

Package ‘EnviroPRA2’

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Description It contains functions for dose calculation for different routes, fitting data to probability distributions, random number generation (Monte Carlo simulation) and calculation of systemic and carcinogenic risks. For more information see the publication: Barrio-Parra et al. (2019) ``Human-health probabilistic risk assessment: the role of exposure factors in an urban garden scenario" <[doi:10.1016/j.landurbplan.2019.02.005](https://doi.org/10.1016/j.landurbplan.2019.02.005)>.

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EnviroPRA2-package *Environmental Probabilistic Risk Assessment Tools*

Description

A collection of functions employed in environmental risk assessment to model exposure to a toxicant and predicting health effects, allowing to characterize variability and uncertainty in risk estimations

Details

A set of tools to perform a deterministic and probabilistic risk assessment.

Author(s)

F.Barrio-Parra

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Examples

```
#### Performs Deterministic Environmental Risk Assessment ####
# Example of dermal contact with a chemical in swimming water
# Estimate the dermal absorbed dose during swimming in waters with a carcinogenic chemical
# (water concentration of 250 mg/m^3)
DWIR ( CW = 250)
```



```

I = DWIR ( CW=250, IR=IRr, EF = EFr, ED = 24, BW = 85)

# Risk Estimation

Risk <- RISKdermal (AD = I, SF = SFAs, GI = GIAs)

hist (Risk)

quantile (Risk, c (0.05, 0.25, 0.5, 0.75, 0.95))

```

AD

*Dermal contact with chemicals in soil***Description**

Estimates the Absorbed dose [mg/Kg*day] of chemicals through dermal contact with a soil

Usage

AD(CS = 1, SA = 2800, AF = 0.2, ABS = 0.001, EF = 350, ED = 24, BW = 70, AT = 365 * 70)

Arguments

CS	Chemical concentration in soil [mg/Kg]
SA	Skin surface area available for contact [cm ²]
AF	Skin adherence factor [mg/cm ²]
ABS	Absorption factor (Chemical specific) [-]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical Absorbed dose [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

```
## Estimated absorbed dose for the estimation of carcinogenic effects using
# the default variables (EPA 2011) for a chemical soil concentration of
# 0.2 mg/Kg

AD( CS=0.2)

# For a systemic effect:

AD( CS=0.2, AT=24*365)

# Specifying all the parameters for the carcinogenic case

AD( CS=0.2, SA=2300, AF=0.25, ABS=0.01, EF=150, ED=10, BW=80)
```

ADboot

*Dermal contact with chemicals in soil by bootstrap***Description**

Dermal contact with chemicals in soil by bootstrap

Usage

ADboot(n, CS, SA, AF, ABS, EF, ED, BW, AT)

Arguments

n	Output vector length
CS	Chemical concentration in soil [mg/Kg]
SA	Skin surface area available for contact [cm ²]
AF	Skin adherence factor [mg/cm ²]
ABS	Absorption factor (Chemical specific) [-]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical Absorbed dose [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Carcinogenic effects

c <- rnorm( n= 10, mean = 0.2, sd = 0.05 )

b <- rnorm( n= 100, mean = 20, sd = 5 )

ADboot (n = 1000, SA=2300, AF=0.25, ABS=0.01,CS = c, BW = b, ED = 10, EF = 250)
```

AIR

*Inhalation of airborne chemicals***Description**

Estimates the Intake rate by inhalation of airborne chemicals (vapor phase) [mg/Kg*day]

Usage

```
AIR(CA = 1, IR = 20, ET = 24, EF = 350, ED = 24, BW = 70, AT = 365 * 70)
```

Arguments

CA	Chemical concentration in air [mg/m ³]
IR	Inhalation Rate [m ³ /hour]
ET	Exposure time [hours/day]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Intake rate by inhalation of airborne chemicals (vapor phase) I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

```

## Estimated absorbed dose for the estimation of carcinogenic effects using
# the default variables (EPA 2011) for a chemical air concentration
# of 0.2 mg/m^3

AIR ( CA=0.2)

# For a systemic effect:

AIR ( CA=0.2, AT=24*365)

# Specifying all the parameters for the carcinogenic case

AIR ( CA=0.2, IR=25, ET = 24, EF = 300, ED = 24, BW = 85)

```

AIRboot

Inhalation of airborne chemicals by bootstrap

Description

Estimates the Intake rate by inhalation of airborne chemicals (vapor phase) [mg/Kg*day]

Usage

AIRboot(n, CA, IR, ET, EF, ED, BW, AT)

Arguments

n	Output vector length
CA	Chemical concentration in air [mg/m ³]
IR	Inhalation Rate [m ³ /hour]
ET	Exposure time [hours/day]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Intake rate by inhalation of airborne chemicals (vapor phase) I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Carcinogenic effects  
c <- rnorm( n= 10, mean = 0.2, sd = 0.05 )  
b <- rnorm( n= 100, mean = 20, sd = 5 )  
AIRboot (n = 1000, CA=c, IR=25, ET = 24, EF = 300, ED = 24, BW = b)
```

condition	<i>p-value significance checking function</i>
-----------	---

Description

Auxiliar function to check p-value significance (Function created for internal use of the model).

Usage

```
condition(n)
```

Arguments

n	p-value
---	---------

Value

Return "Significant" or "Not-significant" - Object class "character"

Examples

```
condition ( 0.001)  
condition (0.1)
```

DWIR	<i>Chemical intake by Drinking Water</i>
------	--

Description

Estimates the chemical Intake rate by Drinking Water [mg/Kg*day]

Usage

```
DWIR(CW = 1, IRW = 2, EF = 350, ED = 24, BW = 80, AT = 365 * 70)
```

Arguments

CW	Chemical concentration in water [mg/L]
IRW	Water Ingestion Rate [L/Day]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical intake rate by drinking water I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

```
# Estimate the dermal absorbed dose during swimming in waters with a carcinogenic chemical
# (water concentration of 250 mg/m^3)
```

```
DWIR ( CW = 250)
```

```
# For a systemic effect:
```

```
DWIR ( CW= 250, AT=24*365)
```

```
# Specifying all the parameters for the carcinogenic case
```

```
DWIR ( CW=250, IR=1.5, EF = 300, ED = 24, BW = 85)
```

DWIRboot

Chemical intake by Drinking Water by bootstrap

Description

Estimates the chemical Intake rate by Drinking Water [mg/Kg*day]

Usage

```
DWIRboot(n, CW, IRW, EF, BW, ED, AT)
```

Arguments

n	Output vector length
CW	Chemical concentration in water [mg/L]
IRW	Water Ingestion Rate [L/Day]
EF	Exposure frequency [day/yr]
BW	Body weight [Kg]
ED	Exposure duration [yr]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical intake rate by drinking water I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Carcinogenic effects

c <- rnorm( n= 10, mean = 250, sd = 15 )

b <- rnorm( n= 100, mean = 20, sd = 5 )

DWIRboot (n = 1000, CW=c, IR=1.5, EF = 300, ED = 24, BW = b)
```

extr_par	<i>Extracts the fitted distribution parameters to be introduced in other function</i>
----------	---

Description

Auxiliar function for internal use only

Usage

```
extr_par(x, dist)
```

Arguments

x	List of parameters obtained by the application of the Fit_dist_parameter function
dist	Name of the distribution we would like to stract the parameters ("norm", "lnorm", "geom", "exp", "pois", "gamma", "cauchy", "logis", "weibull", "nbinom", "beta", "chisq", "t", "f")

Value

A list of fitted parameters.

Author(s)

F. Barrio-Parra

Examples

```
a <- rnorm(n=100, mean =10, sd = 1)
b <- Fit_dist_parameter(a)
extr_par(x = b, dist ="norm")
```

Fit_dist_parameter *Returns adjusted distribution parameters*

Description

Returns the distribution parameters adjusted for by maximum likelihood (mle) for the following distributions: "normal", "log-normal", "geometric", "exponential", "Poisson", "cauchy" , "logistic" and "weibull"

Usage

```
Fit_dist_parameter(x)
```

Arguments

x A numeric vector of length at least one containing only finite values (non-censored data)

Value

normal	Fitted Mean and sd for a normal distribution
'log-normal'	Fitted Meanlog and sdlog for a log-normal distribution
geometric	Fitted prob for a geometric distribution
exponential	Fitted rate for a exponential distribution
Poisson	Fitted lambda for a exponential distribution
cauchy	Fitted location and scale for a Cauchy distribution
logistic	Fitted location and scale for a Logistic distribution
weibull	Fitted shape and scale for a weibull distribution

Author(s)

F. Barrio-Parra

See Also

Function fitdistr in Library (MASS)

Examples

```
a <- rnorm(n=100, mean =10, sd = 1)
b <- Fit_dist_parameter(a)
# Examples of result extraction
b$normal
b$weibull
```

fit_dist_test

Summary of Godness-of-fit tests

Description

Returns a data frame with the summary of Fiting distribution tests for the following distributions: "normal","log-normal","geometric","exponential","Poisson", "cauchy" , "logistic" and "weibull".

The considered Godness-of-fit tests are: Bayesian Information Criterium (BIC), Akaike Information Criterium (AIC), Kolmogorov-Smirnov test and Anderson-Darling test.

Usage

```
fit_dist_test(x)
```

Arguments

x A numeric vector of length at least one containing only finite values

Value

Distribution	Name of the tested distribution
BayesianIC	Bayesian Information Criterium (BIC)
AkaikeIC	Akaike Information Criterium (AIC)
Kol-SmirD	The value of the Kolmogorov-Smirnov test statistic
Kol-SmirPvalue	The value of the Kolmogorov-Smirnov test p-value
Significance KS	A column to check the significance of the Kolmogorov-Smirnov test

And-Dar1	The value of the Anderson-Darling test statistic
And-Dar1Pvalue	The value of the Anderson-Darling test p-value
Significance AD	A column to check the significance of the Anderson-Darling test

Author(s)

F. Barrio-Parra

See Also

ad.test library(kSamples), AIC library(stats), BIC library(stats), ks.test library(stats),

Examples

```
set.seed(123)

a <- rnorm(n=100, mean =10, sd = 1)

fit_dist_test(a)

b<- rexp(n = 100,rate = 1)

fit_dist_test(b)
```

HI	<i>Hazard Index</i>
----	---------------------

Description

Returns the Hazard Index (non carcinogenic effects)

Usage

HI(I, RFD)

Arguments

I	Intake Rate [mg/Kg*day]
RFD	Reference dose [mg/Kg*day]

Value

Hazard Index [-] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Assessing if there is systemic risk for an adult receptor that drinks water with 1000 ug/L
# of hexachlorobence (Reference Dose (IRIS data base) = 8e-04 [mg/Kg*day]) in a residential
# scenario (default EPA Maximum Reasonable Exposure parameters)
```

```
HI (I = DWIR( CW=1, AT=24*365), RFD = 8e-04)
```

HI_{dermal}
Hazard Index for dermal contact

Description

Returns the Hazard Index for dermal exposure with chemicals (non carcinogenic effects)

Usage

```
HIdermal(AD, RFD, GI)
```

Arguments

AD	Absorbed dose [mg/Kg*day]
RFD	Reference dose [mg/Kg*day]
GI	Gastrointestinal Absorption factor (chemical specific) [-]

Value

Hazard Index [-] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Assess if there is non-carcinogenic risk for an adult through dermal
# contact exposed to a soil that contains 45 mg/Kg of As in a residential
# scenario (default EPA Maximum Reasonable Exposure parameters)
```

```
RfDAs = 3e-04
```

```
# Dermal Absorption Factor
```

```
ABSAs = 3e-02
```

```
# Gastrointestinal Absorption Factor
```

```
GIAs = 1
```

$I = AD$ (CS = 45, ABS = ABSAs, AT= 24*365)

HI_{dermal} (AD = I, RFD = RfDAs, GI = GIAs)

HIinhal

Hazard Index for inhalation of vapors

Description

Returns the Hazard Index (systemic effects) for inhalation of vapors

Usage

HIinhal(INH, RFC)

Arguments

INH	Inhaled dose (mg/m ³)
RFC	Reference concentration (mg/m ³)

Value

Hazard Index (non carcinogenic effects) [-] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Assess if there is systemic risk for the exposure of an adult
# (Reasonable Maximum Exposure) to a Toluene air concentration of 2 mg/ m3
```

```
HIinhal (INH = AIR (CA = 2, AT = 365*24), RFC = 5)
```

 INH

Inhalation of resuspended soil particles

Description

Estimates the Intake rate of chemicals by inhalation of resuspended soil particles [mg/Kg*day]

Usage

INH(C = 10, EF = 350, ED = 24, PEF = 1.36⁹, AT = 365 * ED)

Arguments

C	Concentration of chemicals in soil(mg/kg)
EF	Exposure frequency (day/year)
ED	Exposure duration (years)
PEF	Particle emission factor meaning resuspended particles(m ³ /kg)
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical intake rate by inhalation of soil particles I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

```
# Estimated dose for the estimation of carcinogenic effects due to the
# inhalation of soil particles that contains 45 mg/Kg of As in a residential
# scenario (default EPA Maximum Reasonable Exposure parameters)
```

```
INH(C= 45, AT = 365*70)
```

```
# For non-carcinogenic effects:
```

```
INH(C= 45)
```

plot_fit_dist	<i>Graphical representation of data fitting to a distribution</i>
---------------	---

Description

A function to help assessing the distribution that best fit a data vector

Usage

```
plot_fit_dist(x, dist)
```

Arguments

x	A numeric vector of length at least one containing only finite values (values must be ≥ 0)
dist	Character vector indicating the distribution to be plotted: "norm", "lnorm", "geom", "exp", "pois", "cauchy", "logis", "weibull"

Value

Returns: Empirical and theoretical density plots, Empirical and theoretical CDFs, Q-Q plot, P-P plot

Author(s)

F. Barrio-Parra

See Also

plotdist from Library (fitdstrplus)

Examples

```
set.seed(123)
a <- rnorm(n = 100, mean = 10, sd = 1)
plot_fit_dist(a, "norm")
```

random_number_generator

Random number generator

Description

Return a vector of n random numbers following a truncated distribution (dist) in agreement with a fitted parameters "Fited"

Usage

```
random_number_generator(n, Fited, dist, a, b)
```

Arguments

n	The number of desired generated numbers
Fited	A list containing the parameters obtained by application of Fit_dist_parameter
dist	Character vector indicating the distribution to be applied: "norm", "lnorm", "geom", "exp", "pois", "cauchy", "logis", "weibull"
a	Truncation Lower limit
b	Truncation Upper limit

Value

A vector of n random numbers - Object class "numeric"

Author(s)

F. Barrio-Parra

See Also

Fit_dist_parameter

Examples

```
set.seed(123)
a <- rnorm(n = 100, mean = 10, sd = 1)
Fit <- Fit_dist_parameter(a)

b <- random_number_generator(n = 10000, Fited = Fit,
                             dist = "norm", a = 8, b = 12)

hist(a, xlim = c(7, 14))
hist(b, xlim = c(7, 14))
```

RISK

Risk

Description

Returns the Risk estimation (carcinogenic effects)

Usage

RISK(I, SF)

Arguments

I	Intake Rate [mg/Kg*day]
SF	Slope Factor [(mg/Kg*day) ⁻¹] (chemical specific)

Value

Risk [-] - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
# Assessing if there is carcinogenic risk for an adult receptor that drinks water with 1000 ug/L
# of hexachlorobence (Oral Slope Factor (IRIS data base) = 1.6 [mg/Kg*day]-1) in a residential
# scenario (default EPA Maximum Reasonable Exposure parameters)
```

```
RISK (I = DWIR( CW=1), SF = 1.6)
```

RISKdermal

Risk for dermal contact

Description

Returns the Risk for dermal exposure with chemicals (carcinogenic effects)

Usage

RISKdermal(AD, SF, GI)

Arguments

AD	Absorbed dose [mg/Kg*day]
SF	Slope Factor [(mg/Kg*day) ⁻¹] (chemical specific)
GI	Gastrointestinal Absorption factor (chemical specific) [-]

Value

Risk [-] - Object class "numeric"

Author(s)

F. Barrio-Parra

See Also

AD

Examples

```
# Assess if there is carcinogenic risk for an adult thorough dermal
# contact exposed to a soil that contains 45 mg/Kg of As in a residential
# scenario (default EPA Maximum Reasonable Exposure parameters)

SFAs = 1.5

# Dermal Absorption Factor

ABSAs = 3e-02

# Gastrointestinal Absorption Factor

GIAs = 1

I = AD (CS = 45, ABS = ABSAs)

RISKdermal (AD = I, SF = SFAs, GI = GIAs)
```

RISKInhal

Risk for inhalation of vapors

Description

Returns the risk (carcinogenic effects) for inhalation of vapors

Usage

RISKInhal(URi, I)

Arguments

URi Inhalation Unit risk [(ug/m³)⁻¹]
 I Inhaled dose (mg/m³)

Value

Risk [-] - Object class "numeric"

Examples

```
# Assess if there is cancer risk for the exposure of an adult
# (Reasonable Maximum Exposure) to a benzene air concentration of 2 mg/ m^3

RISKInhal ( I = AIR (CA = 2), URi = 7.8e-06)
```

sampler *Execute sampling with replacement*

Description

Auxiliar function (employed only for internal use)

Usage

```
sampler(n, a)
```

Arguments

n Number of sampling iterations
 a data vector

Value

Resampled vector of length n - Object class "numeric"

Author(s)

F. Barrio-Parra

Examples

```
a <- rnorm (n = 20, mean = 0, sd = 1)
b <- sampler (n = 100, a = a)
```


Value

Chemical intake rate by soil ingestion I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

Ingestion rate for a children weighing 20 Kg who ingest 200 mg
of soil every day, 250 days per year during 10 years. 95-UCL of
Arsenic in soil is 25 mg/Kg

Carcinogenic effects

SIR (CS = 25, BW = 20, IR = 200, ED = 10, EF = 250)

Systemic effects

SIR (CS = 25, BW = 20, IR = 200, ED = 10, EF = 250, AT = 365*10)

SIRboot

Chemical intake by accidental soil ingestion by bootstrap

Description

Estimates the chemical Intake rate by accidental soil ingestion [mg/Kg*day]

Usage

SIRboot(n, CS, IR, FI, EF, ED, BW, AT)

Arguments

n	Output vector length
CS	Chemical concentrtrion in soil [mg/Kg]
IR	Soil Ingestion Rate [mg/Day]
FI	Fraction ingested from contaminated source [-]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight [Kg]
AT	Averaging time [day] (Note that for No carcinogenic effects AT should be equal to 365*ED)

Value

Chemical intake rate by soil ingestion I [mg/Kg*day] - Object class "numeric"

Examples

```
# Carcinogenic effects
c <- rnorm( n= 10, mean = 22, sd = 2 )
b <- rnorm( n= 100, mean = 20, sd = 5 )
SIRboot (n = 1000, CS = c, BW = b, IR = 200, ED = 10, EF = 250)
```

 VI

Chemical intake by ingestion of vegetables

Description

Estimates the chemical Intake rate by ingestion of contaminated fruits and vegetables [mg/Kg*day]

Usage

VI(CF = 1, IR = 210, FI = 1, EF = 350, ED = 24, BW = 80, AT = 365 * 70)

Arguments

CF	Chemical concentration in food [mg/Kg]
IR	Vegetables Ingestion Rate [g / Kg * Day]
FI	Fraction ingested from contaminated source [-]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body weight (kg)
AT	Averaging time [day] (For No carcinogenic effects AT = 365*ED)

Value

Chemical intake rate by vegetable ingestion I [mg/Kg*day] - Object class "numeric"

Author(s)

F. Barrio-Parra

References

US Environmental Protection Agency, 2011. Exposure Factors Handbook: 2011 Edition. U.S. Environmental Protection Agency, EPA/600/R-(September), pp 1466.

Examples

```
# Assess the chemical intake by an adult that eats lettuce with a concentration of 2 mg/ Kg
# in a maximum reasonable exposure scenario for non- carcinogenic effects
```

```
VI (CF = 2, AT = 365*24)
```

 VIboot

Chemical intake by ingestion of vegetables by bootstrap

Description

Estimates the chemical Intake rate by ingestion of contaminated fruits and vegetables [mg/Kg*day]

Usage

```
VIboot( n, CF, IR, FI, EF, ED, BW, AT)
```

Arguments

n	Output vector length
CF	Chemical concentration in food [mg/Kg]
IR	Vegetables Ingestion Rate [g / Kg * Day]
FI	Fraction ingested from contaminated source [-]
EF	Exposure frequency [day/yr]
ED	Exposure duration [yr]
BW	Body Weight [Kg]
AT	Averaging time [day] (For No carcinogenic effects AT = 365*ED)

Value

A vector of Chemical intake rate by vegetable ingestion I [mg/Kg*day] - Object class "numeric"

Examples

```
# Assess the chemical intake by an adult that eats lettuce with a concentration of 2 mg/ Kg of a
# chemical with non- carcinogenic effects in a maximum reasonable exposure scenario
# Figure out 10 data of Chemical concentration following a normal distribution (mean = 2, sd= 2)
# and 100 Body weight data that follow a normal distribution (mean = 70, sd = 15)
```

```
c <- rnorm( n= 10, mean = 2, sd = 2 )
```

```
b <- rnorm( n= 100, mean = 70, sd = 5 )
```

```
VIboot (n = 1000, CF = c, BW = b, AT = 365*24)
```

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