE, displayProgress=FALSE)
saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##      longitudinal data for use with the SAEM algorithm
## Dataset theo.saemix
##      Structured data: Concentration ~ Dose + Time | Id
##      X variable for graphs: Time (hr)
##      covariates: Weight (kg), Sex (-)
##      reference class for covariate Sex : 0
## Dataset characteristics:
##      number of subjects:      12
##      number of observations: 120
##      average/min/max nb obs: 10.00 / 10 / 10
## First 10 lines of data:
##      Id      Dose  Time Concentration Weight Sex mdv cens occ ytype
## 1      1 319.992 0.25          2.84   79.6  1  0  0  1  1
## 2      1 319.992 0.57          6.57   79.6  1  0  0  1  1
## 3      1 319.992 1.12         10.50   79.6  1  0  0  1  1
## 4      1 319.992 2.02          9.66   79.6  1  0  0  1  1
## 5      1 319.992 3.82          8.58   79.6  1  0  0  1  1
## 6      1 319.992 5.10          8.36   79.6  1  0  0  1  1
## 7      1 319.992 7.03          7.47   79.6  1  0  0  1  1
## 8      1 319.992 9.05          6.89   79.6  1  0  0  1  1
## 9      1 319.992 12.12         5.94   79.6  1  0  0  1  1
## 10     1 319.992 24.37          3.28   79.6  1  0  0  1  1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
##      Model function: One-compartment model with first-order absorption
##      Model type: structural

```



```

## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-psi[id,2]
##   CL<-psi[id,3]
##   k<-CL/V
##   ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##   return(ypred)
## }
## <bytecode: 0x5618ef977ba8>
##   Nb of parameters: 3
##     parameter names:  ka V CL
##     distribution:
##       Parameter Distribution Estimated
## [1,] ka      log-normal Estimated
## [2,] V      log-normal Estimated
## [3,] CL      log-normal Estimated
##   Variance-covariance matrix:
##     ka V CL
## ka  1 0  0
## V   0 1  1
## CL  0 1  1
##   Error model: combined , initial values: a.1=1 b.1=1
##   Covariate model:
##     [,1] [,2] [,3]
## Weight  0  0  1
##   Initial values
##           ka V   CL
## Pop.CondInit 1.0 20  0.50
## Cov.CondInit 0.1  0 -0.01
## -----
## ----   Key algorithm options   ----
## -----
##   Estimation of individual parameters (MAP)
##   Estimation of standard errors and linearised log-likelihood
##   Estimation of log-likelihood by importance sampling
##   Number of iterations:  K1=300, K2=100
##   Number of chains:  5
##   Seed:  39546
##   Number of MCMC iterations for IS:  5000
##   Simulations:
##     nb of simulated datasets used for npde:  1000
##     nb of simulated datasets used for VPC:  100
##   Input/output
##     save the results to a file:  FALSE
##     save the graphs to files:  FALSE
## -----
## ----                               Results                               ----
## -----
## -----   Fixed effects   -----
## -----
##   Parameter      Estimate SE      CV(%) p-value
## [1,] ka          1.5565  0.3050 19.6  -

```

```

## [2,] V          31.6621  1.4946  4.7  -
## [3,] CL          4.4308  1.9206 43.3  -
## [4,] beta_Weight(CL) -0.0067  0.0061 91.3  0.14
## [5,] a.1         0.5734  0.1211 21.1  -
## [6,] b.1         0.0748  0.0223 29.8  -
## -----
## ----- Variance of random effects -----
## -----
##      Parameter Estimate SE    CV(%)
## ka    omega2.ka 0.412    0.179 44
## V      omega2.V  0.019    0.011 56
## CL      omega2.CL 0.064    0.031 48
## covar cov.V.CL  0.035    0.016 45
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.ka omega2.V omega2.CL
## omega2.ka 1      0      0
## omega2.V  0      1      1
## omega2.CL 0      1      1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 330.7213
##      AIC = 350.7213
##      BIC = 355.5704
##
## Likelihood computed by importance sampling
##      -2LL= 333.9945
##      AIC = 353.9945
##      BIC = 358.8436
## -----
# Warning message
plot(saemix.fit, plot.type="npde")

## Simulating data using nsim = 1000 simulated datasets
## Computing WRES and npde ..

## Please use npdeSaemix to obtain VPC and npde
ynpde<-npdeSaemix(saemix.fit)

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

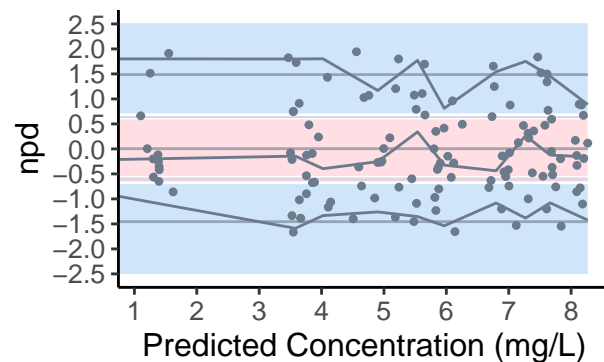
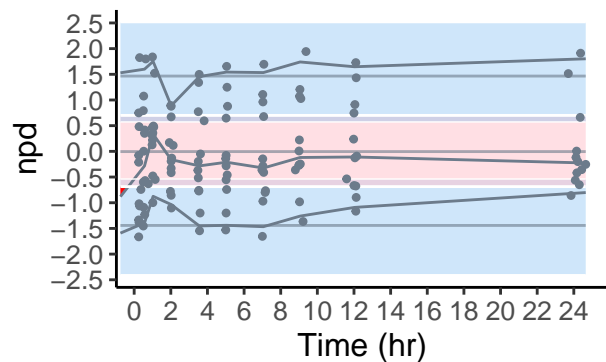
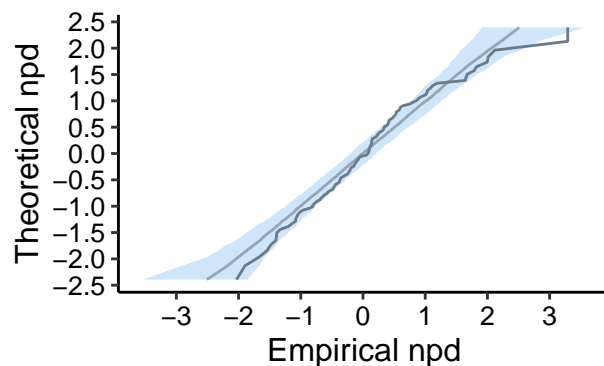
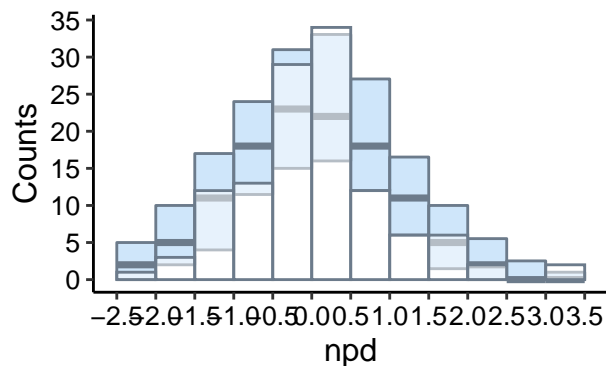
## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

```

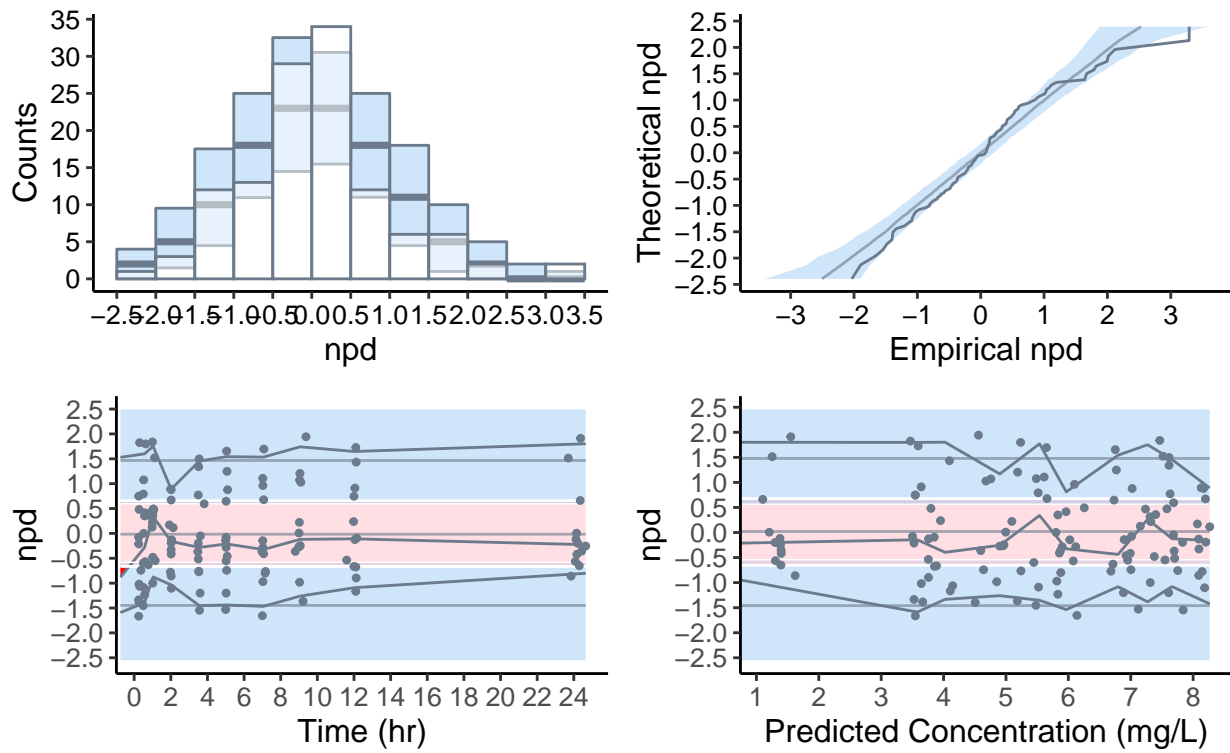
```
## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in which(!is.na(as.integer(object@name.covariates))): NAs introduits
## lors de la conversion automatique

## -----
## Distribution of npde :
##      nb of obs: 120
##      mean= 0.04778   (SE= 0.085 )
##      variance= 0.8765   (SE= 0.11 )
##      skewness= 0.6982
##      kurtosis= 1.474
## -----
## Statistical tests (adjusted p-values):
##      t-test           : 1
##      Fisher variance test : 1
##      SW test of normality : 0.00516 **
##      Global test       : 0.00516 **
## ---
## Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
## -----
```

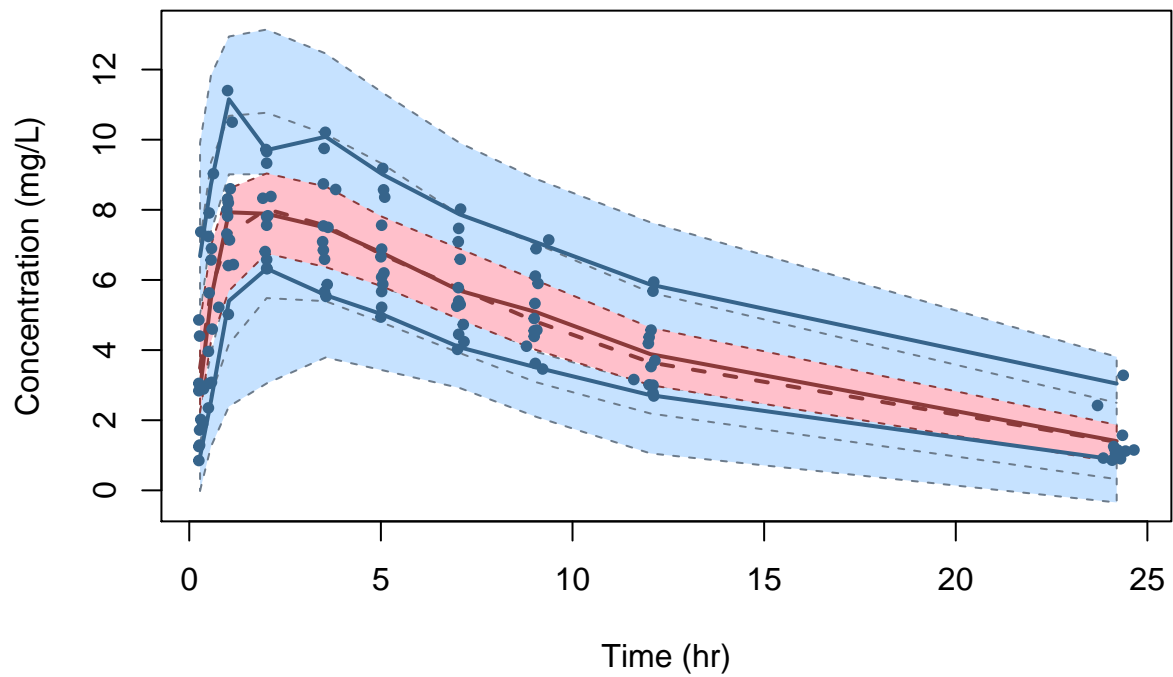


```
plot(ynpde)
```

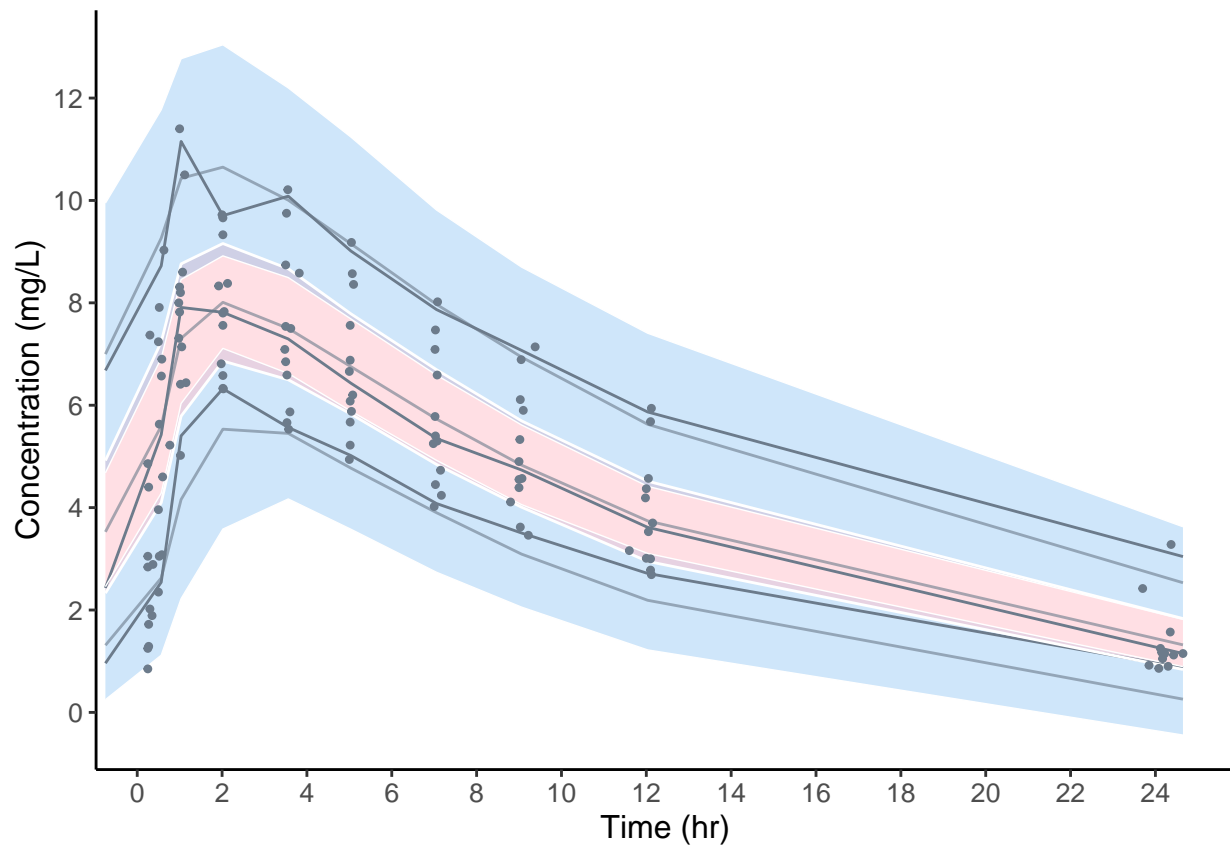


```
# VPC
plot(saemix.fit, plot.type="vpc")
```

Visual Predictive Check



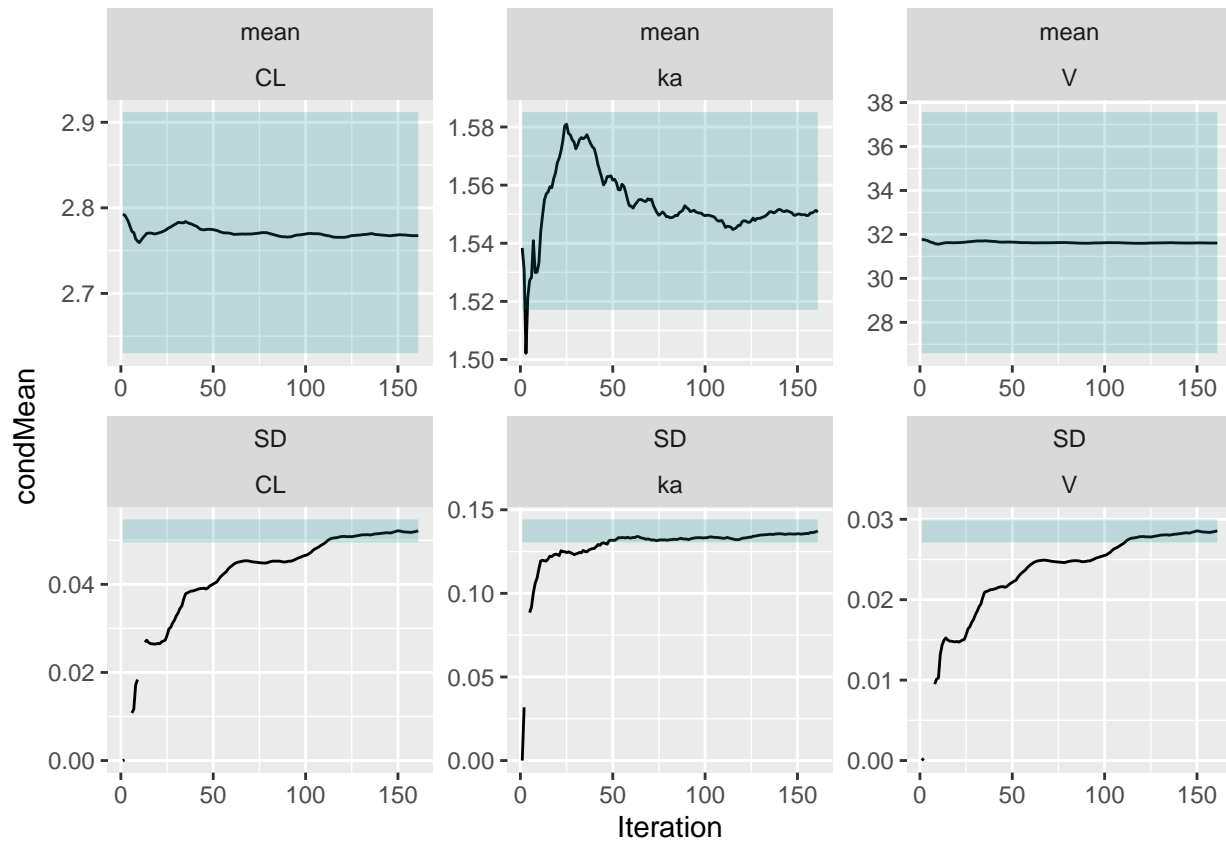
```
plot(ynpde, plot.type="vpc")
```



```
saemix.fit<-condist.saemix(saemix.fit)

## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
saemix.fit<-condist.saemix(saemix.fit, plot=TRUE)

## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
## Warning in sqrt(varik): production de NaN
```



One random effect

Note: sort the message “one-dimensional optimization by Nelder-Mead is unreliable”

```
modellcpt.1<-function(psi,id,xidep) {
  dose<-xidep[,1]
  tim<-xidep[,2]
  ka<-psi[id,1]
  V<-2
  # V<-psi[id,2]
  k<-0.5
  CL<-k*V
  ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
  return(ypred)
}

saemix.model<-saemixModel(model=modellcpt.1,description="warfarin",modeltype="structural",
  psi0=matrix(c(1),ncol=1,byrow=TRUE, dimnames=list(NULL, c("ka"))),
  transform.par=c(1),omega.init=matrix(c(1),ncol=1,byrow=TRUE),
  covariance.model=matrix(c(1),ncol=1,byrow=TRUE))

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
##   Model function:  warfarin
##   Model type:     structural
```

```

## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-2
##   # V<-psi[id,2]
##   k<-0.5
##   CL<-k*V
##   ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##   return(ypred)
## }
##   Nb of parameters: 1
##     parameter names: ka
##     distribution:
##       Parameter Distribution Estimated
## [1,] ka      log-normal      Estimated
##   Variance-covariance matrix:
##     ka
## ka 1
##   Error model: constant , initial values: a.1=1
##     No covariate in the model.
##     Initial values
##       ka
## Pop.CondInit 1
saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset theo.saemix
##   Structured data: Concentration ~ Dose + Time | Id
##   X variable for graphs: Time (hr)
##   covariates: Weight (kg), Sex (-)
##   reference class for covariate Sex : 0
## Dataset characteristics:
##   number of subjects:      12
##   number of observations: 120
##   average/min/max nb obs: 10.00 / 10 / 10
## First 10 lines of data:
##   Id    Dose  Time Concentration Weight Sex mdv cens occ ytype
## 1  1 319.992 0.25          2.84   79.6  1  0  0  1  1
## 2  1 319.992 0.57          6.57   79.6  1  0  0  1  1
## 3  1 319.992 1.12         10.50   79.6  1  0  0  1  1
## 4  1 319.992 2.02          9.66   79.6  1  0  0  1  1
## 5  1 319.992 3.82          8.58   79.6  1  0  0  1  1
## 6  1 319.992 5.10          8.36   79.6  1  0  0  1  1
## 7  1 319.992 7.03          7.47   79.6  1  0  0  1  1
## 8  1 319.992 9.05          6.89   79.6  1  0  0  1  1
## 9  1 319.992 12.12         5.94   79.6  1  0  0  1  1
## 10 1 319.992 24.37         3.28   79.6  1  0  0  1  1
## -----

```

```

## -----      Model      -----
## -----
## Nonlinear mixed-effects model
##   Model function:  warfarin
##   Model type:     structural
## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-2
##   # V<-psi[id,2]
##   k<-0.5
##   CL<-k*V
##   ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##   return(ypred)
## }
## <bytecode: 0x5618f278c818>
##   Nb of parameters: 1
##     parameter names: ka
##     distribution:
##       Parameter Distribution Estimated
## [1,] ka           log-normal Estimated
##   Variance-covariance matrix:
##     ka
## ka 1
##   Error model: constant , initial values: a.1=1
##     No covariate in the model.
##     Initial values
##       ka
## Pop.CondInit 1
## -----
## -----      Key algorithm options      -----
## -----
##   Estimation of individual parameters (MAP)
##   Estimation of standard errors and linearised log-likelihood
##   Estimation of log-likelihood by importance sampling
##   Number of iterations: K1=300, K2=100
##   Number of chains: 5
##   Seed: 39546
##   Number of MCMC iterations for IS: 5000
##   Simulations:
##     nb of simulated datasets used for npde: 1000
##     nb of simulated datasets used for VPC: 100
##   Input/output
##     save the results to a file: FALSE
##     save the graphs to files: FALSE
## -----
## -----      Results      -----
## -----
## -----      Fixed effects      -----
## -----
##   Parameter Estimate SE      CV(%)
## [1,] ka           0.027  0.0015 5.8
## [2,] a.1          2.927  0.1991 6.8

```



```

## ----- Variance of random effects -----
## -----
##      Parameter Estimate SE      CV(%)
## ka omega2.ka 1.3e-05  0.017 130416
## -----
## ----- Correlation matrix of random effects -----
## -----
##          omega2.ka
## omega2.ka 1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 598.2676
##      AIC = 604.2676
##      BIC = 605.7223
##
## Likelihood computed by importance sampling
##      -2LL= 598.2609
##      AIC = 604.2609
##      BIC = 605.7157
## -----

# Alternate, fixing V and CL
saemix.model2<-saemixModel(model=model1cpt,
                           description="One-compartment model with first-order absorption",
                           psi0=matrix(c(1.,20,1),ncol=3,byrow=TRUE, dimnames=list(NULL, c("ka","V","CL")),
                           transform.par=c(1,1,1), fixed.estim=c(1,0,0),
                           covariance.model = diag(c(1,0,0)),
                           omega.init=diag(c(1,1,1)))

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
## Model function: One-compartment model with first-order absorption
## Model type: structural
## function(psi,id,xidep) {
##     dose<-xidep[,1]
##     tim<-xidep[,2]
##     ka<-psi[id,1]
##     V<-psi[id,2]
##     CL<-psi[id,3]
##     k<-CL/V
##     ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##     return(ypred)
## }
## <bytecode: 0x5618ef977ba8>
## Nb of parameters: 3
##     parameter names: ka V CL
##     distribution:
##     Parameter Distribution Estimated
## [1,] ka          log-normal Estimated

```

```

## [2,] V          log-normal   Fixed
## [3,] CL          log-normal   Fixed
##   Variance-covariance matrix:
##   ka V CL
## ka  1 0  0
## V   0 0  0
## CL  0 0  0
##   Error model: constant , initial values: a.1=1
##   No covariate in the model.
##   Initial values
##           ka  V CL
## Pop.CondInit  1 20  1

saemix.fit2<-saemix(saemix.model2,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset theo.saemix
##   Structured data: Concentration ~ Dose + Time | Id
##   X variable for graphs: Time (hr)
##   covariates: Weight (kg), Sex (-)
##   reference class for covariate Sex :  0
## Dataset characteristics:
##   number of subjects:      12
##   number of observations: 120
##   average/min/max nb obs: 10.00 /  10 /  10
## First 10 lines of data:
##   Id    Dose  Time Concentration Weight Sex mdv cens occ ytype
## 1    1 319.992 0.25          2.84  79.6  1  0  0  1  1
## 2    1 319.992 0.57          6.57  79.6  1  0  0  1  1
## 3    1 319.992 1.12         10.50  79.6  1  0  0  1  1
## 4    1 319.992 2.02          9.66  79.6  1  0  0  1  1
## 5    1 319.992 3.82          8.58  79.6  1  0  0  1  1
## 6    1 319.992 5.10          8.36  79.6  1  0  0  1  1
## 7    1 319.992 7.03          7.47  79.6  1  0  0  1  1
## 8    1 319.992 9.05          6.89  79.6  1  0  0  1  1
## 9    1 319.992 12.12         5.94  79.6  1  0  0  1  1
## 10   1 319.992 24.37          3.28  79.6  1  0  0  1  1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
##   Model function: One-compartment model with first-order absorption
##   Model type: structural
## function(psi,id,xidep) {
##   dose<-xidep[,1]
##   tim<-xidep[,2]
##   ka<-psi[id,1]
##   V<-psi[id,2]
##   CL<-psi[id,3]
##   k<-CL/V

```

```

##      ypred<-dose*ka/(V*(ka-k))*(exp(-k*tim)-exp(-ka*tim))
##      return(ypred)
##    }
## <bytecode: 0x5618ef977ba8>
##      Nb of parameters: 3
##      parameter names:  ka V CL
##      distribution:
##      Parameter Distribution Estimated
## [1,] ka      log-normal  Estimated
## [2,] V      log-normal  Fixed
## [3,] CL      log-normal  Fixed
##      Variance-covariance matrix:
##      ka V CL
## ka  1 0 0
## V   0 0 0
## CL  0 0 0
##      Error model: constant , initial values: a.1=1
##      No covariate in the model.
##      Initial values
##      ka V CL
## Pop.CondInit  1 20  1
## -----
## ----      Key algorithm options      ----
## -----
##      Estimation of individual parameters (MAP)
##      Estimation of standard errors and linearised log-likelihood
##      Estimation of log-likelihood by importance sampling
##      Number of iterations:  K1=300, K2=100
##      Number of chains:  5
##      Seed:  39546
##      Number of MCMC iterations for IS:  5000
##      Simulations:
##      nb of simulated datasets used for npde:  1000
##      nb of simulated datasets used for VPC:  100
##      Input/output
##      save the results to a file:  FALSE
##      save the graphs to files:  FALSE
## -----
## ----                        Results                        ----
## -----
## -----      Fixed effects      -----
## -----
##      Parameter Estimate SE      CV(%)
## [1,] ka      0.16      0.018 11.8
## [2,] V      20.00      -      -
## [3,] CL      1.00      -      -
## [4,] a.1     4.09      0.278 6.8
## -----
## -----      Variance of random effects      -----
## -----
##      Parameter Estimate SE      CV(%)
## ka omega2.ka 0.0023      0.072 3143
## -----
## -----      Correlation matrix of random effects      -----

```

```
## -----
##          omega2.ka
## omega2.ka 1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 678.9567
##      AIC = 684.9567
##      BIC = 686.4114
##
## Likelihood computed by importance sampling
##      -2LL= 678.84
##      AIC = 684.84
##      BIC = 686.2948
## -----
```

```
# Checking estimates are close (yes)
saemix.fit@results
```

```
## Fixed effects
## Parameter Estimate SE CV(%)
## ka 0.0266 0.00153 5.77
## a.1 2.9266 0.19905 6.80
##
## Variance of random effects
## Parameter Estimate SE CV(%)
## omega2.ka 1.31e-05 0.0171 130416
##
## Statistical criteria
## Likelihood computed by linearisation
##      -2LL= 598.2676
##      AIC= 604.2676
##      BIC= 605.7223
## Likelihood computed by importance sampling
##      -2LL= 598.2609
##      AIC= 604.2609
##      BIC= 605.7157
```

```
saemix.fit2@results
```

```
## Fixed effects
## Warning in methods::show(x): NAs introduits lors de la conversion automatique
## Warning in methods::show(x): NAs introduits lors de la conversion automatique
## Parameter Estimate SE CV(%)
## ka 0.155 0.0183 11.8
## V 20.000 - -
## CL 1.000 - -
## a.1 4.093 0.2784 6.8
##
## Variance of random effects
## Parameter Estimate SE CV(%)
## omega2.ka 0.00228 0.0716 3143
##
```

```
## Statistical criteria
## Likelihood computed by linearisation
##      -2LL= 678.9567
##      AIC= 684.9567
##      BIC= 686.4114
## Likelihood computed by importance sampling
##      -2LL= 678.84
##      AIC= 684.84
##      BIC= 686.2948
```

Simulated PD

```
if(testMode) {
  data(PD1.saemix)
  data(PD2.saemix)
} else {
  PD1.saemix<-read.table(file.path(datDir, "PD1.saemix.tab"), header=TRUE)
  PD2.saemix<-read.table(file.path(datDir, "PD1.saemix.tab"), header=TRUE)
}

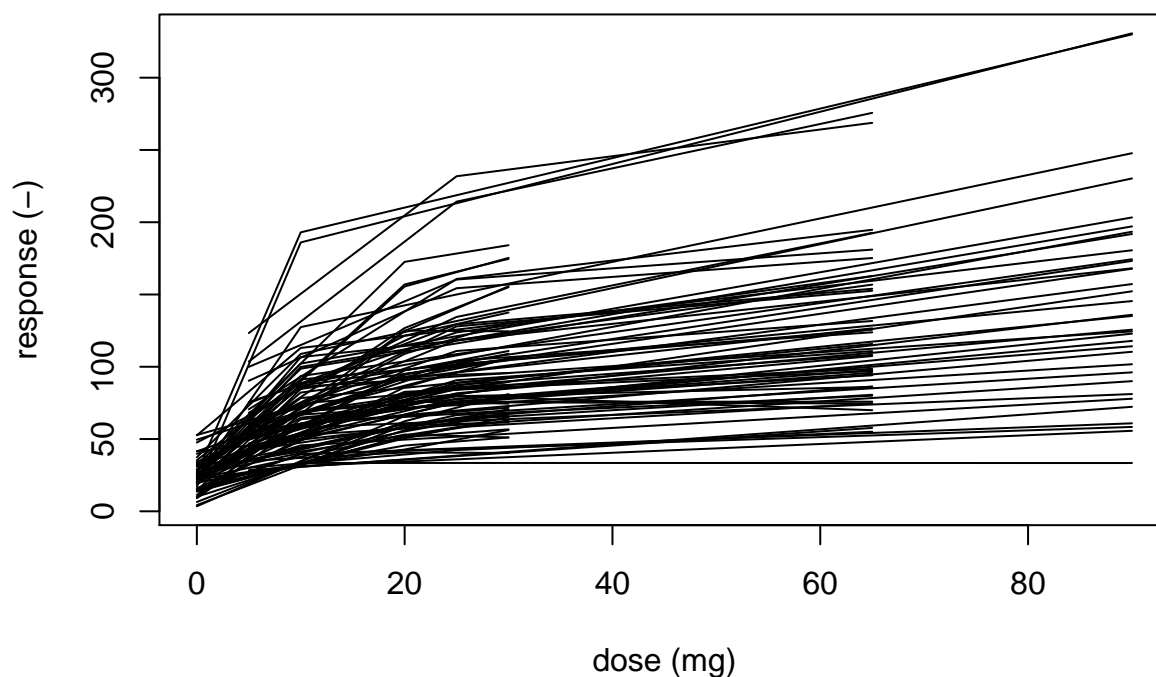
saemix.data<-saemixData(name.data=PD1.saemix,header=TRUE,name.group=c("subject"),
  name.predictors=c("dose"),name.response=c("response"),
  name.covariates=c("gender"), units=list(x="mg",y="-",covariates=c("-")))

##
##
## The following SaemixData object was successfully created:
##
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset PD1.saemix
##   Structured data: response ~ dose | subject
##   Predictor: dose (mg)
##   covariates: gender (-)
##   reference class for covariate gender : 0

modelemax<-function(psi,id,xidep) {
  # input:
  #   psi : matrix of parameters (3 columns, E0, Emax, EC50)
  #   id : vector of indices
  #   xidep : dependent variables (same nb of rows as length of id)
  # returns:
  #   a vector of predictions of length equal to length of id
  dose<-xidep[,1]
  e0<-psi[id,1]
  emax<-psi[id,2]
  e50<-psi[id,3]
  f<-e0+emax*dose/(e50+dose)
  return(f)
}

# Plotting the data
plot(saemix.data,main="Simulated data PD1")
```

Simulated data PD1



```
# Compare models with and without covariates with LL by Importance Sampling
modell1<-saemixModel(model=modelemax,description="Emax growth model",
  psi0=matrix(c(20,300,20,0,0,0),ncol=3,byrow=TRUE,dimnames=list(NULL,
    c("E0","Emax","EC50"))), transform.par=c(1,1,1),
  covariate.model=matrix(c(0,0,0), ncol=3,byrow=TRUE),fixed.estim=c(1,1,1))
```

```
##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
##   Model function: Emax growth model
##   Model type: structural
## function(psi,id,xidep) {
## # input:
## #   psi : matrix of parameters (3 columns, E0, Emax, EC50)
## #   id : vector of indices
## #   xidep : dependent variables (same nb of rows as length of id)
## # returns:
## #   a vector of predictions of length equal to length of id
##   dose<-xidep[,1]
##   e0<-psi[id,1]
##   emax<-psi[id,2]
##   e50<-psi[id,3]
##   f<-e0+emax*dose/(e50+dose)
##   return(f)
## }
##   Nb of parameters: 3
##   parameter names: E0 Emax EC50
##   distribution:
```

```

##      Parameter Distribution Estimated
## [1,] E0      log-normal Estimated
## [2,] Emax    log-normal Estimated
## [3,] EC50    log-normal Estimated
##      Variance-covariance matrix:
##      E0 Emax EC50
## E0      1      0      0
## Emax     0      1      0
## EC50     0      0      1
##      Error model: constant , initial values: a.1=1
##      No covariate in the model.
##      Initial values
##      E0 Emax EC50
## Pop.CondInit 20 300 20
## Cov.CondInit 0 0 0

model2<-saemixModel(model=modelemax,description="Emax growth model",
  psi0=matrix(c(20,300,20,0,0,0),ncol=3,byrow=TRUE,dimnames=list(NULL,
    c("E0","Emax","EC50"))), transform.par=c(1,1,1),
  covariate.model=matrix(c(0,0,1), ncol=3,byrow=TRUE),fixed.estim=c(1,1,1))

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
##      Model function: Emax growth model
##      Model type: structural
##      function(psi,id,xidep) {
## # input:
## #   psi : matrix of parameters (3 columns, E0, Emax, EC50)
## #   id  : vector of indices
## #   xidep : dependent variables (same nb of rows as length of id)
## # returns:
## #   a vector of predictions of length equal to length of id
##      dose<-xidep[,1]
##      e0<-psi[id,1]
##      emax<-psi[id,2]
##      e50<-psi[id,3]
##      f<-e0+emax*dose/(e50+dose)
##      return(f)
## }
##      Nb of parameters: 3
##      parameter names: E0 Emax EC50
##      distribution:
##      Parameter Distribution Estimated
## [1,] E0      log-normal Estimated
## [2,] Emax    log-normal Estimated
## [3,] EC50    log-normal Estimated
##      Variance-covariance matrix:
##      E0 Emax EC50
## E0      1      0      0
## Emax     0      1      0
## EC50     0      0      1
##      Error model: constant , initial values: a.1=1

```

```

## Covariate model:
##      E0 Emax EC50
## [1,]  0   0   1
##      Initial values
##      E0 Emax EC50
## Pop.CondInit 20  300  20
## Cov.CondInit  0   0   0

# SE not computed as not needed for the test
saemix.options<-list(algorithms=c(0,1,1),nb.chains=3,seed=765754,
                     nbiter.saemix=c(500,300),save=FALSE,save.graphs=FALSE, displayProgress=FALSE)

fit1<-saemix(model1,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##      longitudinal data for use with the SAEM algorithm
## Dataset PD1.saemix
##      Structured data: response ~ dose | subject
##      Predictor: dose (mg)
##      covariates: gender (-)
##      reference class for covariate gender :  0
## Dataset characteristics:
##      number of subjects:      100
##      number of observations: 300
##      average/min/max nb obs: 3.00 /  3 /  3
## First 10 lines of data:
##      subject dose response gender mdv cens occ ytype
## 1          1   0  11.2870      1  0   0   1   1
## 2          1  10  63.6114      1  0   0   1   1
## 3          1  90 122.9170      1  0   0   1   1
## 4          2   0  15.0514      1  0   0   1   1
## 5          2  10  39.5296      1  0   0   1   1
## 6          2  90  60.8522      1  0   0   1   1
## 7          3   0  25.5390      1  0   0   1   1
## 8          3  10  58.0035      1  0   0   1   1
## 9          3  90  81.1173      1  0   0   1   1
## 10         4   0  22.1446      1  0   0   1   1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
##      Model function: Emax growth model
##      Model type: structural
## function(psi,id,xidep) {
## # input:
## #   psi : matrix of parameters (3 columns, E0, Emax, EC50)
## #   id  : vector of indices
## #   xidep : dependent variables (same nb of rows as length of id)
## # returns:
## #   a vector of predictions of length equal to length of id
##      dose<-xidep[,1]

```



```

## e0<-psi[id,1]
## emax<-psi[id,2]
## e50<-psi[id,3]
## f<-e0+emax*dose/(e50+dose)
## return(f)
## }
## <bytecode: 0x5618eaca4e80>
## Nb of parameters: 3
## parameter names: E0 Emax EC50
## distribution:
## Parameter Distribution Estimated
## [1,] E0 log-normal Estimated
## [2,] Emax log-normal Estimated
## [3,] EC50 log-normal Estimated
## Variance-covariance matrix:
## E0 Emax EC50
## E0 1 0 0
## Emax 0 1 0
## EC50 0 0 1
## Error model: constant , initial values: a.1=1
## No covariate in the model.
## Initial values
## E0 Emax EC50
## Pop.CondInit 20 300 20
## -----
## ---- Key algorithm options ----
## -----
## Estimation of individual parameters (MAP)
## Estimation of standard errors and linearised log-likelihood
## Estimation of log-likelihood by importance sampling
## Number of iterations: K1=500, K2=300
## Number of chains: 3
## Seed: 765754
## Number of MCMC iterations for IS: 5000
## Simulations:
## nb of simulated datasets used for npde: 1000
## nb of simulated datasets used for VPC: 100
## Input/output
## save the results to a file: FALSE
## save the graphs to files: FALSE
## -----
## ---- Results ----
## -----
## ----- Fixed effects -----
## -----
## Parameter Estimate SE CV(%)
## [1,] E0 23.4 1.08 4.6
## [2,] Emax 107.2 6.09 5.7
## [3,] EC50 15.2 0.77 5.0
## [4,] a.1 4.8 0.42 8.8
## -----
## ----- Variance of random effects -----
## -----
## Parameter Estimate SE CV(%)

```

```

## E0    omega2.E0    0.128    0.028 22
## Emax omega2.Emax 0.302    0.045 15
## EC50 omega2.EC50 0.071    0.027 38
## -----
## ----- Correlation matrix of random effects -----
## -----
##              omega2.E0 omega2.Emax omega2.EC50
## omega2.E0    1          0          0
## omega2.Emax  0          1          0
## omega2.EC50  0          0          1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 2463.063
##      AIC = 2477.063
##      BIC = 2495.299
##
## Likelihood computed by importance sampling
##      -2LL= 2466.154
##      AIC = 2480.154
##      BIC = 2498.39
## -----
fit2<-saemix(model2,saemix.data,saemix.options)

## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ---- Data ----
## -----
## Object of class SaemixData
##      longitudinal data for use with the SAEM algorithm
## Dataset PD1.saemix
##      Structured data: response ~ dose | subject
##      Predictor: dose (mg)
##      covariates: gender (-)
##      reference class for covariate gender : 0
## Dataset characteristics:
##      number of subjects:      100
##      number of observations: 300
##      average/min/max nb obs: 3.00 / 3 / 3
## First 10 lines of data:
##      subject dose response gender mdv cens occ ytype
## 1          1    0 11.2870      1  0    0  1    1
## 2          1   10 63.6114      1  0    0  1    1
## 3          1   90 122.9170     1  0    0  1    1
## 4          2    0 15.0514      1  0    0  1    1
## 5          2   10 39.5296      1  0    0  1    1
## 6          2   90 60.8522      1  0    0  1    1
## 7          3    0 25.5390      1  0    0  1    1
## 8          3   10 58.0035      1  0    0  1    1
## 9          3   90 81.1173      1  0    0  1    1
## 10         4    0 22.1446      1  0    0  1    1
## -----
## ---- Model ----

```

```

## -----
## Nonlinear mixed-effects model
## Model function: Emax growth model
## Model type: structural
## function(psi,id,xidep) {
## # input:
## #   psi : matrix of parameters (3 columns, E0, Emax, EC50)
## #   id : vector of indices
## #   xidep : dependent variables (same nb of rows as length of id)
## # returns:
## #   a vector of predictions of length equal to length of id
## dose<-xidep[,1]
## e0<-psi[id,1]
## emax<-psi[id,2]
## e50<-psi[id,3]
## f<-e0+emax*dose/(e50+dose)
## return(f)
## }
## <bytecode: 0x5618eaca4e80>
## Nb of parameters: 3
##   parameter names: E0 Emax EC50
##   distribution:
##   Parameter Distribution Estimated
## [1,] E0      log-normal Estimated
## [2,] Emax    log-normal Estimated
## [3,] EC50    log-normal Estimated
## Variance-covariance matrix:
##   E0 Emax EC50
## E0  1  0  0
## Emax 0  1  0
## EC50 0  0  1
## Error model: constant , initial values: a.1=1
## Covariate model:
##   [,1] [,2] [,3]
## gender  0  0  1
## Initial values
##   E0 Emax EC50
## Pop.CondInit 20 300 20
## Cov.CondInit 0  0  0
## -----
## ---- Key algorithm options ----
## -----
## Estimation of individual parameters (MAP)
## Estimation of standard errors and linearised log-likelihood
## Estimation of log-likelihood by importance sampling
## Number of iterations: K1=500, K2=300
## Number of chains: 3
## Seed: 765754
## Number of MCMC iterations for IS: 5000
## Simulations:
##   nb of simulated datasets used for npde: 1000
##   nb of simulated datasets used for VPC: 100
## Input/output
## save the results to a file: FALSE

```

```

##          save the graphs to files: FALSE
## -----
## ----- Results -----
## ----- Fixed effects -----
## -----
##      Parameter      Estimate SE    CV(%) p-value
## [1,] E0             23.24   1.072  4.6   -
## [2,] Emax           107.20   6.120  5.7   -
## [3,] EC50            11.45   0.980  8.6   -
## [4,] beta_gender(EC50) 0.39   0.099 25.6  4.7e-05
## [5,] a.1             4.72   0.407  8.6   -
## -----
## ----- Variance of random effects -----
## -----
##      Parameter  Estimate SE    CV(%)
## E0  omega2.E0   0.129   0.028  22
## Emax omega2.Emax 0.307   0.045  15
## EC50 omega2.EC50 0.052   0.022  43
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.E0 omega2.Emax omega2.EC50
## omega2.E0    1         0         0
## omega2.Emax  0         1         0
## omega2.EC50  0         0         1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 2448.635
##      AIC = 2464.635
##      BIC = 2485.477
##
## Likelihood computed by importance sampling
##      -2LL= 2452.279
##      AIC = 2468.279
##      BIC = 2489.121
## -----
wstat<-(-2)*(fit1["results"]["ll.is"]-fit2["results"]["ll.is"])

cat("LRT test for covariate effect on EC50: p-value=",1-pchisq(wstat,1),"\n")

## LRT test for covariate effect on EC50: p-value= 0.0001954234

if(FALSE) {
  plot(model1, saemix.data)
  plot(model1, saemix.data, psi=c(0, 200, 50))
}

```

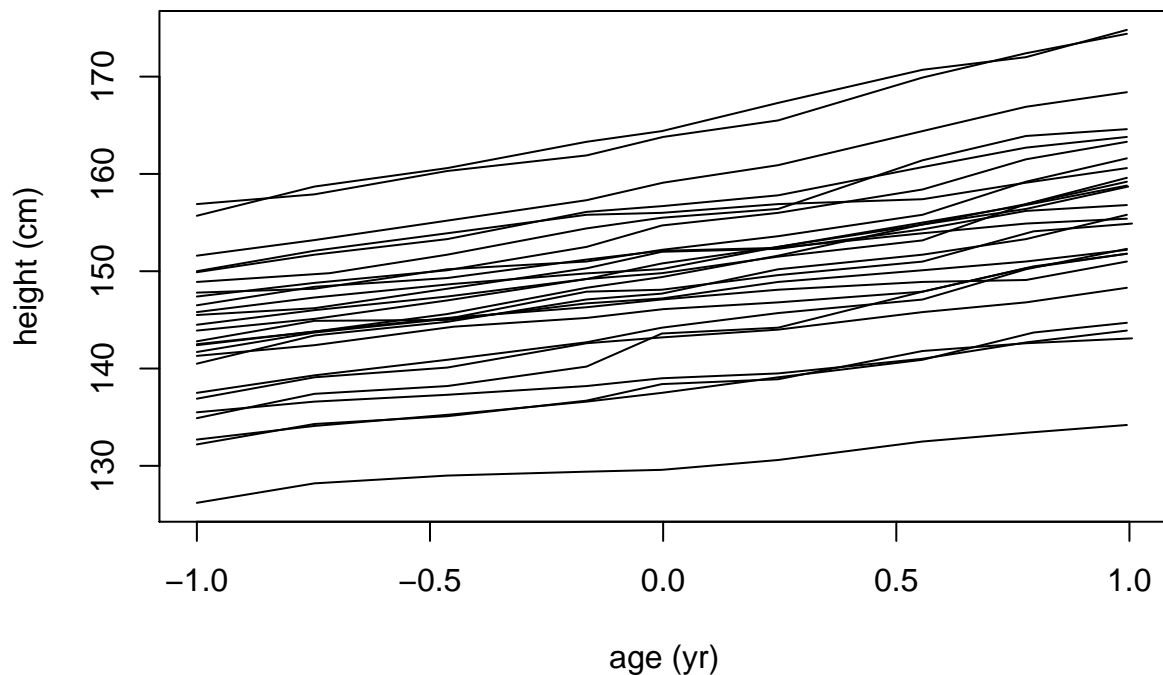
Oxford boys

```
if(testMode)
  data(oxboys.saemix) else
  oxboys.saemix<-read.table(file.path(datDir, "oxboys.saemix.tab"), header=TRUE)

saemix.data<-saemixData(name.data=oxboys.saemix,header=TRUE,
  name.group=c("Subject"),name.predictors=c("age"),name.response=c("height"),
  units=list(x="yr",y="cm"))

##
##
## The following SaemixData object was successfully created:
##
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset oxboys.saemix
##   Structured data: height ~ age | Subject
##   Predictor: age (yr)

# plot the data
plot(saemix.data)
```



```
growth.linear<-function(psi,id,xidep) {
  x<-xidep[,1]
  base<-psi[id,1]
  slope<-psi[id,2]
  f<-base+slope*x
  return(f)
}

saemix.model<-saemixModel(model=growth.linear,description="Linear model",
```

```
psi0=matrix(c(140,1),ncol=2,byrow=TRUE,dimnames=list(NULL,c("base","slope"))),
transform.par=c(1,0),covariance.model=matrix(c(1,1,1,1),ncol=2,byrow=TRUE),
error.model="constant")
```

```
##
##
## The following SaemixModel object was successfully created:
```

```
##
## Nonlinear mixed-effects model
##   Model function:  Linear model
##   Model type:     structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   base<-psi[id,1]
##   slope<-psi[id,2]
##   f<-base+slope*x
##   return(f)
## }
##   Nb of parameters: 2
##       parameter names:  base slope
##       distribution:
##       Parameter Distribution Estimated
## [1,] base      log-normal      Estimated
## [2,] slope     normal          Estimated
##   Variance-covariance matrix:
##       base slope
## base      1      1
## slope     1      1
##   Error model: constant , initial values: a.1=1
##   No covariate in the model.
##   Initial values
##           base slope
## Pop.CondInit 140      1
```

```
saemix.options<-list(algorithms=c(1,1,1),nb.chains=1,seed=201004,
  save=FALSE,save.graphs=FALSE, displayProgress=FALSE)
saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)
```

```
## The number of subjects is small, increasing the number of chains to 2 to improve convergence
## Nonlinear mixed-effects model fit by the SAEM algorithm
```

```
## -----
## ----          Data          ----
## -----
```

```
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset oxboys.saemix
##   Structured data: height ~ age | Subject
##   Predictor: age (yr)
## Dataset characteristics:
##   number of subjects:      26
##   number of observations: 234
##   average/min/max nb obs: 9.00 / 9 / 9
## First 10 lines of data:
##   Subject      age height mdv cens occ ytype
```

```

## 1      1 -1.0000 140.5  0  0  1  1
## 2      1 -0.7479 143.4  0  0  1  1
## 3      1 -0.4630 144.8  0  0  1  1
## 4      1 -0.1643 147.1  0  0  1  1
## 5      1 -0.0027 147.7  0  0  1  1
## 6      1  0.2466 150.2  0  0  1  1
## 7      1  0.5562 151.7  0  0  1  1
## 8      1  0.7781 153.3  0  0  1  1
## 9      1  0.9945 155.8  0  0  1  1
## 10     2 -1.0000 136.9  0  0  1  1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
## Model function: Linear model
## Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   base<-psi[id,1]
##   slope<-psi[id,2]
##   f<-base+slope*x
##   return(f)
## }
## <bytecode: 0x5618eeb065c8>
## Nb of parameters: 2
##   parameter names: base slope
##   distribution:
##   Parameter Distribution Estimated
## [1,] base      log-normal Estimated
## [2,] slope     normal      Estimated
## Variance-covariance matrix:
##   base slope
## base      1      1
## slope     1      1
## Error model: constant , initial values: a.1=1
## No covariate in the model.
## Initial values
##   base slope
## Pop.CondInit 140      1
## -----
## ---- Key algorithm options ----
## -----
## Estimation of individual parameters (MAP)
## Estimation of standard errors and linearised log-likelihood
## Estimation of log-likelihood by importance sampling
## Number of iterations: K1=300, K2=100
## Number of chains: 2
## Seed: 201004
## Number of MCMC iterations for IS: 5000
## Simulations:
##   nb of simulated datasets used for npde: 1000
##   nb of simulated datasets used for VPC: 100
## Input/output
## save the results to a file: FALSE

```

```

##          save the graphs to files:  FALSE
## -----
## ----- Results -----
## -----
## ----- Fixed effects -----
## -----
##      Parameter Estimate SE      CV(%)
## [1,] base      149.16   1.563 1.0
## [2,] slope       6.51   0.331 5.1
## [3,] a.1         0.66   0.035 5.2
## -----
## ----- Variance of random effects -----
## -----
##      Parameter      Estimate SE      CV(%)
## base omega2.base    0.0029   0.00079 28
## slope omega2.slope  2.7361   0.79109 29
## covar cov.base.slope 0.0564   0.02087 37
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.base omega2.slope
## omega2.base  1.00      0.64
## omega2.slope 0.64      1.00
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 726.5422
##      AIC = 738.5422
##      BIC = 746.0908
##
## Likelihood computed by importance sampling
##      -2LL= 726.5619
##      AIC = 738.5619
##      BIC = 746.1105
## -----
ynpde<-npdeSaemix(saemix.fit)

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

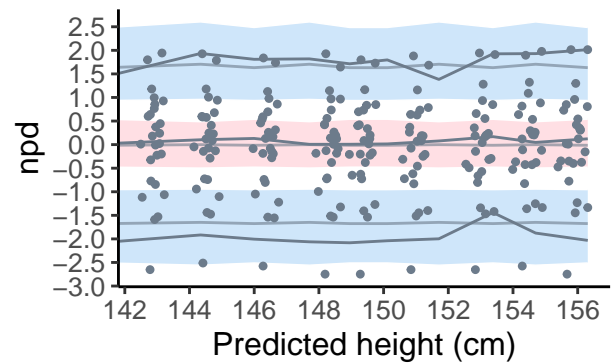
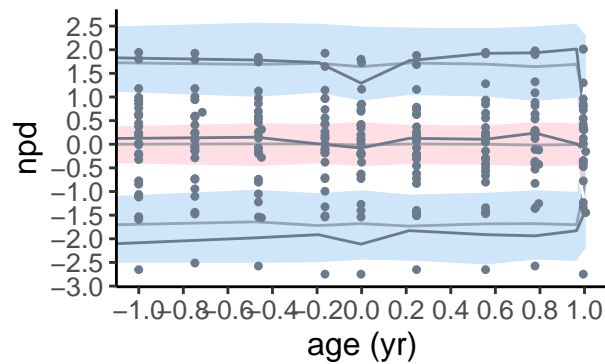
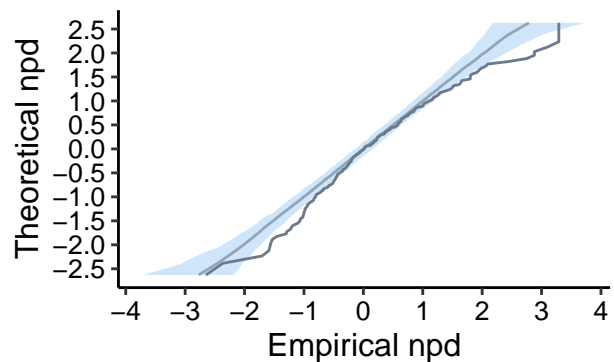
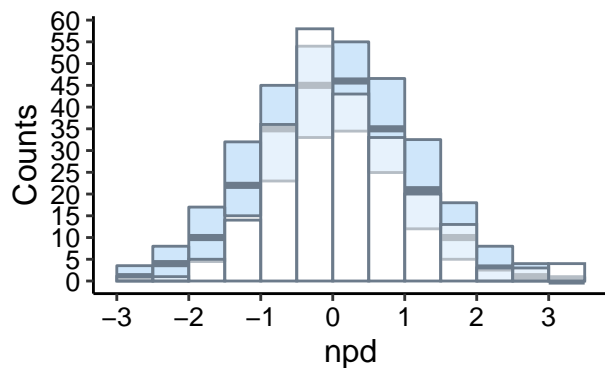
## Warning in read(x, dat, detect = detect, verbose = verbose): NAs introduits lors
## de la conversion automatique

## -----

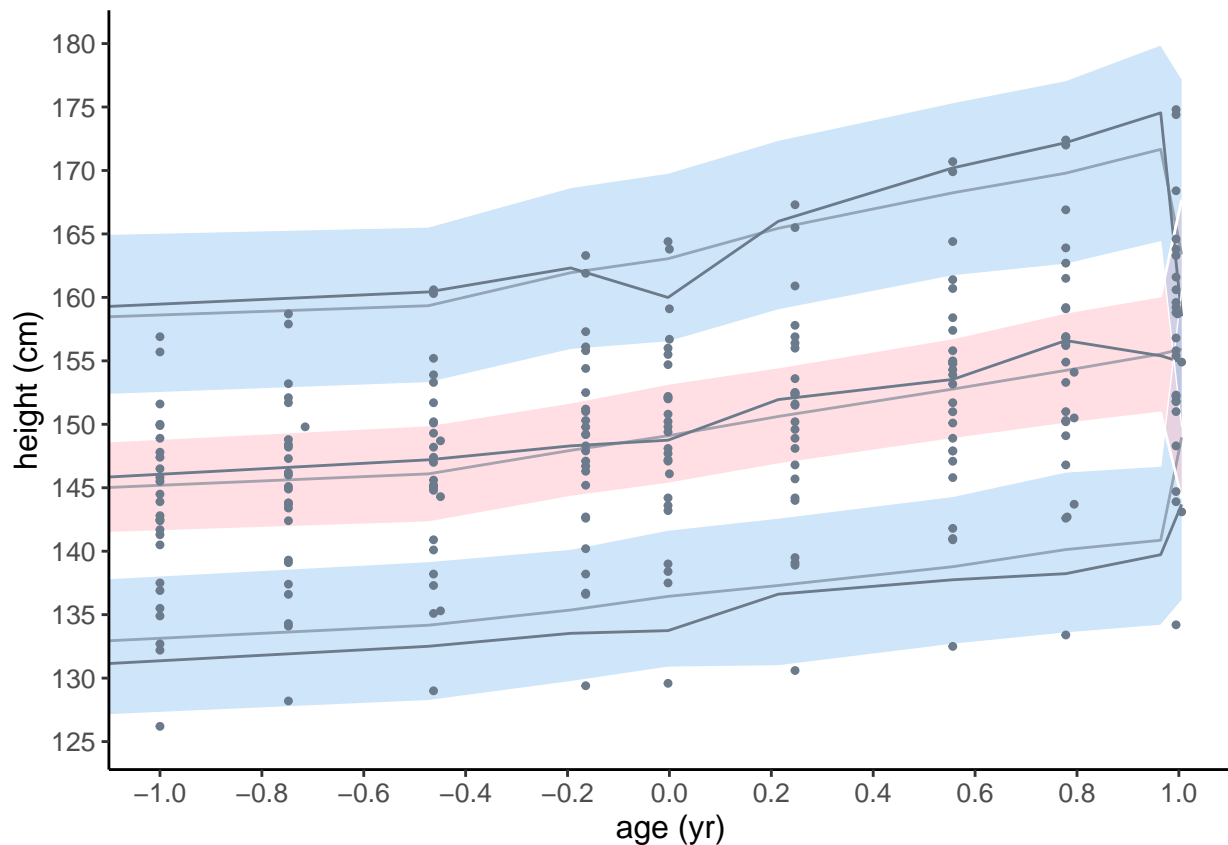
```



```
## Distribution of npde :
##      nb of obs: 234
##      mean= 0.1538   (SE= 0.066 )
##      variance= 1.014   (SE= 0.094 )
##      skewness= 0.6498
##      kurtosis= 0.8492
## -----
## Statistical tests (adjusted p-values):
## t-test      : 0.0609 .
## Fisher variance test : 1
## SW test of normality : 0.000177 ***
## Global test  : 0.000177 ***
## ---
## Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
## -----
```



```
plot(ynpde, plot.type="vpc")
```



Cow

```
if(testMode)
  data(cow.saemix) else
  cow.saemix<-read.table(file.path(datDir, "cow.saemix.tab"), header=TRUE)

saemix.data<-saemixData(name.data=cow.saemix,header=TRUE,name.group=c("cow"),
  name.predictors=c("time"),name.response=c("weight"),
  name.covariates=c("birthyear","twin","birthrank"),
  units=list(x="days",y="kg",covariates=c("yr","-","-")))
```

```
##
##
## The following SaemixData object was successfully created:
##
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset cow.saemix
##   Structured data: weight ~ time | cow
##   Predictor: time (days)
##   covariates: birthyear (yr), twin (-), birthrank (-)
##   reference class for covariate twin : 1
```

```
growthcow<-function(psi,id,xidep) {
  x<-xidep[,1]
  a<-psi[id,1]
```

```

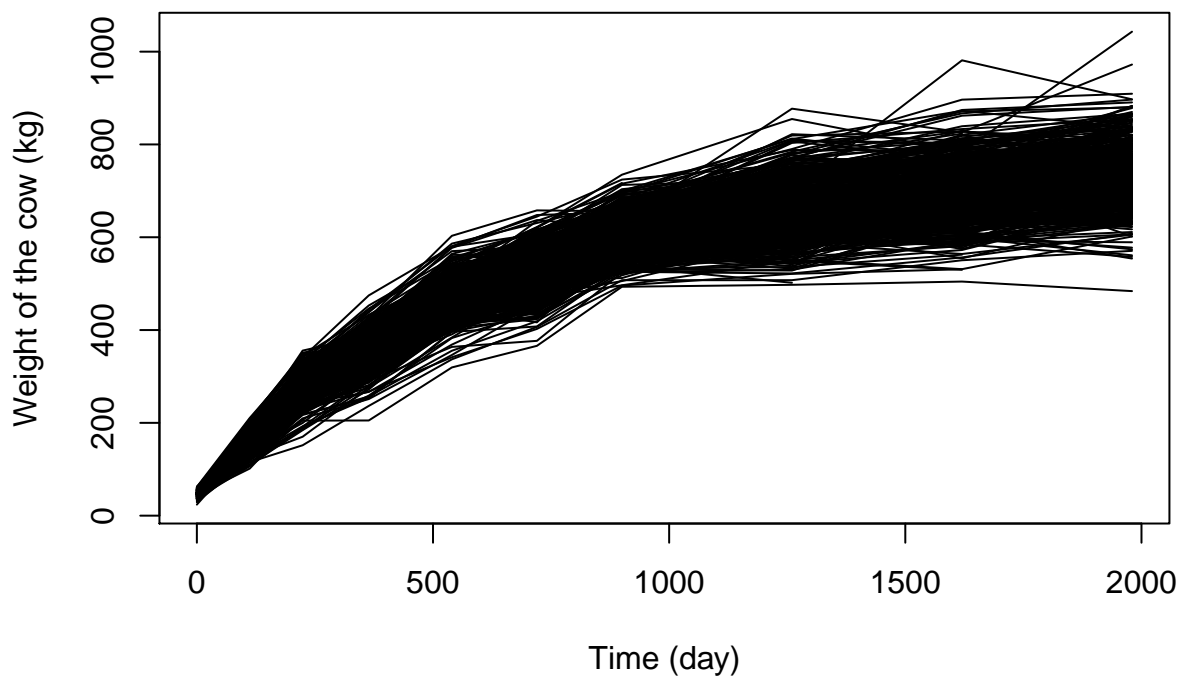
b<-psi[id,2]
k<-psi[id,3]
f<-a*(1-b*exp(-k*x))
return(f)
}
saemix.model<-saemixModel(model=growthcow,
  description="Exponential growth model",
  psi0=matrix(c(700,0.9,0.02,0,0,0),ncol=3,byrow=TRUE,
    dimnames=list(NULL,c("A","B","k"))),transform.par=c(1,1,1),fixed.estim=c(1,1,1),
  covariate.model=matrix(c(0,0,0),ncol=3,byrow=TRUE),
  covariance.model=matrix(c(1,0,0,0,1,0,0,0,1),ncol=3,byrow=TRUE),
  omega.init=matrix(c(1,0,0,0,1,0,0,0,1),ncol=3,byrow=TRUE),error.model="constant")

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
## Model function: Exponential growth model
## Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   a<-psi[id,1]
##   b<-psi[id,2]
##   k<-psi[id,3]
##   f<-a*(1-b*exp(-k*x))
##   return(f)
## }
## Nb of parameters: 3
##   parameter names:  A B k
##   distribution:
##   Parameter Distribution Estimated
## [1,] A          log-normal Estimated
## [2,] B          log-normal Estimated
## [3,] k          log-normal Estimated
## Variance-covariance matrix:
##   A B k
## A 1 0 0
## B 0 1 0
## k 0 0 1
## Error model: constant , initial values: a.1=1
## No covariate in the model.
## Initial values
##           A    B    k
## Pop.CondInit 700 0.9 0.02
## Cov.CondInit  0 0.0 0.00

saemix.options<-list(algorithms=c(1,1,1),nb.chains=1,nbiter.saemix=c(200,100),
  seed=4526,save=FALSE,save.graphs=FALSE, displayProgress=FALSE)

# Plotting the data
plot(saemix.data,xlab="Time (day)",ylab="Weight of the cow (kg)")

```



```
saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)
```

```
## Nonlinear mixed-effects model fit by the SAEM algorithm
```

```
## -----
```

```
## ---- Data ----
```

```
## -----
```

```
## Object of class SaemixData
```

```
## longitudinal data for use with the SAEM algorithm
```

```
## Dataset cow.saemix
```

```
## Structured data: weight ~ time | cow
```

```
## Predictor: time (days)
```

```
## covariates: birthyear (yr), twin (-), birthrank (-)
```

```
## reference class for covariate twin : 1
```

```
## Dataset characteristics:
```

```
## number of subjects: 560
```

```
## number of observations: 5455
```

```
## average/min/max nb obs: 9.74 / 7 / 10
```

```
## First 10 lines of data:
```

##	cow	time	weight	birthyear	twin	birthrank	mdv	cens	occ	ytype
## 1	1988005	0	44.0	1988	1	3	0	0	1	1
## 2	1988005	112	173.4	1988	1	3	0	0	1	1
## 3	1988005	224	292.8	1988	1	3	0	0	1	1
## 4	1988005	364	364.6	1988	1	3	0	0	1	1
## 5	1988005	540	490.4	1988	1	3	0	0	1	1
## 6	1988005	720	522.0	1988	1	3	0	0	1	1
## 7	1988005	900	601.1	1988	1	3	0	0	1	1
## 8	1988005	1260	698.1	1988	1	3	0	0	1	1
## 9	1988005	1620	657.7	1988	1	3	0	0	1	1
## 10	1988005	1980	776.7	1988	1	3	0	0	1	1

```
## -----
```

```

## -----      Model      -----
## -----
## Nonlinear mixed-effects model
##   Model function: Exponential growth model
##   Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   a<-psi[id,1]
##   b<-psi[id,2]
##   k<-psi[id,3]
##   f<-a*(1-b*exp(-k*x))
##   return(f)
## }
## <bytecode: 0x5618eb011fb0>
##   Nb of parameters: 3
##     parameter names:  A B k
##     distribution:
##     Parameter Distribution Estimated
## [1,] A      log-normal Estimated
## [2,] B      log-normal Estimated
## [3,] k      log-normal Estimated
##   Variance-covariance matrix:
##   A B k
## A 1 0 0
## B 0 1 0
## k 0 0 1
##   Error model: constant , initial values: a.1=1
##   No covariate in the model.
##   Initial values
##           A   B   k
## Pop.CondInit 700 0.9 0.02
## -----
## -----      Key algorithm options      -----
## -----
##   Estimation of individual parameters (MAP)
##   Estimation of standard errors and linearised log-likelihood
##   Estimation of log-likelihood by importance sampling
##   Number of iterations:  K1=200, K2=100
##   Number of chains:  1
##   Seed: 4526
##   Number of MCMC iterations for IS: 5000
##   Simulations:
##     nb of simulated datasets used for npde: 1000
##     nb of simulated datasets used for VPC: 100
##   Input/output
##     save the results to a file: FALSE
##     save the graphs to files: FALSE
## -----
## -----      Results      -----
## -----
## -----      Fixed effects      -----
## -----
##   Parameter Estimate SE      CV(%)
## [1,] A      7.5e+02 2.9e+00 0.38

```

```
## [2,] B          9.4e-01  1.2e-03 0.13
## [3,] k          1.6e-03  1.2e-05 0.72
## [4,] a.1        2.7e+01  3.0e-01 1.12
## -----
## ----- Variance of random effects -----
## -----
## Parameter Estimate SE      CV(%)
## A omega2.A  6.4e-03  4.4e-04   7.0
## B omega2.B  4.7e-05  5.2e-05 110.7
## k omega2.k  1.4e-02  1.4e-03   9.8
## -----
## ----- Correlation matrix of random effects -----
## -----
##          omega2.A omega2.B omega2.k
## omega2.A 1          0          0
## omega2.B 0          1          0
## omega2.k 0          0          1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 53732
##      AIC = 53746
##      BIC = 53776.29
##
## Likelihood computed by importance sampling
##      -2LL= 53731.51
##      AIC = 53745.51
##      BIC = 53775.8
## -----
```

Wheat yield

```
if(testMode)
  data(yield.saemix) else
  yield.saemix<-read.table(file.path(datDir, "yield.saemix.tab"), header=TRUE)
saemix.data<-saemixData(name.data=yield.saemix,header=TRUE,name.group=c("site"),
  name.predictors=c("dose"),name.response=c("yield"),
  name.covariates=c("soil.nitrogen"),units=list(x="kg/ha",y="t/ha",covariates=c("kg/ha")))

##
##
## The following SaemixData object was successfully created:
##
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset yield.saemix
##   Structured data: yield ~ dose | site
##   Predictor: dose (kg/ha)
##   covariates: soil.nitrogen (kg/ha)
# Model: linear + plateau
yield.LP<-function(psi,id,xidep) {
```

```

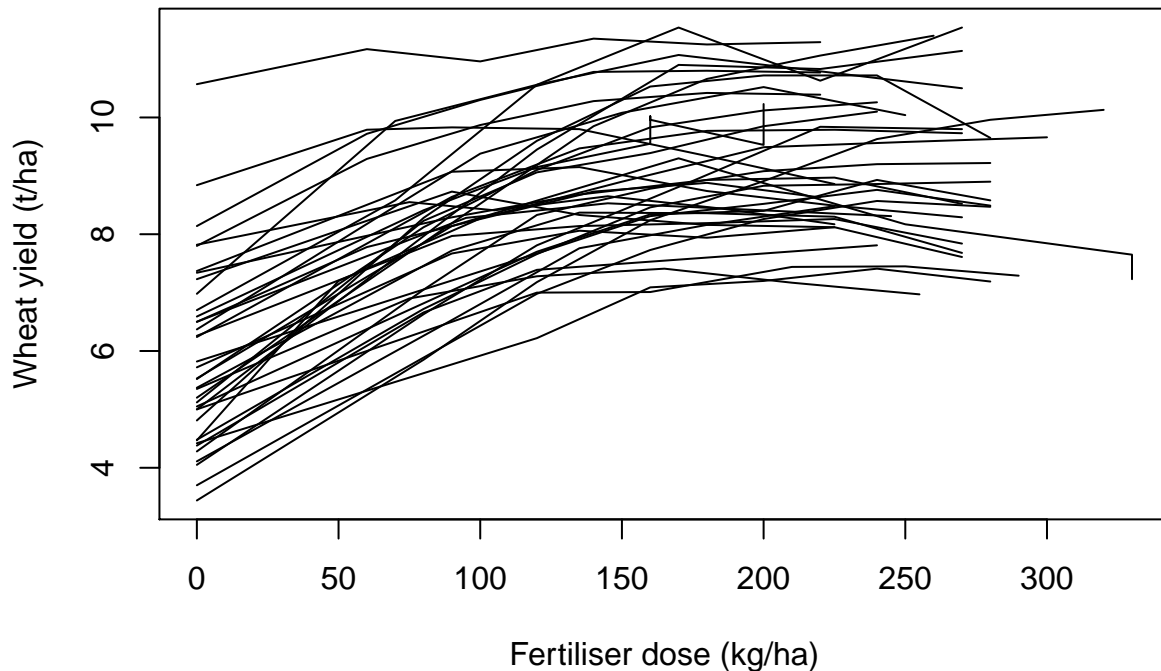
x<-xidep[,1]
ymax<-psi[id,1]
xmax<-psi[id,2]
slope<-psi[id,3]
f<-ymax+slope*(x-xmax)
#' cat(length(f)," ",length(ymax),"\\n")
f[x>xmax]<-ymax[x>xmax]
return(f)
}
saemix.model<-saemixModel(model=yield.LP,description="Linear plus plateau model",
  psi0=matrix(c(8,100,0.2,0,0,0),ncol=3,byrow=TRUE,dimnames=list(NULL,
    c("Ymax","Xmax","slope"))),covariate.model=matrix(c(0,0,0),ncol=3,byrow=TRUE),
  transform.par=c(0,0,0),covariance.model=matrix(c(1,0,0,0,1,0,0,0,1),ncol=3,
    byrow=TRUE),error.model="constant")

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
## Model function: Linear plus plateau model
## Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   ymax<-psi[id,1]
##   xmax<-psi[id,2]
##   slope<-psi[id,3]
##   f<-ymax+slope*(x-xmax)
##   #' cat(length(f)," ",length(ymax),"\\n")
##   f[x>xmax]<-ymax[x>xmax]
##   return(f)
## }
## Nb of parameters: 3
##   parameter names: Ymax Xmax slope
##   distribution:
##   Parameter Distribution Estimated
## [1,] Ymax      normal      Estimated
## [2,] Xmax      normal      Estimated
## [3,] slope     normal      Estimated
## Variance-covariance matrix:
##   Ymax Xmax slope
## Ymax   1    0    0
## Xmax   0    1    0
## slope  0    0    1
## Error model: constant , initial values: a.1=1
## No covariate in the model.
## Initial values
##   Ymax Xmax slope
## Pop.CondInit   8  100  0.2
## Cov.CondInit   0   0  0.0

saemix.options<-list(algorithms=c(1,1,1),nb.chains=1,seed=666,
  save=FALSE,save.graphs=FALSE, displayProgress=FALSE)

```

```
# Plotting the data
plot(saemix.data,xlab="Fertiliser dose (kg/ha)", ylab="Wheat yield (t/ha)")
```



```
saemix.fit<-saemix(saemix.model,saemix.data,saemix.options)
```

```
## The number of subjects is small, increasing the number of chains to 2 to improve convergence
## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
##      Data      ----
## -----
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset yield.saemix
##   Structured data: yield ~ dose | site
##   Predictor: dose (kg/ha)
##   covariates: soil.nitrogen (kg/ha)
## Dataset characteristics:
##   number of subjects:    37
##   number of observations: 224
##   average/min/max nb obs: 6.05 / 5 / 8
## First 10 lines of data:
##   site dose yield soil.nitrogen mdv cens occ ytype
## 145  931   0  5.12          105   0   0   1   1
## 146  931  80  8.23          105   0   0   1   1
## 147  931 120  9.06          105   0   0   1   1
## 148  931 160  9.39          105   0   0   1   1
## 149  931 200  9.85          105   0   0   1   1
## 150  931 240 10.10          105   0   0   1   1
## 151  932   0  4.47           88   0   0   1   1
## 152  932  50  7.20           88   0   0   1   1
```



```

## 153  932  100  8.27          88  0  0  1  1
## 154  932  150  8.90          88  0  0  1  1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
##   Model function:  Linear plus plateau model
##   Model type:  structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   ymax<-psi[id,1]
##   xmax<-psi[id,2]
##   slope<-psi[id,3]
##   f<-ymax+slope*(x-xmax)
##   #' cat(length(f)," ",length(ymax),"\\n")
##   f[x>xmax]<-ymax[x>xmax]
##   return(f)
## }
## <bytecode: 0x5618edaea5d0>
##   Nb of parameters: 3
##     parameter names:  Ymax Xmax slope
##     distribution:
##       Parameter Distribution Estimated
## [1,] Ymax      normal      Estimated
## [2,] Xmax      normal      Estimated
## [3,] slope     normal      Estimated
##   Variance-covariance matrix:
##     Ymax Xmax slope
## Ymax    1    0    0
## Xmax    0    1    0
## slope   0    0    1
##   Error model: constant , initial values: a.1=1
##   No covariate in the model.
##   Initial values
##           Ymax Xmax slope
## Pop.CondInit    8 100  0.2
## -----
## ----   Key algorithm options   ----
## -----
##   Estimation of individual parameters (MAP)
##   Estimation of standard errors and linearised log-likelihood
##   Estimation of log-likelihood by importance sampling
##   Number of iterations:  K1=300, K2=100
##   Number of chains:  2
##   Seed:  666
##   Number of MCMC iterations for IS:  5000
##   Simulations:
##     nb of simulated datasets used for npde:  1000
##     nb of simulated datasets used for VPC:  100
##   Input/output
##     save the results to a file:  FALSE
##     save the graphs to files:  FALSE
## -----
## ----          Results          ----

```

```

## ----- Fixed effects -----
## -----
##      Parameter Estimate SE      CV(%)
## [1,] Ymax      8.88   0.175  2.0
## [2,] Xmax     13.41   3.265 24.3
## [3,] slope      0.22   0.056 25.4
## [4,] a.1        0.70   0.040  5.8
## -----
## ----- Variance of random effects -----
## -----
##      Parameter      Estimate SE      CV(%)
## Ymax  omega2.Ymax  1.0335   0.2622   25
## Xmax  omega2.Xmax  0.0716  13.9406 19465
## slope omega2.slope 0.0067   0.0048   71
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.Ymax omega2.Xmax omega2.slope
## omega2.Ymax  1          0          0
## omega2.Xmax  0          1          0
## omega2.slope 0          0          1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##      -2LL= 616.5778
##      AIC = 630.5778
##      BIC = 641.8542
##
## Likelihood computed by importance sampling
##      -2LL= 616.4578
##      AIC = 630.4578
##      BIC = 641.7342
## -----
# Comparing the likelihoods obtained by linearisation and importance sampling
# to the likelihood obtained by Gaussian Quadrature
saemix.fit<-llgq.saemix(saemix.fit)
{
  cat("LL by Importance sampling, LL_IS=",saemix.fit["results"]["ll.is"],"\n")
  cat("LL by linearisation, LL_lin=",saemix.fit["results"]["ll.lin"],"\n")
  cat("LL by Gaussian Quadrature, LL_GQ=",saemix.fit["results"]["ll.gq"],"\n")
}

## LL by Importance sampling, LL_IS= -308.2289
## LL by linearisation, LL_lin= -308.2889
## LL by Gaussian Quadrature, LL_GQ= -308.3099
# Testing for an effect of covariate soil.nitrogen on Xmax
saemix.model2<-saemixModel(model=yield.LP,description="Linear plus plateau model",
  psi0=matrix(c(8,100,0.2,0,0,0),ncol=3,byrow=TRUE,dimnames=list(NULL,
    c("Ymax","Xmax","slope"))),covariate.model=matrix(c(0,1,0),ncol=3,byrow=TRUE),
  transform.par=c(0,0,0),covariance.model=matrix(c(1,0,0,0,1,0,0,0,1),ncol=3,
    byrow=TRUE),error.model="constant")

```

```

##
##
## The following SaemixModel object was successfully created:
##
## Nonlinear mixed-effects model
##   Model function: Linear plus plateau model
##   Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   ymax<-psi[id,1]
##   xmax<-psi[id,2]
##   slope<-psi[id,3]
##   f<-ymax+slope*(x-xmax)
##   #' cat(length(f)," ",length(ymax),"\\n")
##   f[x>xmax]<-ymax[x>xmax]
##   return(f)
## }
## <bytecode: 0x5618edaea5d0>
##   Nb of parameters: 3
##     parameter names: Ymax Xmax slope
##     distribution:
##       Parameter Distribution Estimated
## [1,] Ymax      normal      Estimated
## [2,] Xmax      normal      Estimated
## [3,] slope     normal      Estimated
##   Variance-covariance matrix:
##     Ymax Xmax slope
## Ymax    1    0    0
## Xmax    0    1    0
## slope   0    0    1
##   Error model: constant , initial values: a.1=1
##   Covariate model:
##     Ymax Xmax slope
## [1,]    0    1    0
##   Initial values
##     Ymax Xmax slope
## Pop.CondInit    8 100  0.2
## Cov.CondInit    0  0  0.0

saemix.fit2<-saemix(saemix.model2,saemix.data,saemix.options)

## The number of subjects is small, increasing the number of chains to 2 to improve convergence
## Nonlinear mixed-effects model fit by the SAEM algorithm
## -----
## ----          Data          ----
## -----
## Object of class SaemixData
##   longitudinal data for use with the SAEM algorithm
## Dataset yield.saemix
##   Structured data: yield ~ dose | site
##   Predictor: dose (kg/ha)
##   covariates: soil.nitrogen (kg/ha)
## Dataset characteristics:
##   number of subjects:      37
##   number of observations: 224

```

```

##      average/min/max nb obs: 6.05 / 5 / 8
## First 10 lines of data:
##      site dose yield soil.nitrogen mdv cens occ ytype
## 145 931    0 5.12          105  0    0  1    1
## 146 931    80 8.23          105  0    0  1    1
## 147 931   120 9.06          105  0    0  1    1
## 148 931   160 9.39          105  0    0  1    1
## 149 931   200 9.85          105  0    0  1    1
## 150 931   240 10.10         105  0    0  1    1
## 151 932    0 4.47           88  0    0  1    1
## 152 932    50 7.20           88  0    0  1    1
## 153 932   100 8.27           88  0    0  1    1
## 154 932   150 8.90           88  0    0  1    1
## -----
## ----          Model          ----
## -----
## Nonlinear mixed-effects model
## Model function: Linear plus plateau model
## Model type: structural
## function(psi,id,xidep) {
##   x<-xidep[,1]
##   ymax<-psi[id,1]
##   xmax<-psi[id,2]
##   slope<-psi[id,3]
##   f<-ymax+slope*(x-xmax)
##   #' cat(length(f)," ",length(ymax),"\\n")
##   f[x>xmax]<-ymax[x>xmax]
##   return(f)
## }
## <bytecode: 0x5618edaea5d0>
## Nb of parameters: 3
##      parameter names: Ymax Xmax slope
##      distribution:
##      Parameter Distribution Estimated
## [1,] Ymax      normal      Estimated
## [2,] Xmax      normal      Estimated
## [3,] slope     normal      Estimated
## Variance-covariance matrix:
##      Ymax Xmax slope
## Ymax    1    0    0
## Xmax    0    1    0
## slope   0    0    1
## Error model: constant , initial values: a.1=1
## Covariate model:
##      [,1] [,2] [,3]
## soil.nitrogen  0  1  0
## Initial values
##      Ymax Xmax slope
## Pop.CondInit   8 100  0.2
## Cov.CondInit   0  0  0.0
## -----
## ---- Key algorithm options ----
## -----
## Estimation of individual parameters (MAP)

```

```

## Estimation of standard errors and linearised log-likelihood
## Estimation of log-likelihood by importance sampling
## Number of iterations: K1=300, K2=100
## Number of chains: 2
## Seed: 666
## Number of MCMC iterations for IS: 5000
## Simulations:
##     nb of simulated datasets used for npde: 1000
##     nb of simulated datasets used for VPC: 100
## Input/output
##     save the results to a file: FALSE
##     save the graphs to files: FALSE
## -----
## ----                      Results                      ----
## -----
## ----- Fixed effects -----
## -----
##      Parameter          Estimate SE      CV(%) p-value
## [1,] Ymax                9.179  0.1908  2.1  -
## [2,] Xmax               217.787 15.6758  7.2  -
## [3,] beta_soil.nitrogen(Xmax) -1.104  0.1712 15.5 5.7e-11
## [4,] slope                0.026  0.0013  4.8  -
## [5,] a.1                  0.303  0.0193  6.4  -
## -----
## ----- Variance of random effects -----
## -----
##      Parameter      Estimate SE      CV(%)
## Ymax omega2.Ymax 1.3e+00 3.1e-01 24
## Xmax omega2.Xmax 1.0e+03 2.9e+02 28
## slope omega2.slope 3.2e-05 1.2e-05 37
## -----
## ----- Correlation matrix of random effects -----
## -----
##      omega2.Ymax omega2.Xmax omega2.slope
## omega2.Ymax 1          0          0
## omega2.Xmax 0          1          0
## omega2.slope 0          0          1
## -----
## ----- Statistical criteria -----
## -----
## Likelihood computed by linearisation
##     -2LL= 388.7811
##     AIC = 404.7811
##     BIC = 417.6684
##
## Likelihood computed by importance sampling
##     -2LL= 380.854
##     AIC = 396.854
##     BIC = 409.7413
## -----

```

```

# BIC for the two models
{
  cat("Model without covariate, BIC=",saemix.fit["results"]["bic.is"],"\n")
}

```

```

cat("Model with covariate, BIC=",saemix.fit2["results"]["bic.is"],"\n")
pval<-1-pchisq(-2*saemix.fit["results"]["ll.is")+2*saemix.fit2["results"]["ll.is"],1)
cat("          LRT: p=",pval,"\n")
}

```

```

## Model without covariate, BIC= 641.7342
## Model with covariate, BIC= 409.7413
##          LRT: p= 0

```

Exiting

```

if(testMode) {
  dev_mode()
}

```

```

## v Dev mode: OFF

```