

# Package ‘meteorits’

August 27, 2019

**Type** Package

**Title** Mixtures-of-Experts Modeling for Complex and Non-Normal Distributions ('MEteorits')

**Version** 0.1.0

**Description** Provides several original and flexible mixtures-of-experts models to model, cluster and classify heterogeneous data in many complex situations where the data are distributed according to non-normal, possibly skewed distributions, and when they might be corrupted by atypical observations. Mixtures-of-Experts Models for Complex and Non-Normal Distributions ('MEteorits') are originally introduced and written in 'Matlab' by Faicel Chamroukhi. The references are mainly the following ones.

Chamroukhi F., Same A., Govaert, G. and Aknin P. (2009) <doi:10.1016/j.neunet.2009.06.040>.

Chamroukhi F. (2010) <<https://chamroukhi.com/FChamroukhi-PhD.pdf>>.

Chamroukhi F. (2015) <arXiv:1506.06707>.

Chamroukhi F. (2015) <<https://chamroukhi.com/FChamroukhi-HDR.pdf>>.

Chamroukhi F. (2016) <doi:10.1109/IJCNN.2016.7727580>.

Chamroukhi F. (2016) <doi:10.1016/j.neunet.2016.03.002>.

Chamroukhi F. (2017) <doi:10.1016/j.neucom.2017.05.044>.

**URL** <https://github.com/fchamroukhi/MEteorits>

**BugReports** <https://github.com/fchamroukhi/MEteorits/issues>

**License** GPL (>= 3)

**Depends** R (>= 2.10)

**Imports** pracom,  
methods,  
stats,  
MASS,  
Rcpp

**Suggests** knitr,  
rmarkdown

**LinkingTo** Rcpp,  
RcppArmadillo

**Collate** meteorits-package.R  
RcppExports.R  
logsumexp.R  
utils.R  
sampleUnivNMoE.R

sampleUnivSNMoE.R  
 sampleUnivSTMoE.R  
 sampleUnivTMoE.R  
 ParamSNMoE.R  
 ParamStMoE.R  
 ParamTMoE.R  
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 StatStMoE.R  
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 ModelSNMoE.R  
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 ModelNMoE.R  
 emSNMoE.R  
 emStMoE.R  
 emTMoE.R  
 emNMoE.R  
 data-tempanomalies.R

**VignetteBuilder** knitr

**Encoding** UTF-8

**LazyData** true

**Roxygen** list(markdown = TRUE)

**RoxygenNote** 6.1.1

## R topics documented:

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| meteorits-package | <i>MEteorits: Mixtures-of-ExperTs modEling for cOmplex and non-normal dIsTributions</i> |
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**Description**

meteorits is a package containing several original and flexible mixtures-of-experts models to model, cluster and classify heterogeneous data in many complex situations where the data are distributed according to non-normal and possibly skewed distributions, and when they might be corrupted by atypical observations. The toolbox also contains sparse mixture-of-experts models for high-dimensional data.

meteorits contains the following Mixture-of-Experts models:

- NMoE provides a flexible framework for heterogeneous data with Normal expert regressors network;
- SNMoE provides a flexible modeling framework for heterogeneous data with possibly skewed distributions to generalize the standard Normal mixture of expert model;
- TMoE provides a flexible and robust modeling framework for heterogeneous data with possibly heavy-tailed distributions and corrupted by atypical observations;
- StMoE provides a flexible and robust modeling framework for heterogeneous data with possibly skewed, heavy-tailed distributions and corrupted by atypical observations.

For the advantages/differences of each of them, the user is referred to our mentioned paper references.

To learn more about meteorits, start with the vignettes: `browseVignettes(package = "meteorits")`

**Author(s)**

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- Marius Bartcus <marius.bartcus@gmail.com> (R port) [translator]

**References**

Chamroukhi, F. 2017. *Skew-T Mixture of Experts*. Neurocomputing - Elsevier 266: 390–408. <https://chamroukhi.com/papers/STMoE.pdf>.

Chamroukhi, F. 2016a. *Robust Mixture of Experts Modeling Using the T-Distribution*. Neural Networks - Elsevier 79: 20–36. <https://chamroukhi.com/papers/TMoE.pdf>.

Chamroukhi, F. 2016b. *Skew-Normal Mixture of Experts*. In The International Joint Conference on Neural Networks (IJCNN). Vancouver, Canada. <https://chamroukhi.com/papers/Chamroukhi-SNMoE-IJCNN2016.pdf>.

Chamroukhi, F. 2015a. *Non-Normal Mixtures of Experts*. <http://arxiv.org/pdf/1506.06707.pdf>.

Chamroukhi, F. 2015b. *Statistical Learning of Latent Data Models for Complex Data Analysis*. Habilitation Thesis (HDR), Universite de Toulon. <https://chamroukhi.com/FChamroukhi-HDR.pdf>.

Chamroukhi, F. 2010. *Hidden Process Regression for Curve Modeling, Classification and Tracking*. Ph.D. Thesis, Université de Technologie de Compiègne. <https://chamroukhi.com/FChamroukhi-PhD.pdf>.

Chamroukhi, F., A. Same, G. Govaert, and P. Aknin. 2009. *Time Series Modeling by a Regression Approach Based on a Latent Process*. *Neural Networks* 22 (5-6): 593–602. [https://chamroukhi.com/papers/Chamroukhi\\_Neural\\_Networks\\_2009.pdf](https://chamroukhi.com/papers/Chamroukhi_Neural_Networks_2009.pdf).

## See Also

Useful links:

- <https://github.com/fchamroukhi/MEteorits>
- Report bugs at <https://github.com/fchamroukhi/MEteorits/issues>

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|        |  |
|--------|--|
| emNMoE | <i>emNMoE implements the EM algorithm to fit a Normal Mixture of Experts (NMoE).</i> |
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## Description

emNMoE implements the maximum-likelihood parameter estimation of a Normal Mixture of Experts (NMoE) model by the Expectation-Maximization (EM) algorithm.

## Usage

```
emNMoE(X, Y, K, p = 3, q = 1, n_tries = 1, max_iter = 1500,
        threshold = 1e-06, verbose = FALSE, verbose_IRLS = FALSE)
```

## Arguments

|              |  |
|--------------|--|
| X            | Numeric vector of length $n$ representing the covariates/inputs $x_1, \dots, x_n$ .  |
| Y            | Numeric vector of length $n$ representing the observed response/output $y_1, \dots, y_n$ .   |
| K            | The number of experts.   |
| p            | Optional. The order of the polynomial regression for the experts.  |
| q            | Optional. The order of the logistic regression for the gating network.   |
| n_tries      | Optional. Number of runs of the EM algorithm. The solution providing the highest log-likelihood will be returned.                                  |
| max_iter     | Optional. The maximum number of iterations for the EM algorithm.   |
| threshold    | Optional. A numeric value specifying the threshold for the relative difference of log-likelihood between two steps of the EM as stopping criteria. |
| verbose      | Optional. A logical value indicating whether or not values of the log-likelihood should be printed during EM iterations.                           |
| verbose_IRLS | Optional. A logical value indicating whether or not values of the criterion optimized by IRLS should be printed at each step of the EM algorithm.  |

## Details

emNMoE function implements the EM algorithm for the NMoE model. This function starts with an initialization of the parameters done by the method `initParam` of the class [ParamNMoE](#), then it alternates between the E-Step (method of the class [StatNMoE](#)) and the M-Step (method of the class [ParamNMoE](#)) until convergence (until the relative variation of log-likelihood between two steps of the EM algorithm is less than the threshold parameter).

## Value

EM returns an object of class [ModelNMoE](#).

## See Also

[ModelNMoE](#), [ParamNMoE](#), [StatNMoE](#)

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|         |  |
|---------|--|
| emSNMoE | <i>emSNMoE implements the ECM algorithm to fit a Skew-Normal Mixture of Experts (SNMoE).</i> |
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## Description

emSNMoE implements the maximum-likelihood parameter estimation of a Skew-Normal Mixture of Experts (SNMoE) model by the Expectation Conditional Maximization (ECM) algorithm.

## Usage

```
emSNMoE(X, Y, K, p = 3, q = 1, n_tries = 1, max_iter = 1500,
        threshold = 1e-06, verbose = FALSE, verbose_IRLS = FALSE)
```

## Arguments

|              |   |
|--------------|---|
| X            | Numeric vector of length $n$ representing the covariates/inputs $x_1, \dots, x_n$ .   |
| Y            | Numeric vector of length $n$ representing the observed response/output $y_1, \dots, y_n$ .  |
| K            | The number of experts.  |
| p            | Optional. The order of the polynomial regression for the experts.   |
| q            | Optional. The order of the logistic regression for the gating network.  |
| n_tries      | Optional. Number of runs of the ECM algorithm. The solution providing the highest log-likelihood will be returned.                                  |
| max_iter     | Optional. The maximum number of iterations for the ECM algorithm.   |
| threshold    | Optional. A numeric value specifying the threshold for the relative difference of log-likelihood between two steps of the ECM as stopping criteria. |
| verbose      | Optional. A logical value indicating whether or not values of the log-likelihood should be printed during ECM iterations.                           |
| verbose_IRLS | Optional. A logical value indicating whether or not values of the criterion optimized by IRLS should be printed at each step of the ECM algorithm.  |

## Details

emSNMoE function implements the ECM algorithm for the SNMoE model. This function starts with an initialization of the parameters done by the method `initParam` of the class [ParamSNMoE](#), then it alternates between the E-Step (method of the class [StatSNMoE](#)) and the M-Step (method of the class [ParamSNMoE](#)) until convergence (until the relative variation of log-likelihood between two steps of the ECM algorithm is less than the threshold parameter).

## Value

ECM returns an object of class [ModelSNMoE](#).

## See Also

[ModelSNMoE](#), [ParamSNMoE](#), [StatSNMoE](#)

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|         |   |
|---------|---|
| emStMoE | <i>emStMoE implements the ECM algorithm to fit a Skew-t Mixture of Experts (StMoE).</i> |
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## Description

emStMoE implements the maximum-likelihood parameter estimation of a Skew-t Mixture of Experts (StMoE) model by the Expectation Conditional Maximization (ECM) algorithm.

## Usage

```
emStMoE(X, Y, K, p = 3, q = 1, n_tries = 1, max_iter = 1500,
        threshold = 1e-06, verbose = FALSE, verbose_IRLS = FALSE)
```

## Arguments

|              |   |
|--------------|---|
| X            | Numeric vector of length $n$ representing the covariates/inputs $x_1, \dots, x_n$ .   |
| Y            | Numeric vector of length $n$ representing the observed response/output $y_1, \dots, y_n$ .  |
| K            | The number of experts.  |
| p            | Optional. The order of the polynomial regression for the experts.   |
| q            | Optional. The order of the logistic regression for the gating network.  |
| n_tries      | Optional. Number of runs of the ECM algorithm. The solution providing the highest log-likelihood will be returned.                                  |
| max_iter     | Optional. The maximum number of iterations for the ECM algorithm.   |
| threshold    | Optional. A numeric value specifying the threshold for the relative difference of log-likelihood between two steps of the ECM as stopping criteria. |
| verbose      | Optional. A logical value indicating whether or not values of the log-likelihood should be printed during ECM iterations.                           |
| verbose_IRLS | Optional. A logical value indicating whether or not values of the criterion optimized by IRLS should be printed at each step of the ECM algorithm.  |

## Details

emStMoE function implements the ECM algorithm for the StMoE model. This function starts with an initialization of the parameters done by the method `initParam` of the class [ParamStMoE](#), then it alternates between the E-Step (method of the class [StatStMoE](#)) and the M-Step (method of the class [ParamStMoE](#)) until convergence (until the relative variation of log-likelihood between two steps of the ECM algorithm is less than the threshold parameter).

## Value

ECM returns an object of class [ModelStMoE](#).

## See Also

[ModelStMoE](#), [ParamStMoE](#), [StatStMoE](#)

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|        |  |
|--------|--|
| emTMoE | <i>emTMoE implements the ECM algorithm to fit a t Mixture of Experts (TMoE).</i> |
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## Description

emTMoE implements the maximum-likelihood parameter estimation of a Student Mixture of Experts (TMoE) model by the Conditional Expectation Maximization (ECM) algorithm.

## Usage

```
emTMoE(X, Y, K, p = 3, q = 1, n_tries = 1, max_iter = 1500,
       threshold = 1e-06, verbose = FALSE, verbose_IRLS = FALSE)
```

## Arguments

|              |   |
|--------------|---|
| X            | Numeric vector of length $n$ representing the covariates/inputs $x_1, \dots, x_n$ .   |
| Y            | Numeric vector of length $n$ representing the observed response/output $y_1, \dots, y_n$ .  |
| K            | The number of experts.  |
| p            | Optional. The order of the polynomial regression for the experts.   |
| q            | Optional. The order of the logistic regression for the gating network.  |
| n_tries      | Optional. Number of runs of the ECM algorithm. The solution providing the highest log-likelihood will be returned.                                  |
| max_iter     | Optional. The maximum number of iterations for the ECM algorithm.   |
| threshold    | Optional. A numeric value specifying the threshold for the relative difference of log-likelihood between two steps of the ECM as stopping criteria. |
| verbose      | Optional. A logical value indicating whether or not values of the log-likelihood should be printed during ECM iterations.                           |
| verbose_IRLS | Optional. A logical value indicating whether or not values of the criterion optimized by IRLS should be printed at each step of the ECM algorithm.  |

## Details

emTMoE function implements the ECM algorithm for the TMoE model. This function starts with an initialization of the parameters done by the method `initParam` of the class [ParamTMoE](#), then it alternates between the E-Step (method of the class [StatTMoE](#)) and the M-Step (method of the class [ParamTMoE](#)) until convergence (until the relative variation of log-likelihood between two steps of the ECM algorithm is less than the threshold parameter).

## Value

ECM returns an object of class [ModelTMoE](#).

## See Also

[ModelTMoE](#), [ParamTMoE](#), [StatTMoE](#)

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|                 |  |
|-----------------|--|
| ModelNMoE-class | <i>A Reference Class which represents a fitted NMoE model.</i> |
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## Description

ModelNMoE represents an estimated NMoE model.

## Fields

`param` A [ParamNMoE](#) object. It contains the estimated values of the parameters.

`stat` A [StatNMoE](#) object. It contains all the statistics associated to the NMoE model.

## Methods

`plot(what = c("meancurve", "confregions", "clusters", "loglikelihood"), ...)` Plot method.

`what` The type of graph requested:

- "meancurve" = Estimated mean and estimated experts means given the input X (fields `Ey` and `Ey_k` of class [StatNMoE](#)).
- "confregions" = Estimated mean and confidence regions. Confidence regions are computed as plus and minus twice the estimated standard deviation (the square root of the field `Vary` of class [StatNMoE](#)).
- "clusters" = Estimated experts means (field `Ey_k`) and hard partition (field `klas` of class [StatNMoE](#)).
- "loglikelihood" = Value of the log-likelihood for each iteration (field `stored_loglik` of class [StatNMoE](#)).

`...` Other graphics parameters.

By default, all the graphs mentioned above are produced.

## See Also

[ParamNMoE](#), [StatNMoE](#)



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|                  |   |
|------------------|---|
| ModelSNMoE-class | <i>A Reference Class which represents a fitted SNMoE model.</i> |
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### Description

ModelSNMoE represents an estimated SNMoE model.

### Fields

param A [ParamSNMoE](#) object. It contains the estimated values of the parameters.

stat A [StatSNMoE](#) object. It contains all the statistics associated to the SNMoE model.

### Methods

plot(what = c("meancurve", "confregions", "clusters", "loglikelihood"), ...) Plot method.

what The type of graph requested:

- "meancurve" = Estimated mean and estimated experts means given the input X (fields Ey and Ey\_k of class [StatSNMoE](#)).
- "confregions" = Estimated mean and confidence regions. Confidence regions are computed as plus and minus twice the estimated standard deviation (the square root of the field Vary of class [StatSNMoE](#)).
- "clusters" = Estimated experts means (field Ey\_k) and hard partition (field klas of class [StatSNMoE](#)).
- "loglikelihood" = Value of the log-likelihood for each iteration (field stored\_loglik of class [StatSNMoE](#)).

... Other graphics parameters.

By default, all the graphs mentioned above are produced.

### See Also

[ParamSNMoE](#), [StatSNMoE](#)

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|                  |   |
|------------------|---|
| ModelStMoE-class | <i>A Reference Class which represents a fitted StMoE model.</i> |
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### Description

ModelStMoE represents an estimated StMoE model.

### Fields

param A [ParamStMoE](#) object. It contains the estimated values of the parameters.

stat A [StatStMoE](#) object. It contains all the statistics associated to the StMoE model.

## Methods

`plot(what = c("meancurve", "confregions", "clusters", "loglikelihood"), ...)` Plot method.

`what` The type of graph requested:

- "meancurve" = Estimated mean and estimated experts means given the input  $X$  (fields `Ey` and `Ey_k` of class [StatStMoE](#)).
- "confregions" = Estimated mean and confidence regions. Confidence regions are computed as plus and minus twice the estimated standard deviation (the square root of the field `Vary` of class [StatStMoE](#)).
- "clusters" = Estimated experts means (field `Ey_k`) and hard partition (field `klas` of class [StatStMoE](#)).
- "loglikelihood" = Value of the log-likelihood for each iteration (field `stored_loglik` of class [StatStMoE](#)).

... Other graphics parameters.

By default, all the graphs mentioned above are produced.

## See Also

[ParamStMoE](#), [StatStMoE](#)

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ModelTMOE-class

*A Reference Class which represents a fitted TMOE model.*

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## Description

ModelTMOE represents an estimated TMOE model.

## Fields

`param` A [ParamTMOE](#) object. It contains the estimated values of the parameters.

`stat` A [StatTMOE](#) object. It contains all the statistics associated to the TMOE model.

## Methods

`plot(what = c("meancurve", "confregions", "clusters", "loglikelihood"), ...)` Plot method.

`what` The type of graph requested:

- "meancurve" = Estimated mean and estimated experts means given the input  $X$  (fields `Ey` and `Ey_k` of class [StatTMOE](#)).
- "confregions" = Estimated mean and confidence regions. Confidence regions are computed as plus and minus twice the estimated standard deviation (the square root of the field `Vary` of class [StatTMOE](#)).
- "clusters" = Estimated experts means (field `Ey_k`) and hard partition (field `klas` of class [StatTMOE](#)).
- "loglikelihood" = Value of the log-likelihood for each iteration (field `stored_loglik` of class [StatTMOE](#)).

... Other graphics parameters.

By default, all the graphs mentioned above are produced.

## See Also

[ParamTMOE](#), [StatTMOE](#)

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|                 |   |
|-----------------|---|
| ParamNMoE-class | <i>A Reference Class which contains parameters of a NMoE model.</i> |
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### Description

ParamNMoE contains all the parameters of a NMoE model.

### Fields

- X Numeric vector of length  $n$  representing the covariates/inputs  $x_1, \dots, x_n$ .
- Y Numeric vector of length  $n$  representing the observed response/output  $y_1, \dots, y_n$ .
- n Numeric. Length of the response/output vector Y.
- K The number of experts.
- p The order of the polynomial regression for the experts.
- q The order of the logistic regression for the gating network.
- alpha Parameters of the gating network.  $\alpha = (\alpha_1, \dots, \alpha_{K-1})$  is a matrix of dimension  $(q + 1, K - 1)$ , with q the order of the logistic regression for the gating network. q is fixed to 1 by default.
- beta Polynomial regressions coefficients for each expert.  $\beta = (\beta_1, \dots, \beta_K)$  is a matrix of dimension  $(p + 1, K)$ , with p the order of the polynomial regression. p is fixed to 3 by default.
- sigma2 The variances for the K mixture components (matrix of size  $(1, K)$ ).
- df The degree of freedom of the NMoE model representing the complexity of the model.

### Methods

- initParam(segmental = FALSE) Method to initialize parameters alpha, beta and sigma2.  
If segmental = TRUE then alpha, beta and sigma2 are initialized by clustering the response Y uniformly into K contiguous segments. Otherwise, alpha, beta and sigma2 are initialized by clustering randomly the response Y into K segments.

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|                  |  |
|------------------|--|
| ParamSNMoE-class | <i>A Reference Class which contains parameters of a SNMoE model.</i> |
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### Description

ParamSNMoE contains all the parameters of a SNMoE model.

### Fields

- X Numeric vector of length  $n$  representing the covariates/inputs  $x_1, \dots, x_n$ .
- Y Numeric vector of length  $n$  representing the observed response/output  $y_1, \dots, y_n$ .
- n Numeric. Length of the response/output vector Y.
- K The number of experts.
- p The order of the polynomial regression for the experts.
- q The order of the logistic regression for the gating network.

- alpha Parameters of the gating network.  $\alpha = (\alpha_1, \dots, \alpha_{K-1})$  is a matrix of dimension  $(q + 1, K - 1)$ , with  $q$  the order of the logistic regression for the gating network.  $q$  is fixed to 1 by default.
- beta Polynomial regressions coefficients for each expert.  $\beta = (\beta_1, \dots, \beta_K)$  is a matrix of dimension  $(p + 1, K)$ , with  $p$  the order of the polynomial regression.  $p$  is fixed to 3 by default.
- sigma2 The variances for the  $K$  mixture components (matrix of size  $(1, K)$ ).
- lambda The skewness parameters for each experts (matrix of size  $(1, K)$ ).
- delta delta is equal  $\delta = \frac{\lambda}{\sqrt{1+\lambda^2}}$ .
- df The degree of freedom of the SNMoE model representing the complexity of the model.

## Methods

- initParam(segmental = FALSE) Method to initialize parameters alpha, beta and sigma2.  
If segmental = TRUE then alpha, beta and sigma2 are initialized by clustering the response  $Y$  uniformly into  $K$  contiguous segments. Otherwise, alpha, beta and sigma2 are initialized by clustering randomly the response  $Y$  into  $K$  segments.
- MStep(statSNMoE, verbose\_IRLS) Method which implements the M-step of the EM algorithm to learn the parameters of the SNMoE model based on statistics provided by the object statSNMoE of class [StatSNMoE](#) (which contains the E-step).

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|                  |  |
|------------------|--|
| ParamStMoE-class | <i>A Reference Class which contains parameters of a StMoE model.</i> |
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## Description

ParamStMoE contains all the parameters of a StMoE model.

## Fields

- X Numeric vector of length  $n$  representing the covariates/inputs  $x_1, \dots, x_n$ .
- Y Numeric vector of length  $n$  representing the observed response/output  $y_1, \dots, y_n$ .
- n Numeric. Length of the response/output vector  $Y$ .
- K The number of experts.
- p The order of the polynomial regression for the experts.
- q The order of the logistic regression for the gating network.
- alpha Parameters of the gating network.  $\alpha = (\alpha_1, \dots, \alpha_{K-1})$  is a matrix of dimension  $(q + 1, K - 1)$ , with  $q$  the order of the logistic regression for the gating network.  $q$  is fixed to 1 by default.
- beta Polynomial regressions coefficients for each expert.  $\beta = (\beta_1, \dots, \beta_K)$  is a matrix of dimension  $(p + 1, K)$ , with  $p$  the order of the polynomial regression.  $p$  is fixed to 3 by default.
- sigma2 The variances for the  $K$  mixture components (matrix of size  $(1, K)$ ).
- lambda The skewness parameters for each experts (matrix of size  $(1, K)$ ).
- delta delta is equal  $\delta = \frac{\lambda}{\sqrt{1+\lambda^2}}$ .
- nuk The degree of freedom for the Student distribution for each experts (matrix of size  $(1, K)$ ).
- df The degree of freedom of the StMoE model representing the complexity of the model.

## Methods

`initParam(segmental = FALSE)` Method to initialize parameters alpha, beta and sigma2.

If `segmental = TRUE` then alpha, beta and sigma2 are initialized by clustering the response Y uniformly into K contiguous segments. Otherwise, alpha, beta and sigma2 are initialized by clustering randomly the response Y into K segments.

`MStep(statStMoE, calcAlpha = FALSE, calcBeta = FALSE, calcSigma2 = FALSE, calcLambda = FALSE, calcNu = 1)`

Method which implements the M-step of the EM algorithm to learn the parameters of the StMoE model based on statistics provided by the object `statStMoE` of class [StatStMoE](#) (which contains the E-step).

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|                 |   |
|-----------------|---|
| ParamTMoE-class | <i>A Reference Class which contains parameters of a TMoE model.</i> |
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## Description

ParamTMoE contains all the parameters of a TMoE model.

## Fields

X Numeric vector of length  $n$  representing the covariates/inputs  $x_1, \dots, x_n$ .

Y Numeric vector of length  $n$  representing the observed response/output  $y_1, \dots, y_n$ .

n Numeric. Length of the response/output vector Y.

K The number of experts.

p The order of the polynomial regression for the experts.

q The order of the logistic regression for the gating network.

alpha Parameters of the gating network.  $\alpha = (\alpha_1, \dots, \alpha_{K-1})$  is a matrix of dimension  $(q + 1, K - 1)$ , with q the order of the logistic regression for the gating network. q is fixed to 1 by default.

beta Polynomial regressions coefficients for each expert.  $\beta = (\beta_1, \dots, \beta_K)$  is a matrix of dimension  $(p + 1, K)$ , with p the order of the polynomial regression. p is fixed to 3 by default.

sigma2 The variances for the K mixture components (matrix of size  $(1, K)$ ).

nu The degree of freedom for the Student distribution for each experts (matrix of size  $(1, K)$ ).

df The degree of freedom of the TMoE model representing the complexity of the model.

## Methods

`initParam(segmental = FALSE)` Method to initialize parameters alpha, beta and sigma2.

If `segmental = TRUE` then alpha, beta and sigma2 are initialized by clustering the response Y uniformly into K contiguous segments. Otherwise, alpha, beta and sigma2 are initialized by clustering randomly the response Y into K segments.

`MStep(statTMoE, verbose_IRLS)` Method which implements the M-step of the EM algorithm to learn the parameters of the TMoE model based on statistics provided by the object `statTMoE` of class [StatTMoE](#) (which contains the E-step).

---

|                |   |
|----------------|---|
| sampleUnivNMoE | <i>Draw a sample from a normal mixture of linear experts model.</i> |
|----------------|---|

---

## Description

Draw a sample from a normal mixture of linear experts model.

## Usage

```
sampleUnivNMoE(alphak, betak, sigmak, x)
```

## Arguments

|        |  |
|--------|--|
| alphak | The parameters of the gating network. alphak is a matrix of size $(q + 1, K - 1)$ , with $K - 1$ , the number of regressors (experts) and $q$ the order of the logistic regression |
| betak  | Matrix of size $(p + 1, K)$ representing the regression coefficients of the experts network.   |
| sigmak | Vector of length $K$ giving the standard deviations of the experts network.  |
| x      | A vector of length $n$ representing the inputs (predictors).   |

## Value

A list with the output variable  $y$  and statistics.

- $y$  Vector of length  $n$  giving the output variable.
- $z_i$  A vector of size  $n$  giving the hidden label of the expert component generating the  $i$ -th observation. Its elements are  $z_i[i] = k$ , if the  $i$ -th observation has been generated by the  $k$ -th expert.
- $z$  A matrix of size  $(n, K)$  giving the values of the binary latent component indicators  $Z_{ik}$  such that  $Z_{ik} = 1$  iff  $Z_i = k$ .
- stats A list whose elements are:
  - $Ey\_k$  Matrix of size  $(n, K)$  giving the conditional expectation of  $Y_i$  the output variable given the value of the hidden label of the expert component generating the  $i$ th observation  $z_i = k$ , and the value of predictor  $X = x_i$ .
  - $Ey$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given the value of predictor  $X = x_i$ .
  - $Vary\_k$  Vector of length  $k$  representing the conditional variance of  $Y_i$  given  $z_i = k$ , and  $X = x_i$ .
  - $Vary$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given  $X = x_i$ .

---

|                 |  |
|-----------------|--|
| sampleUnivSNMoE | <i>Draw a sample from a skew-normal mixture of linear experts model.</i> |
|-----------------|--|

---

## Description

Draw a sample from a skew-normal mixture of linear experts model.

## Usage

```
sampleUnivSNMoE(alphak, betak, sigmak, lambdak, x)
```

## Arguments

|         |  |
|---------|--|
| alphak  | The parameters of the gating network. alphak is a matrix of size $(q + 1, K - 1)$ , with $K - 1$ , the number of regressors (experts) and $q$ the order of the logistic regression |
| betak   | Matrix of size $(p + 1, K)$ representing the regression coefficients of the experts network.   |
| sigmak  | Vector of length $K$ giving the standard deviations of the experts network.  |
| lambdak | Vector of length $K$ giving the skewness parameter of each experts.  |
| x       | A vector of length $n$ representing the inputs (predictors).   |

## Value

A list with the output variable  $y$  and statistics.

- $y$  Vector of length  $n$  giving the output variable.
- $z_i$  A vector of size  $n$  giving the hidden label of the expert component generating the  $i$ -th observation. Its elements are  $z_i[i] = k$ , if the  $i$ -th observation has been generated by the  $k$ -th expert.
- $z$  A matrix of size  $(n, K)$  giving the values of the binary latent component indicators  $Z_{ik}$  such that  $Z_{ik} = 1$  iff  $Z_i = k$ .
- stats A list whose elements are:
  - $Ey\_k$  Matrix of size  $(n, K)$  giving the conditional expectation of  $Y_i$  the output variable given the value of the hidden label of the expert component generating the  $i$ th observation  $z_i = k$ , and the value of predictor  $X = x_i$ .
  - $Ey$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given the value of predictor  $X = x_i$ .
  - $Vary\_k$  Vector of length  $k$  representing the conditional variance of  $Y_i$  given  $z_i = k$ , and  $X = x_i$ .
  - $Vary$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given  $X = x_i$ .

---

sampleUnivSTMoE

---

*Draw a sample from a univariate skew-t mixture.*


---

### Description

Draw a sample from a univariate skew-t mixture.

### Usage

```
sampleUnivSTMoE(alphak, betak, sigmak, lambdak, nuk, x)
```

### Arguments

|         |  |
|---------|--|
| alphak  | The parameters of the gating network. alphak is a matrix of size $(q + 1, K - 1)$ , with $K - 1$ , the number of regressors (experts) and $q$ the order of the logistic regression |
| betak   | Matrix of size $(p + 1, K)$ representing the regression coefficients of the experts network.   |
| sigmak  | Vector of length $K$ giving the standard deviations of the experts network.  |
| lambdak | Vector of length $K$ giving the skewness parameter of each experts.  |
| nuk     | Vector of length $K$ giving the degrees of freedom of the experts network t densities.   |
| x       | A vector of length $n$ representing the inputs (predictors).   |

### Value

A list with the output variable  $y$  and statistics.

- $y$  Vector of length  $n$  giving the output variable.
- $zi$  A vector of size  $n$  giving the hidden label of the expert component generating the  $i$ -th observation. Its elements are  $zi[i] = k$ , if the  $i$ -th observation has been generated by the  $k$ -th expert.
- $z$  A matrix of size  $(n, K)$  giving the values of the binary latent component indicators  $Z_{ik}$  such that  $Z_{ik} = 1$  iff  $Z_i = k$ .
- stats A list whose elements are:
  - $Ey\_k$  Matrix of size  $(n, K)$  giving the conditional expectation of  $Y_i$  the output variable given the value of the hidden label of the expert component generating the  $i$ th observation  $zi = k$ , and the value of predictor  $X = xi$ .
  - $Ey$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given the value of predictor  $X = xi$ .
  - $Vary\_k$  Vector of length  $k$  representing the conditional variance of  $Y_i$  given  $zi = k$ , and  $X = xi$ .
  - $Vary$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given  $X = xi$ .



sampleUnivTMoE

*Draw a sample from a univariate t mixture of experts (TMoE).***Description**

Draw a sample from a univariate t mixture of experts (TMoE).

**Usage**

```
sampleUnivTMoE(alphak, betak, sigmak, nuk, x)
```

**Arguments**

|        |  |
|--------|--|
| alphak | The parameters of the gating network. alphak is a matrix of size $(q + 1, K - 1)$ , with $K - 1$ , the number of regressors (experts) and $q$ the order of the logistic regression |
| betak  | Matrix of size $(p + 1, K)$ representing the regression coefficients of the experts network.   |
| sigmak | Vector of length $K$ giving the standard deviations of the experts network.  |
| nuk    | Vector of length $K$ giving the degrees of freedom of the experts network t densities.   |
| x      | A vector of length $n$ representing the inputs (predictors).   |

**Value**

A list with the output variable  $y$  and statistics.

- $y$  Vector of length  $n$  giving the output variable.
- $zi$  A vector of size  $n$  giving the hidden label of the expert component generating the  $i$ -th observation. Its elements are  $zi[i] = k$ , if the  $i$ -th observation has been generated by the  $k$ -th expert.
- $z$  A matrix of size  $(n, K)$  giving the values of the binary latent component indicators  $Z_{ik}$  such that  $Z_{ik} = 1$  iff  $Z_i = k$ .
- $stats$  A list whose elements are:
  - $Ey\_k$  Matrix of size  $(n, K)$  giving the conditional expectation of  $Y_i$  the output variable given the value of the hidden label of the expert component generating the  $i$ th observation  $zi = k$ , and the value of predictor  $X = xi$ .
  - $Ey$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given the value of predictor  $X = xi$ .
  - $Vary\_k$  Vector of length  $k$  representing the conditional variance of  $Y_i$  given  $zi = k$ , and  $X = xi$ .
  - $Vary$  Vector of length  $n$  giving the conditional expectation of  $Y_i$  given  $X = xi$ .

StatNMoE-class

*A Reference Class which contains statistics of a NMoE model.***Description**

StatNMoE contains all the statistics associated to a [NMoE](#) model. It mainly includes the E-Step of the EM algorithm calculating the posterior distribution of the hidden variables, as well as the calculation of the log-likelihood.

**Fields**

**piik** Matrix of size  $(n, K)$  representing the probabilities  $\pi_k(x_i; \Psi) = P(z_i = k | \mathbf{x}; \Psi)$  of the latent variable  $z_i, i = 1, \dots, n$ .

**z\_ik** Hard segmentation logical matrix of dimension  $(n, K)$  obtained by the Maximum a posteriori (MAP) rule:  $z_{ik} = 1$  if  $z_{ik} = \arg \max_s \tau_{is}$ ; 0 otherwise,  $k = 1, \dots, K$ .

**klas** Column matrix of the labels issued from **z\_ik**. Its elements are  $klas(i) = k, k = 1, \dots, K$ .

**tik** Matrix of size  $(n, K)$  giving the posterior probability  $\tau_{ik}$  that the observation  $y_i$  originates from the  $k$ -th expert.

**Ey\_k** Matrix of dimension  $(n, K)$  giving the estimated means of the experts.

**Ey** Column matrix of dimension  $n$ .

**Var\_yk** Column matrix of dimension  $K$  giving the estimated means of the experts.

**Vary** Column matrix of dimension  $n$  giving the estimated variance of the response.

**loglik** Numeric. Observed-data log-likelihood of the NMoE model.

**com\_loglik** Numeric. Complete-data log-likelihood of the NMoE model.

**stored\_loglik** Numeric vector. Stored values of the log-likelihood at each EM iteration.

**BIC** Numeric. Value of BIC (Bayesian Information Criterion).

**ICL** Numeric. Value of ICL (Integrated Completed Likelihood).

**AIC** Numeric. Value of AIC (Akaike Information Criterion).

**log\_piik\_fik** Matrix of size  $(n, K)$  giving the values of the logarithm of the joint probability  $P(y_i, z_i = k | \mathbf{x}, \Psi), i = 1, \dots, n$ .

**log\_sum\_piik\_fik** Column matrix of size  $m$  giving the values of  $\log \sum_{k=1}^K P(y_i, z_i = k | \mathbf{x}, \Psi), i = 1, \dots, n$ .

**Methods**

**computelikelihood(reg\_irls)** Method to compute the log-likelihood. **reg\_irls** is the value of the regularization part in the IRLS algorithm.

**computeStats(paramNMoE)** Method used in the EM algorithm to compute statistics based on parameters provided by the object **paramNMoE** of class [ParamNMoE](#).

**EStep(paramNMoE)** Method used in the EM algorithm to update statistics based on parameters provided by the object **paramNMoE** of class [ParamNMoE](#) (prior and posterior probabilities).

**MAP()** MAP calculates values of the fields **z\_ik** and **klas** by applying the Maximum A Posteriori Bayes allocation rule.

$z_{ik} = 1$  if  $k = \arg \max_s \tau_{is}$ ; 0 otherwise

**See Also**[ParamNMoE](#)

StatSNMoE-class

*A Reference Class which contains statistics of a SNMoE model.***Description**

StatSNMoE contains all the statistics associated to a [SNMoE](#) model. It mainly includes the E-Step of the ECM algorithm calculating the posterior distribution of the hidden variables, as well as the calculation of the log-likelihood.

**Fields**

- piik Matrix of size  $(n, K)$  representing the probabilities  $\pi_k(x_i; \Psi) = P(z_i = k | x; \Psi)$  of the latent variable  $z_i, i = 1, \dots, n$ .
- z\_ik Hard segmentation logical matrix of dimension  $(n, K)$  obtained by the Maximum a posteriori (MAP) rule:  $z_{ik} = 1$  if  $z_{ik} = \arg \max_s \tau_{is}$ ; 0 otherwise,  $k = 1, \dots, K$ .
- klas Column matrix of the labels issued from z\_ik. Its elements are  $klas(i) = k, k = 1, \dots, K$ .
- tik Matrix of size  $(n, K)$  giving the posterior probability  $\tau_{ik}$  that the observation  $y_i$  originates from the  $k$ -th expert.
- Ey\_k Matrix of dimension  $(n, K)$  giving the estimated means of the experts.
- Ey Column matrix of dimension  $n$ .
- Var\_yk Column matrix of dimension  $K$  giving the estimated means of the experts.
- Vary Column matrix of dimension  $n$  giving the estimated variance of the response.
- loglik Numeric. Observed-data log-likelihood of the SNMoE model.
- com\_loglik Numeric. Complete-data log-likelihood of the SNMoE model.
- stored\_loglik Numeric vector. Stored values of the log-likelihood at each ECM iteration.
- BIC Numeric. Value of BIC (Bayesian Information Criterion).
- ICL Numeric. Value of ICL (Integrated Completed Likelihood).
- AIC Numeric. Value of AIC (Akaike Information Criterion).
- log\_piik\_fik Matrix of size  $(n, K)$  giving the values of the logarithm of the joint probability  $P(y_i, z_i = k | x, \Psi), i = 1, \dots, n$ .
- log\_sum\_piik\_fik Column matrix of size  $m$  giving the values of  $\log \sum_{k=1}^K P(y_i, z_i = k | x, \Psi), i = 1, \dots, n$ .
- E1ik Conditional expectations of  $U_i$  (Matrix of size  $(n, K)$ ).
- E2ik Conditional expectations of  $U_i^2$  (Matrix of size  $(n, K)$ ).

**Methods**

- computeLikelihood(reg\_irls) Method to compute the log-likelihood. reg\_irls is the value of the regularization part in the IRLS algorithm.
- computeStats(paramSNMoE) Method used in the ECM algorithm to compute statistics based on parameters provided by the object paramSNMoE of class [ParamSNMoE](#).
- EStep(paramSNMoE) Method used in the ECM algorithm to update statistics based on parameters provided by the object paramSNMoE of class [ParamSNMoE](#) (prior and posterior probabilities).
- MAP() MAP calculates values of the fields z\_ik and klas by applying the Maximum A Posteriori Bayes allocation rule.  
 $z_{ik} = 1$  if  $k = \arg \max_s \tau_{is}$ ; 0 otherwise

**See Also**[ParamSNMoE](#)

StatStMoE-class

*A Reference Class which contains statistics of a StMoE model.***Description**

StatStMoE contains all the statistics associated to a [StMoE](#) model. It mainly includes the E-Step of the ECM algorithm calculating the posterior distribution of the hidden variables, as well as the calculation of the log-likelihood.

**Fields**

piik Matrix of size  $(n, K)$  representing the probabilities  $\pi_k(x_i; \Psi) = P(z_i = k | \mathbf{x}; \Psi)$  of the latent variable  $z_i, i = 1, \dots, n$ .

z\_ik Hard segmentation logical matrix of dimension  $(n, K)$  obtained by the Maximum a posteriori (MAP) rule:  $z_{ik} = 1$  if  $z_{ik} = \arg \max_s \tau_{is}$ ; 0 otherwise,  $k = 1, \dots, K$ .

klas Column matrix of the labels issued from z\_ik. Its elements are  $klas(i) = k, k = 1, \dots, K$ .

tik Matrix of size  $(n, K)$  giving the posterior probability  $\tau_{ik}$  that the observation  $y_i$  originates from the  $k$ -th expert.

Ey\_k Matrix of dimension  $(n, K)$  giving the estimated means of the experts.

Ey Column matrix of dimension  $n$ .

Var\_yk Column matrix of dimension  $K$  giving the estimated means of the experts.

Vary Column matrix of dimension  $n$  giving the estimated variance of the response.

loglik Numeric. Observed-data log-likelihood of the StMoE model.

com\_loglik Numeric. Complete-data log-likelihood of the StMoE model.

stored\_loglik Numeric vector. Stored values of the log-likelihood at each ECM iteration.

BIC Numeric. Value of BIC (Bayesian Information Criterion).

ICL Numeric. Value of ICL (Integrated Completed Likelihood).

AIC Numeric. Value of AIC (Akaike Information Criterion).

log\_piik\_fik Matrix of size  $(n, K)$  giving the values of the logarithm of the joint probability  $P(y_i, z_i = k | \mathbf{x}, \Psi), i = 1, \dots, n$ .

log\_sum\_piik\_fik Column matrix of size  $m$  giving the values of  $\log \sum_{k=1}^K P(y_i, z_i = k | \mathbf{x}, \Psi), i = 1, \dots, n$ .

dik It represents the value of  $d_{ik}$ .

wik Conditional expectations  $w_{ik}$ .

E1ik Conditional expectations  $e_{1,ik}$ .

E2ik Conditional expectations  $e_{2,ik}$ .

E3ik Conditional expectations  $e_{3,ik}$ .

stme\_pdf Skew-t mixture of experts density.

## Methods

- `computeLikelihood(reg_irls)` Method to compute the log-likelihood. `reg_irls` is the value of the regularization part in the IRLS algorithm.
- `computeStats(paramStMoE)` Method used in the ECM algorithm to compute statistics based on parameters provided by the object `paramStMoE` of class [ParamStMoE](#).
- `EStep(paramStMoE, calcTau = FALSE, calcE1 = FALSE, calcE2 = FALSE, calcE3 = FALSE)` Method used in the ECM algorithm to update statistics based on parameters provided by the object `paramStMoE` of class [ParamStMoE](#) (prior and posterior probabilities).
- `MAP()` MAP calculates values of the fields `z_ik` and `klas` by applying the Maximum A Posteriori Bayes allocation rule.
- $$z_{ik} = 1 \text{ if } k = \arg \max_s \tau_{is}; 0 \text{ otherwise}$$

## See Also

[ParamStMoE](#)

---

StatTMOE-class

*A Reference Class which contains statistics of a TMOE model.*

---

## Description

StatTMOE contains all the statistics associated to a [TMOE](#) model. It mainly includes the E-Step of the ECM algorithm calculating the posterior distribution of the hidden variables, as well as the calculation of the log-likelihood.

## Fields

- `piik` Matrix of size  $(n, K)$  representing the probabilities  $\pi_k(x_i; \Psi) = P(z_i = k | x; \Psi)$  of the latent variable  $z_i, i = 1, \dots, n$ .
- `z_ik` Hard segmentation logical matrix of dimension  $(n, K)$  obtained by the Maximum a posteriori (MAP) rule:  $z_{ik} = 1$  if  $z_{ik} = \arg \max_s \tau_{is}; 0$  otherwise,  $k = 1, \dots, K$ .
- `klas` Column matrix of the labels issued from `z_ik`. Its elements are  $klas(i) = k, k = 1, \dots, K$ .
- `tik` Matrix of size  $(n, K)$  giving the posterior probability  $\tau_{ik}$  that the observation  $y_i$  originates from the  $k$ -th expert.
- `Ey_k` Matrix of dimension  $(n, K)$  giving the estimated means of the experts.
- `Ey` Column matrix of dimension  $n$ .
- `Var_yk` Column matrix of dimension  $K$  giving the estimated means of the experts.
- `Vary` Column matrix of dimension  $n$  giving the estimated variance of the response.
- `loglik` Numeric. Observed-data log-likelihood of the TMOE model.
- `com_loglik` Numeric. Complete-data log-likelihood of the TMOE model.
- `stored_loglik` Numeric vector. Stored values of the log-likelihood at each ECM iteration.
- `BIC` Numeric. Value of BIC (Bayesian Information Criterion).
- `ICL` Numeric. Value of ICL (Integrated Completed Likelihood).
- `AIC` Numeric. Value of AIC (Akaike Information Criterion).
- `log_piik_fik` Matrix of size  $(n, K)$  giving the values of the logarithm of the joint probability  $P(y_i, z_i = k | x, \Psi), i = 1, \dots, n$ .
- `log_sum_piik_fik` Column matrix of size  $m$  giving the values of  $\log \sum_{k=1}^K P(y_i, z_i = k | x, \Psi), i = 1, \dots, n$ .
- `Wik` Conditional expectations  $w_{ik}$ .

Methods

computeLikelihood(reg\_irls) Method to compute the log-likelihood. reg\_irls is the value of the regularization part in the IRLS algorithm.

computeStats(paramTmoe) Method used in the ECM algorithm to compute statistics based on parameters provided by the object paramTmoe of class ParamTmoe.

EStep(paramTmoe) Method used in the ECM algorithm to update statistics based on parameters provided by the object paramTmoe of class ParamTmoe (prior and posterior probabilities).

MAP() MAP calculates values of the fields z\_ik and klas by applying the Maximum A Posteriori Bayes allocation rule.

$z_{ik} = 1$  if  $k = \arg \max_s \tau_{is}$ ; 0 otherwise

See Also

ParamTmoe

---

|               |  |
|---------------|--|
| tempanomalies | Global Annual Temperature Anomalies (Land Meteorological Stations) (1880-2015) |
|---------------|--|

---

Description

This dataset is from [https://cdiac.ess-dive.lbl.gov/ftp/trends/temp/hansen/gl\\_land.txt](https://cdiac.ess-dive.lbl.gov/ftp/trends/temp/hansen/gl_land.txt).

Usage

tempanomalies

Format

A data frame with 136 rows and 3 columns:

**Year** Year of observation.

**AnnualAnomaly** Value in degrees C of the global annual temperature anomaly.

**5-YearMean** 5-Year mean of temperature anomalies.

Details

Global annual temperature anomalies (degrees C) computed using data from land meteorological stations, 1880-2015. Anomalies are relative to the 1951-1980 base period means.

Non-computed values are indicated by "-99.99".

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