

# Package ‘esd’

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**Title** Climate analysis and empirical-statistical downscaling (ESD) package for monthly and daily data.

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**Depends** ncd4, zoo, R (>= 2.10.0)

**Description** The package contains R functions for retrieving data, making climate analysis and downscaling of monthly mean and daily mean global climate scenarios.

**License** GPL (>= 2)

**URL** <http://rcg.gvc.gu.se/edu/esd.pdf>

**ZipData** no

## R topics documented:

aggregate . . . . .	2
annual . . . . .	3
anomaly . . . . .	5
as . . . . .	6
CCA . . . . .	10
combine . . . . .	12
corfield . . . . .	14
crossval . . . . .	15
Data . . . . .	16
diagnose . . . . .	18
DS . . . . .	19
DSE . . . . .	23
DSensemble . . . . .	25
ele2param . . . . .	27
EOF . . . . .	28

iid.test . . . . .	30
InfoGraphics . . . . .	31
is . . . . .	32
map . . . . .	33
MVR . . . . .	35
plot.station . . . . .	37
regrid . . . . .	39
retrieve . . . . .	40
spatial.avg.field . . . . .	42
spell . . . . .	43
station . . . . .	45
subset . . . . .	47
test.retrieve.ncdf4 . . . . .	49
transforms . . . . .	51
trend . . . . .	52
WG . . . . .	52
write2ncdf . . . . .	55
<b>Index</b>	<b>56</b>

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aggregate

*aggregate*

---

## Description

The aggregation is based on the S3 method for zoo objects, but takes care of extra house keeping, such as attributes with meta data.

## Usage

```
aggregate.station(x,by,FUN = mean, ..., regular = NULL, frequency = NULL)
aggregate.field(x,by,FUN = mean, ..., regular = NULL, frequency = NULL)
aggregate.comb(x,by,FUN = mean, ...,
               regular = NULL, frequency = NULL)
aggregate.area(x,is=NULL,it=NULL,FUN=sum,na.rm=TRUE,smallx=FALSE)
```

## Arguments

x	A <a href="#">station</a> , <a href="#">spell</a> or a <a href="#">field</a> object
by	see <a href="#">aggregate.zoo</a>
FUN	see <a href="#">aggregate.zoo</a>
regular	see <a href="#">aggregate.zoo</a>
frequency	see <a href="#">aggregate.zoo</a>
is	spatial selection - see <a href="#">subset.field</a>
na.rm	TRUE: ignore NA - see <a href="#">mean</a>

**Value**

The call returns a station object

**Author(s)**

R.E. Benestad

**See Also**

[spatial.avg.field](#), [as.4seasons](#), [annual](#)

**Examples**

```
# Example: use aggregate to compute annual mean temperature for Svalbard:
data(Svalbard)
yr <- year(Svalbard)
y <- aggregate(Svalbard, by=yr, mean, na.rm = FALSE)
plot(y)

# Example for getting seasonal aggregate of standard deviation of
oslo <- station("Oslo Blindern",stid="193",src="ECAD")
ym <- as.4seasons(oslo,FUN=mean)
ys <- as.4seasons(oslo,FUN=sd)
y <- combine(ym,ys)
plot(y)

x <- t2m.NCEP()
z <- aggregate.area(x)
plot(z)
```

---

annual

---

*Conversion to esd objects.*


---

**Description**

annual aggregates time series into annual values (e.g. means). year, month, season return the years, months, and days associated with the data.

**Usage**

```
annual(x,...)
annual.zoo(x,FUN=mean,na.rm=TRUE,nmin=NULL, ...)
annual.default(x,FUN=mean,na.rm=TRUE,nmin=NULL, ...)
annual.dsensemble(x,FUN=mean)
annual.station(x,FUN=mean,nmin=NULL, ...)
annual.spell(x,FUN=mean,nmin=NULL,...)
annual.field(x,FUN=mean,na.rm=TRUE, nmin=NULL, ...)
year(x, ...)
```

```

month(x, ...)
day(x, ...)
season(x, format="numeric", ...)
season.name()
pentad(x, l=5, ...)

```

### Arguments

x	a station, field object, or a date
FUN	see <a href="#">aggregate.zoo</a>
nmin	Minimum number of data points (e.g. days or months) with valid data accepted for annual estimate. NULL demands complete years.
format	'numeric' or 'character'
na.rm	TRUE: ignore NA - see <a href="#">mean</a>
l	length of window

### Value

Same as x, or a numeric for year, month, day, or pentad.

### Author(s)

R.E. Benestad and A. Mezghanil

### See Also

[as.annual](#), [aggregate.station](#)

### Examples

```

# Example: how to generate a new station object.
data <- round(matrix(rnorm(20*12),20,12),2); colnames(data) <- month.abb
x <- data.frame(year=1981:2000,data)
X <- as.station.data.frame(x,loc="",param="noise",unit="none")

# Example: how to generate a new field object.
year <- sort(rep(1991:2000,12))
month <- rep(1:12,length(1991:2000))
n <- length(year)
lon <- seq(-30,40,by=5); nx <- length(lon)
lat <- seq(40,70,by=5); ny <- length(lat)
# Time dimension should come first, space second.
y <- matrix(rnorm(nx*ny*n),n,nx*ny)
index <- as.Date(paste(year,month,1,sep="-"))
Y <- as.field(y,index,lon,lat,param="noise",unit="none")
map(Y)
plot EOF(Y)

data(Oslo)
plot(as.anomaly(Oslo))

```

```

data(ferder)
plot(annual(ferder,FUN=min))
plot(annual(ferder,FUN=IQR,na.rm=TRUE))
plot(as.4seasons(ferder))

data(bjornholt)
plot(annual(bjornholt,FUN="exceedance",fun="counts"))
plot(annual(bjornholt,FUN="exceedance",fun="freq"))
plot(annual(bjornholt,FUN="exceedance"))

# Test the as.4seasons function:
data(ferder)
#Daily data:
yd <- ferder
# Monthly data:
ym <- aggregate(ferder,as.yearmon)
ym <- zoo(coredata(ym),as.Date(index(ym)))
ym <- attrcp(ferder,ym)
plot(ym)

#Monthly reanalyses:
t2m <- t2m.ERAINT(lon=c(-30,40),lat=c(50,70))
T2m <- as.4seasons(t2m)
#Extract the grid point with location corresponding to that of the station:
x <- regrid(t2m,is=ferder)
x4s <- as.4seasons(x)
X4s <- regrid(T2m,is=ferder)
y4s1 <- as.4seasons(yd)
y4s2 <- as.4seasons(ym)
plot.zoo(y4s1,lwd=2,xlim=as.Date(c("1980-01-01","2000-01-01")),ylim=c(-10,20))
lines(y4s2,col="red",lty=2)
lines(x4s,col="darkblue",lwd=2)
lines(X4s,col="lightblue",lty=2)

```

## Description

S3-method that computes anomalies and/or climatology for time series and fields. `clim2pca` is unfinished

## Usage

```

anomaly(x,...)
anomaly.default(x,...)
anomaly.comb(x,...)
anomaly.field(x,...)
anomaly.station(x,...)

```

```

anomaly.annual(x,ref=1961:1990)
anomaly.month(x,ref=NULL)
anomaly.season(x,ref=NULL)
anomaly.day(x,ref=NULL)
climatology(x,...)
climatology.default(x)
climatology.field(x)
climatology.station(x)
clim2pca(x,...)
clim2pca.default(x)
clim2pca.month(x)
clim2pca.day(x)

```

### Arguments

x	A station or field object
ref	vector defining the reference interval

### Value

The call returns a similar object as x

### Author(s)

R.E. Benestad

### See Also

[as.anomaly](#), [as.climatology](#)

### Examples

```

data(ferder)
plot(anomaly(ferder))

```

---

as	<i>Conversion to esd objects.</i>
----	-----------------------------------

---

### Description

Various methods for converting objects from one shape to another. These methods do the house keeping, keeping track of attributes and metadata.

`as.field.station` uses `regrid` to generate a field based on bi-linear interpolation of station values and their coordinates. Unfinished...

**Usage**

```

as.4seasons(x,FUN=mean,...)
as.4seasons.default(x,FUN=mean,...)
as.4seasons.station(x,FUN=mean,...)
as.4seasons.day(x,FUN=mean,na.rm=TRUE,dateindex=TRUE,...)
as.4seasons.field(x,FUN=mean,...)
as.4seasons.spell(x,FUN=mean,...)
as.seasons(x,start=01-01,end=12-31,FUN=mean, ...)
as.annual(x,...)
as.annual.default(x, ...)
as.annual.numeric(x, ...)
as.annual.integer(x, ...)
as.annual.yearqtr(x, frac = 0, ...)
as.annual.spell(x, ...)
as.annual.station(x, ...)
as.anomaly(x,...)
as.anomaly.default(x,ref=NULL,monthly=NULL,na.rm=TRUE)
as.anomaly.station(x,ref=NULL,monthly=NULL,na.rm=TRUE)
as.anomaly.field(x,ref=NULL,monthly=NULL,na.rm=TRUE)
as.anomaly.zoo(x,ref=NULL,monthly=NULL,na.rm=TRUE)
as.appended(x,...)
as.appended.ds.comb(x,iapp=1)
as.appended.eof.comb(x,iapp=1)
as.appended.field.comb(x,iapp=1)
as.eof(x,...)
as.eof.zoo(x,...)
as.eof.eof(x,iapp=NULL)
as.eof.comb(x,iapp=NULL)
as.eof.field(x,iapp=NULL,...)
as.eof.appendix(x,iapp=1)
as.calibrationdata(x)
as.calibrationdata.ds(x)
as.calibrationdata.station(x)
as.climatology(x,...)
as.comb(x,...)
as.comb.eof(x,...)
as.ds(x)
as.field(x,...)
as.field.zoo(x,lon,lat,param,unit,
             longname=NA,quality=NA,src=NA,url=NA,
             reference=NA,info=NA,calendar=gregorian,
             greenwich=TRUE, method= NA,type=NA,aspect=NA)
as.field.default(x,index,lon,lat,param,unit,
                 longname=NA,quality=NA,src=NA,url=NA,
                 reference=NA,info=NA,calendar=gregorian,
                 greenwich=TRUE, method= NA,type=NA,aspect=NA)
as.field.eof(x,...)
as.field.comb(x,iapp=NULL,...)

```

```

as.field.station(x,...)
as.fitted.values(x)
as.fitted.values.ds(x)
as.fitted.values.station(x)
as.monthly(x,fun=mean)
as.observed.station(x)
as.original.data(x)
as.original.data.ds(x)
as.original.data.station(x)
as.pattern(x)
as.pattern.ds(x)
as.pattern.eof(x)
as.pattern.cca(x)
as.pattern.mvr(x)
as.pattern.field(x)
as.pattern.trend(x)
as.pattern.corfield(x)
as.residual(x)
as.residual.ds(x)
as.residual.station(x)
as.station(x,...)
as.station.zoo(x,loc=NA,param=NA,unit=NA,lon=NA,lat=NA,alt=NA,
               cntr=NA,longname=NA,stid=NA,quality=NA,src=NA,url=NA,
               reference=NA,info=NA, method= NA)
as.station.data.frame(x,location=NA,param=NA,unit=NA,lon=NA,lat=NA,alt=NA,
                      cntr=NA,longname=NA,stid=NA,quality=NA,src=NA,url=NA,
                      reference=NA,info=NA, method= NA)
as.station.zoo(x,location=NA,param=NA,unit=NA,lon=NA,lat=NA,alt=NA,
               cntr=NA,longname=NA,stid=NA,quality=NA,src=NA,url=NA,
               reference=NA,info=NA, method= NA,type=NA,aspect=NA)

as.station.list(x)
as.station.ds(x)
as.station.pca(x)
as.station.field(x)
as.station.spell(x)
as.station.eof(x,pattern=1:10)

```

### Arguments

x	Data object
location	define location attribute attr(x,location)
param	define variable attribute attr(x,variable)
unit	define unit attribute attr(x,unit)
lon	define longitude attribute attr(x,longitude)
lat	define latitude attribute attr(x,latitude)
alt	define altitude attribute attr(x,altitude)
cntr	define country attribute attr(x,country)



longname	define long-name attribute attr(x, loongname)
stid	define station ID attribute attr(x, station_id)
quality	define quality attribute attr(x, quality)
src	define source attribute attr(x, source)
url	define URL attribute attr(x, URL)
reference	define reference attribute attr(x, reference)
info	define info attribute attr(x, info)
method	define method attribute attr(x, method)
FUN	function
na.rm	TRUE: ignore NA's
dateindex	
monthly	
aspect	
iapp	For values greater than 1, select the corresponding appended field in 'comb' objects (e.g. 1 gives attr(x, appendix.1))
pattern	Which EOF pattern (mode) to extract as a series for PC

### Value

A field object

### Author(s)

R.E. Benestad and A. Mezghanil

### Examples

```
# Example: how to generate a new station object.
data <- round(matrix(rnorm(20*12),20,12),2); colnames(data) <- month.abb
x <- data.frame(year=1981:2000,data)
X <- as.station.data.frame(x,loc="",param="noise",unit="none")

# Example: how to generate a new field object.
year <- sort(rep(1991:2000,12))
month <- rep(1:12,length(1991:2000))
n <-length(year)
lon <- seq(-30,40,by=5); nx <- length(lon)
lat <- seq(40,70,by=5); ny <- length(lat)
# Time dimension should come first, space second.
y <- matrix(rnorm(nx*ny*n),n,nx*ny)
index <- as.Date(paste(year,month,1,sep="-"))
Y <- as.field(y,index,lon,lat,param="noise",unit="none")
map(Y)
plot(EOF(Y))

data(Oslo)
```

```

plot(as.anomaly(Oslo))

data(ferder)
plot(annual(ferder,FUN=min))
plot(annual(ferder,FUN=IQR,na.rm=TRUE))
plot(as.4seasons(ferder))

data(bjornholt)
plot(annual(bjornholt,FUN="exceedance",fun="counts"))
plot(annual(bjornholt,FUN="exceedance",fun="freq"))
plot(annual(bjornholt,FUN="exceedance"))

# Test the as.4seasons function:
data(ferder)
#Daily data:
yd <- ferder
# Monthly data:
ym <- aggregate(ferder,as.yearmon)
ym <- zoo(coredat(ym),as.Date(index(ym)))
ym <- attrcp(ferder,ym)
plot(ym)

#Monthly reanalyses:
t2m <- t2m.ERAINT(lon=c(-30,40),lat=c(50,70))
T2m <- as.4seasons(t2m)
#Extract the grid point with location corresponding to that of the station:
x <- regrid(t2m,is=ferder)
x4s <- as.4seasons(x)
X4s <- regrid(T2m,is=ferder)
y4s1 <- as.4seasons(yd)
y4s2 <- as.4seasons(ym)
plot.zoo(y4s1,lwd=2,xlim=as.Date(c("1980-01-01","2000-01-01")),ylim=c(-10,20))
lines(y4s2,col="red",lty=2)
lines(x4s,col="darkblue",lwd=2)
lines(X4s,col="lightblue",lty=2)

# Select a random season
data(bjornholt)
data(ferder)
plot(as.seasons(ferder,FUN=CDD))
plot(as.seasons(ferder,start=05-17,end=11-11,FUN=HDD))

```

## Description

Applies a canonical correlation analysis (CCA) to two data sets. The CCA here can be carried out based on an [svd](#) based approach (after Bretherton et al. (1992), J. Clim. Vol 5, p. 541, also documented in Benestad (1998): "Evaluation of Seasonal Forecast Potential for Norwegian Land

Temperatures and Precipitation using CCA", DNMI KLIMA Report 23/98 at [http://met.no/english/r\\_and\\_d\\_activities/publications/1998.html](http://met.no/english/r_and_d_activities/publications/1998.html)) or ii) a covariance-eigenvalue approach (after Wilks, 1995, "Statistical methods in the Atmospheric Sciences", Academic Press, p. 401).

The analysis can also be applied to either EOFs or fields.

Note: the analysis has sometimes been somewhat unstable, returning inconsistent results. The recommendation is to use EOFs and SVD option.

The CCA analysis can be used to develop statistical models according to:

$$Y = \Psi X$$

Where Y is the predictand and X the predictor. `plotCCA` plots the CCA results, `testCCA` is for code verification, and `Psi` returns the matrix

$$\Psi$$

`stations2field` turns a group of station objects into a field by the means of a simple and crude interpolation/gridding. `check.repeat` is a quality-control function that eliminates repeated years in the station objects.

Try the same type of argument as in `lm ( ' y ~ x, data= ' )`

### Usage

```
CCA(Y,X,...)
CCA.default(Y,X,...)
CCA.eof(Y,X,i.eofs=1:8)
CCA.pca(Y,X,i.eofs=1:8)
CCA.field(Y,X,i.eofs=1:8)
test.cca(method="CCA",reconstr=FALSE,mode=1,test=TRUE,LINPACK=TRUE,
         SVD=TRUE,n.pc=4,synthetic=TRUE)

predict.CCA <- function(object, newdata=NULL, ...)
```

### Arguments

Y	An object with climate data: field, eof, pca.
X	Same as Y.
SVD	Use a singular value decomposition as a basis for the PCA.
i.eofs	Which EOFs to include in the CCA.
LINPACK	an option for <a href="#">svd</a> .
object	The result from CCA.
newdata	The same as X.

### Value

A CCA object: a list containing a.m, b.m, u.k, v.k, and r, describing the Canonical Correlation variates, patterns and correlations. a.m and b.m are the patterns and u.k and v.k the vectors (time evolution).

**Author(s)**

R.E. Benestad

**Examples**

```
# CCA with two eofs
slp <- slp.NCEP(lat=c(-40,40),anomaly=TRUE)
sst <- sst.NCEP(lat=c(-40,40),anomaly=TRUE)
eof.1 <- EOF(slp,it=1)
eof.2 <- EOF(sst,it=1)
cca <- CCA(eof.1,eof.2)
plot(cca)

# CCA with PCA and EOF:
NACD <- station.nacd()
plot(annual(NACD))
map(NACD,fun="sd")
pca <- PCA(NACD)
plot(pca)
naslp <- slp.NCEP(lon=c(-30,40),lat=c(30,70),anomaly=TRUE)
map(naslp)
eof <- EOF(naslp,mon=1)
nacca <- CCA(pca,eof)
plot(nacca)
```

combine

*Combine***Description**

combine is a S3 method for combining esd objects, e.g. into groups of stations, stations and eof object, or fields. The function is based on [merge](#), and is also used to synchronise the esd objects.

For fields, combine.field is used to append different data sets, e.g. for the purpose of computing common EOFs (see [EOF](#) or for mixing fields (coupled EOFs).

For stations, combine.station can work two ways: (1) to combine a set of stations and group them into one data object; (2) combine series with different monthly values for one specific site into one record for the monthly data. E.g. January, February, ..., December months can be combined into one complete series of monthly data.

For DS-results, combine.ds is based on combine.station, but also takes care of the additional meta data (the original series and predictor patterns). For instance, this method can combine separate downscaled results for each calendar months at a single location into one complete time series.

g2d1 transform objects between grid starting at the greenwich (greenwich=TRUE) and the data line (greenwich=FALSE).

sp2np re-arranges field objects according to a grid going from 90S (South Pole) to 90N (North Pole) for SP2NP=TRUE. Otherwise, the object is arranged from 90N to 90S.

softattr copies the names of a subset of the attributes excluding "index", "dim" and others specified by ignore. attrcp passes on the attributes from one object (x) to another (y).

zeros counts the occurrence of zero values in a vector.

Other operations, such as `c(...)`, `rbind(...)` (combine along the time dimension), and `cbind(...)` (combine along the space dimension) also work.

## Usage

```
attrcp(x,y,ignore=NULL)
combine(x,y,...)
combine.default(x,y,all=FALSE,orig.format=TRUE)
combine.ds(...,all=TRUE)
combine.ds.comb(...,all=TRUE)
combine.ds.station(...,all=TRUE)
combine.ds.pca(...,all=TRUE)
combine.field(x,y,all=FALSE,dimension="time",approach="field",orig.format=TRUE)
combine.field.station(x,y,all=FALSE,orig.format=TRUE)
combine.list(...,all=TRUE)
combine.station(...,all=TRUE)
combine.station.month(...,all=TRUE)
combine.station.eof(x,y,all=FALSE,orig.format=TRUE)
combine.station.field(x,y,all=FALSE,orig.format=TRUE)
combine.stations(...,all=TRUE)
combine.zoo(...,all=TRUE)
g2dl(x,greenwich=TRUE,...)
g2dl.field(x,greenwich=TRUE)
g2dl.corfield(x,greenwich=TRUE)
g2dl.default(x,greenwich=TRUE,lon=NULL,lat=NULL,d=NULL)
g2dl.eof(x,greenwich=TRUE)
sp2np(x,SP2NP=TRUE)
softattr(x,ignore=NULL)
zeros(x)
```

## Arguments

<code>x</code>	station, eof, or field object
<code>all</code>	See <code>link{merge.zoo}</code>
<code>orig.format</code>	TRUE: the result will be formatted the same way as the input.
<code>dimension</code>	Which dimension to combine - in time or in space
<code>approach</code>	How to combine
<code>greenwich</code>	TRUE: center map on the Greenwich line (0E)
<code>SP2NP</code>	TRUE: order from south pole (bottom of plot) to north pole (top of plot)
<code>ignore</code>	List of attributes to ignore.

## Value

A field object

**Author(s)**

R.E. Benestad

**Examples**

```
library(esd)
t2m <- t2m.NCEP(lon=c(-40,40),lat=c(30,70))
T2m <- t2m.NorESM.M(lon=c(-40,40),lat=c(30,70))

# Combine in time to compute common EOFs:
X <- combine(t2m,T2m)
ceof <- EOF(X,it=1)
plot(ceof)

# Use combine to synchronise field and station data:
data(Oslo)
y <- combine.field.station(Oslo,t2m)
plot(y$y)
```

corfield

*Correlation***Description**

Compute the correlation between field objects and station/field.

**Usage**

```
corfield(x,y, use=pairwise.complete.obs,...)
corfield.default(x,y,...)
corfield.zoo(x,y,plot=TRUE,use=pairwise.complete.obs,...)
corfield.field(x,y,plot=TRUE,use=pairwise.complete.obs,...)
corfield.field.station(x,y,plot=TRUE, use=pairwise.complete.obs,...)
corfield.station(x,y,plot=TRUE, use=pairwise.complete.obs,...)
corfield.eof(x,y,pattern=1,plot=TRUE,
             use=pairwise.complete.obs,na.action=na.omit,...)
```

**Arguments**

x	data object
y	data object
plot	TRUE: plot the results
use	see <a href="#">cor</a> .

**Value**

Map of correlation

**Author(s)**

R.E. Benestad and A. Mezghani

**Examples**

```
x <- t2m.ERAINT(lon=c(-40,30),lat=c(0,50))
y <- t2m.NCEP(lon=c(-40,30),lat=c(0,50))
r <- corfield(annual(x),annual(y))

data(Oslo)
t2m <- t2m.ERAINT()
x <- subset(Oslo,it=1)
y <- subset(t2m,it=1)
r <- corfield(x,y)
```

---

crossval

---

*Cross-validation*


---

**Description**

Applies a cross-validation of DS results, using the same strategy as in the DS exercise. Any step-wise screening is applied for each iteration independently of that used to identify the subset of skillful predictors in the original analysis. The model coefficients (beta) is saved for each iteration, and both correlation and root-mean-squared-error are returned as scores.

**Usage**

```
crossval(x, m=5, ...)
crossval.ds(x, m=5, ...)
crossval.list(x, m=5, ...)
```

**Arguments**

x	The results from <a href="#">DS</a> .
m	window with - leave m-out for each iteration.

**Value**

Cross-validation object.

**Author(s)**

R.E. Benestad

## Examples

```
data(Oslo)
t2m <- t2m.NCEP(lon=c(-20,40),lat=c(45,65))
eof <- EOF(t2m,1)

ds <- DS(Oslo,eof)
xv <- crossval(ds)
plot(xv)
```

---

Data

*Sample data.*

---

## Description

Different data sets: station data from northern Europe (NACD, NARP) and historic reconstructions (Oslo, Svalbard) from Dr. Nordli, Met Norway.

The object `station.meta` contains station information, used in the methods [station](#).

Also reduced representation of re-analyses, where the data have been sampled by skipping grid points to reduce the spatila dimensions and stored as 20 EOFs (30 for precipitation). The data compression facilitated by the EOFs can provide 80-90% of the variance in the data. ESD uses the large-scale features from these reanalyses, and hence this information loss may be acceptable for downscaling work.

A reduced copy of the NorESM (M RCP 4.5) is also provided for the examples and demonstrations on how the downscaling can be implemented. Note: downscaling for end-users should never be based on one GCM simulation alone.

The object `geoborders` contains data on coastlines and borders, used in the methods [map](#).

## Usage

```
data(bjornholt)
data(ferder)
data(vardo)
data(eca.meta)
data(station.meta)
data(NACD)
data(NARP)
data(Oslo)
data(Svalbard)
data(eof.t2m.ERAINT)
data(eof.t2m.ERA40)
data(eof.t2m.NCEP)
data(eof.precip.ERAINT)
data(eof.slp.ERAINT)
data(eof.slp.MERRA)
data(eof.slp.NCEP)
data(eof.t2m.NorESM.M)
```



```
data(eof.t2m.DNMI)
data(eof.sst.DNMI)
data(eof.slp.DNMI)
data(geoborders)
slp.MERRA(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.MERRA(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.NCEP(lon=NULL,lat=NULL,anomaly=FALSE)
sst.NCEP(lon=NULL,lat=NULL,anomaly=FALSE)
slp.NCEP(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.ERAINT(lon=NULL,lat=NULL,anomaly=FALSE)
precip.ERAINT(lon=NULL,lat=NULL,anomaly=FALSE)
slp.ERAINT(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.ERA40(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.DNMI(lon=NULL,lat=NULL,anomaly=FALSE)
slp.DNMI(lon=NULL,lat=NULL,anomaly=FALSE)
sst.DNMI(lon=NULL,lat=NULL,anomaly=FALSE)
t2m.NorESM.M(lon=NULL,lat=NULL,anomaly=FALSE)
data(NAOI)
data(sunspots)
data(NINO3.4)
HadCRUT4(url="http://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/time_series/HadCRUT.4.2.0.0.")
```

### Arguments

lon	longitude range c(lin.min,lon.max)
lat	latitude range
anomaly	TRUE: return anomaly
url	source of data
plot	TRUE:plot

### Value

Numeric vectors/matrices with a set of attributes describing the data.

### Author(s)

R.E. Benestad

### See Also

[spatial.avg.field as.4seasons](#), [annual](#)

### Examples

```
data(Oslo)
year <- as.numeric( format(index(Oslo), %Y) )
plot(aggregate(Oslo, by=year, mean, na.rm = FALSE))
```

diagnose

*Diagnose***Description**

Diagnose and examine combined fields, MVR, and CCA results. applies some tests to check for consistency.

The method `diagnose.comb.eof` which estimates the difference in the mean for the PCs of the calibration data and GCMs over a common period in addition to the ratio of standard deviations and lag-one autocorrelation. This 'bias correction' is described in Imbert and Benestad (2005), *Theor. Appl. Clim.* <http://dx.doi.org/10.1007/s00704-005-0133-4>.

`climvar` estimates the climatological variance, e.g. how the inter-annual variance varies with seasons.

**Usage**

```
diagnose(x,...)
diagnose.default(x,...)
diagnose.comb(x)
diagnose.eof(x)
diagnose.comb.eof(x)
diagnose.mvr(x)
diagnose.cca(x)
diagnose.ds(x,plot=FALSE)
diagnose.station(x,it=NULL,...)
diagnose.dsensemble(x,plot=TRUE,plot.type=target,...)
```

**Arguments**

<code>x</code>	data object
<code>it</code>	temporal selection - see <a href="#">subset</a>
<code>plot</code>	
<code>plot.type</code>	

**Value**

A 'diag' object containing test results

**Author(s)**

R.E. Benestad

## Examples

```
t2m <- t2m.NCEP(lon=c(-40,40),lat=c(30,70))
T2m <- t2m.NorESM.M(lon=c(-40,40),lat=c(30,70))
# Combine in time to compute common EOFs:
X <- combine(t2m,T2m)
diagnose(X)

ceof <- EOF(X,it=1)
plot(diagnose(ceof))

slp <- slp.NCEP(lat=c(-40,40),anomaly=TRUE)
sst <- sst.NCEP(lat=c(-40,40),anomaly=TRUE)
eof.1 <- EOF(slp,it=1)
eof.2 <- EOF(sst,it=1)
cca <- CCA(eof.1,eof.2)
diagnose(cca)
```

DS

*Downscale*

## Description

Identifies statistical relationships between large-scale spatial climate patterns and local climate variations for monthly and daily data series.

The function calibrates a linear regression model using step-wise screening and common EOFs ([EOF](#)) as basis functions. It then evaluates the statistical relationship and predicts the local climate parameter from predictor fields.

The function is a S3 method that Works with ordinary EOFs, common EOFs ([combine](#)) and mixed-common EOFs. DS can downscale results for a single station record as well as a set of stations. There are two ways to apply the downscaling to several stations; either by looping through each station and carrying out the DS individually or by using [PCA](#) to describe the characteristics of the whole set. Using PCA will preserve the spatial covariance seen in the past. It is also possible to compute the PCA prior to carrying out the DS, and use the method `DS.pca`. `DS.pca` differs from the more generic DS by (default) invoking different regression modules (`link{MVR}` or [CCA](#)).

The rationale for using mixed-common EOFs is that the coupled structures described by the mixed-field EOFs may have a more physical meaning than EOFs of single fields [Benestad et al. (2002), "Empirically downscaled temperature scenarios for Svalbard", *Atm. Sci. Lett.*, doi.10.1006/asle.2002.0051].

The function `DS()` is a generic routine which in principle works for when there is any real statistical relationship between the predictor and predictand. The predictand is therefore not limited to a climate variable, but may also be any quantity affected by the regional climate. *It is important to stress that the downscaling model must reflect a well-understood (physical) relationship.*

The routine uses a step-wise regression (step) using the leading EOFs. The calibration is by default carried out on de-trended data [ref: Benestad (2001), "The cause of warming over Norway in the ECHAM4/OPYC3 GHG integration", *Int. J. Clim.*, 15 March, **vol 21**, p.371-387.].

The function `biasfix` provides a type of 'bias correction' based on the method `diagnose` which estimates the difference in the mean for the PCs of the calibration data and GCMs over a common period in addition to the ratio of standard deviations and lag-one autocorrelation. This 'bias correction' is described in Imbert and Benestad (2005), *Theor. Appl. Clim.* <http://dx.doi.org/10.1007/s00704-005-0133-4>.

## Usage

```
DS(y,X,verbose=TRUE,plot=FALSE,...)
DS.default(y,X,mon=NULL,
           method="lm",swsm="step",
           rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
           verbose=FALSE,...)
DS.station(y,X,biascorrect=FALSE,mon=NULL,
           method="lm",swsm="step",
           rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
           verbose=FALSE,pca=TRUE,neofs=20,...)
DS.eof(X,y,mon=NULL,
       method="lm",swsm="step",
       rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
       verbose=FALSE,pca=TRUE,npca=20,...)
DS.comb(X,y,biascorrect=FALSE,mon=NULL,
        method="lm",swsm="step",
        rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
        verbose=FALSE,...)
DS.field(X,y,biascorrect=FALSE,mon=NULL,
         method="lm",swsm="step",
         rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
         verbose=FALSE,...)
DS.t2m.month.field(y,X,biascorrect=FALSE,mon=NULL,
                  method="lm",swsm="step",
                  rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
                  verbose=FALSE,station=TRUE)
DS.t2m.season.field(y,X,biascorrect=FALSE,
                   method="lm",swsm="step",
                   rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
                   verbose=FALSE,station=TRUE)
DS.t2m.annual.field(y,X,biascorrect=FALSE,
                   method="lm",swsm="step",
                   rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
                   verbose=FALSE,station=TRUE)
DS.precip.season.field(y,X,biascorrect=FALSE,
                      method="lm",swsm="step",
                      rmtrend=TRUE,eofs=1:7,area.mean.expl=FALSE,
                      verbose=FALSE,...)
DS.freq(y,X,threshold=1,biascorrect=FALSE,method="glm",
        family="gaussian",swsm="step",
        rmtrend=TRUE,eofs=1:7,verbose=FALSE,...)
DS.spell(y,X,threshold=1,biascorrect=FALSE,method="glm",
```

```

family="gaussian",swsm="step",
    rmtrend=TRUE,eofs=1:7,verbose=FALSE,...)
DS.pca(y,X,biascorrect=FALSE,mon=NULL,
    method="MVR",swsm=NULL,rmtrend=TRUE,...)
predict.ds.mon(x,...)
sametimescale(y,X,FUN=mean)
biasfix(x)

```

## Arguments

y	The predictand - the station series representing local climate parameter
X	The predictor - an EOF object representing the large-scale situation.
mon	An integer or a vector of integers. The calendar month to downscale, e.g. '1' is all January months, '2' is February, and so on.
method	Model type, e.g. <code>lm</code> or <code>glm</code>
swsm	Stepwise screening, e.g. <code>step</code> . NULL skips stepwise screening
rmtrend	TRUE for detrending the predicant and predictors (in the PCs) before calibrating the model
eofs	Which EOF modes to include in the model training.
plot	TRUE: plot the results
verbose	TRUE: suppress output to the terminal.
station	TRUE: convert monthly data to station class using <code>combine.ds</code> , else return a list of different monthly DS-results.
area.mean.exp1	When TRUE, subtract the area mean for the domain and use as a the first co-variate before the PCs from the EOF analysis.

## Value

The downscaling analysis returns a time series representing the local climate, patterns of large-scale anomalies associated with this, ANOVA, and analysis of residuals. Care must be taken when using this routine to infer local scenarios: check the R2 and p-values to check whether the calibration yielded an appropriate model. It is also important to examine the spatial structures of the large-scale anomalies associated with the variations in the local climate: do these patterns make physical sense?

It is a good idea to check whether there are any structure in the residuals: if so, then a linear model for the relationship between the large and small-scale structures may not be appropriate. It is furthermore important to experiment with predictors covering different regions [ref: Benestad (2001), "A comparison between two empirical downscaling strategies", *Int. J. Climatology*, **vol 21**, Issue 13, pp.1645–1668. DOI 10.1002/joc.703].

There is a cautionary tale for how the results can be misleading if the predictor domain is not appropriate: domain for northern Europe used for sites in Greenland [ref: Benestad (2002), "Empirically downscaled temperature scenarios for northern Europe based on a multi-model ensemble", *Climate Research*, **vol 21** (2), pp.105–125. <http://www.int-res.com/abstracts/cr/v21/n2/index.html>]

**Author(s)**

R.E. Benestad

**Examples**

```

# One exampe doing a simple ESD analysis:
X <- t2m.ERA40(lon=c(-40,50),lat=c(40,75))
data(Oslo)
#X <- OptimalDomain(X,Oslo)
Y <- DS(Oslo,X)
plot(Y)
str(Y)

# Look at the residual of the ESD analysis
y <- as.residual(Y)
plot(y)

# Check the residual: dependency to the global mean temperature?
T2m <- (t2m.ERA40())
yT2m <- merge.zoo(y,T2m)
plot(coredata(yT2m[,1]),coredata(yT2m[,2]))

data(t2m.DNMI)
y <- station.eca("Oslo")
X <- EOF(t2m.DNMI,mon=1)
ds <- DS.month.eof(y,X)

# Example: downscale annual wet-day mean precipitation -calibrate over
# part of the record and use the other part for evaluation.
T2M <- as.annual(t2m.NCEP(lon=c(-10,30),lat=c(50,70)))
cal <- subset(T2M,it=c("1948-01-01","1980-01-01"))
pre <- subset(T2M,it=c("1981-01-01","2013-01-01"))
comb <- combine(cal,pre)
X <- EOF(comb)
data(bjornholt)
y <- as.annual(bjornholt,FUN="exceedance")
z <- DS(y,X)
plot(z)

lon <- c(-12,37)
lat <- c(52,72)
ylim <- c(-6,6)
t2m <- t2m.NCEP(lon=lon,lat=lat)
T2m <- t2m.NorESM.M(lon=lon,lat=lat)
data(Oslo)
X <- combine(t2m,T2m)

eof <- EOF(X,it=7)
ds <- DS(Oslo,eof)
plot(ds)

DS(Oslo,X,station=FALSE) -> y

```

```

Y <- combine.ds.comb(y)
plot(Y)

data(ferder)
t2m <- t2m.NCEP(lon=c(-30,50),lat=c(40,70))
slp <- slp.NCEP(lon=c(-30,50),lat=c(40,70))
T2m <- as.4seasons(t2m)
SLP <- as.4seasons(slp)
X <- EOF(T2m,it=1)
Z <- EOF(SLP,it=1)
y <- ferder
sametimescale(y,X) -> z
ym <- as.4seasons(y,FUN="mean")
ys <- as.4seasons(y,FUN="sd")
dsm <- DS(ym,X)
dss <- DS(ys,Z)

```

DSE

*Downscale monthly climate variables and parameters for several stations.*

## Description

Performs a complete downscaling job based on [DSensemble](#) for several stations and save the down-scaled results locally. DSE can be used to downscale climate variables, parameters or statistics for various stations. Each station is downscaled separately for the whole rcp/gcm ensemble and stored the results in a separate rda file. DSE() will also generate two files: an inventory file containing the meta data and some statistics for the successfully downscaled stations and log file containing encountered errors and a list of stations that have not been downscaled.

## Usage

```

DSE.default(cntr, src, param, FUN, lon, lat, path, rcp, biascorrect, reanalysis,
            email, save, out.dir, force, update, ...)
DSE.metno(x,...) # Downscale METNO stations
DSE.ecad(x,...)
DSE.ghcnd(x,...)
meta.dse(path) # update the inventory file with additional downscaled results.

```

## Arguments

stid	A string of characters as an identifier of the weather/climate station.
param	Parameter or element type or variable identifier. There are several core parameters or elements as well as a number of additional parameters. The parameters or elements are: prcp, pr = Precipitation (mm) tas, tavg = 2m-surface temperature (in degrees Celcius) tmax, tasmax = Maximum temperature (in degrees Celcius) tmin, tasmin = Minimum temperature (in degrees Celcius)

<code>FUN</code>	A mathematical transformation of the parameter e.g. "mean", "sd", "r1", etc ...
<code>rcp</code>	A character string corresponding to the name of the RCP experiment. Possible values for CMIP5 are rcp20, rcp45, rcp65, rcp85. For the CMIP3, they are: sresa1b, sresa2.
<code>src</code>	Source: limit the downscaling to a specific data set ("NARP", "NACD", "NORD-KLIMA", "GHCNM", "METNOM", "ECAD", "GHCND" and "METNOD")
<code>stid</code>	A string of characters as an identifier of the weather/climate station.
<code>lon</code>	A numeric vector containing the range of longitude values in the form of c(lon.min,lon.max) which corresponds to the predictor longitude extension
<code>lat</code>	A numeric vector containing the range of latitude values in the form of c(lat.min,lat.max) which corresponds to the predictor latitude domain extension
<code>biascorrect</code>	Logical value. If TRUE, a bias correction method is applied
<code>save</code>	Logical value. If TRUE, the results are save in rda files and stored locally in directory specified by path.
<code>out.dir</code>	A character string of the full path specifying the name of the output directory. If the directory does not exist, it will be created automaitcally.
<code>cntr</code>	A string or a vector of strings of the full name of the country. Select the stations from a specified country or a set of countries.
<code>force</code>	Logical value. If TRUE, the DSE is performed from scratch and all existing DSE files will be re-written. If FALSE, DSE will skip already downscaled stations and do the downscaling only for non existing file stations.
<code>path</code>	A character string corresponding to the full path name of the CMIP3/5 results.
<code>reanalysis</code>	A character string with the full path file name of the reanalysis to be used. Only netcdf files are accepted. update=
<code>email</code>	A character string with an email address. If specified, a notification email is sent when the downscaling is complete. The email text message contains a list of non-downscaled stations because of errors. If any error, please forward the email to abdelkadem@met.no
<code>update</code>	A logical value. If TRUE, <a href="#">meta.dse</a> is called and the inventory file is updated if additional DSE files are copied to output directory.
<code>...</code>	Additional arguments to be passed in the function

**Value**

A "zoo" "DSensemble" object

**Author(s)**

A. Mezghani, MET Norway

**See Also**

[DSensemble](#)



## Examples

```
## Not run:
DSE.metno(cntr = "NORWAY", src = "METNO", param = "t2m", nmin=100,
  lon = c(-10, 10), lat = c(-10, 10), FUN = "mean", path = "CMIP5.monthly",
  rcp = "rcp45", biascorrect = TRUE, reanalysis = "ERA40_t2m_mon.nc",
  email = NULL, save = TRUE, force = FALSE, verbose = FALSE,
  out.dir = "dse.100", update = FALSE)

## End(Not run)
```

---

DSensemble

*Downscale ensemble runs*


---

## Description

Downscales an ensemble of climate model runs, e.g. CMIP5, taking the results to be seasonal climate statistics. For temperature, the result hold the seasonal mean and standard deviation, whereas for precipitation, the results hold the wet-day mean, the wet-day frequency, and the wet/dry-spell statistics. The call assumes that netCDF files containing the climate model ensemble runs are stores in a file structure, linked to the path argument and the rcp argument.

These methods are based on [DS](#), and DSensemble is designed to make a number of checks and evaluations in addition to performing the DS on an ensemble of models. It is based on a similar philosophy as the old R-package 'clim.pact', but there is a new default way of handling the predictors. In order to attempt to ensure a degree of consistency between the downscaled results and those of the GCMs, a fist covariate is introduced before the principal components (PCs) describing the [EOFs](#). The argument `area.mean.exp1=TRUE` will take the time series describing area mean value for the selected predictor domain as the first covariate, followed by the PCs. These are then used in the regression analysis.

The argument `non.stationarity.check` is used to conduct an additional test, taking the GCM results as 'pseudo-reality' where the predictand is replaced by GCM results interpolated to the same location as the provided predictand. The time series with interpolated values are then used as predictor in calibrating the model, and used to predict future values. This set of prediction is then compared with the interpolated value itself to see if the dependency between the large and small scales in the model world is non-stationary.

Other chekch include cross-validation ([crossval](#)) and diagnostics comparing the sample of ensemble results with the observations: number of observations outside the predicted 90-percent conf. int and comparing trends for the past.

## Usage

```
DSensemble(y,...)
DSensemble.default(y,path=CMIP5.monthly/,rcp=rcp45,...)
DSensemble.t2m(y,plot=TRUE,path="CMIP5.monthly/",
  predictor="ERA40_t2m_mon.nc",
  rcp="rcp45",biascorrect=FALSE,
  area.mean.exp1=FALSE,
```

```

        non.stationarity.check=FALSE,
        eofs=1:6,lon=c(-15,15),lat=c(-10,10),
        select=NULL,FUN="mean",FUNX="mean",
        pattern="tas_Amon_ens_",verbose=FALSE)
DSensemble.precip(y,plot=TRUE,path="CMIP5.monthly/",
        rcp="rcp45",biascorrect=FALSE,
        predictor="ERA40_pr_mon.nc",
        area.mean.expl=FALSE,
        non.stationarity.check=FALSE,
        eofs=1:6,lon=c(-15,15),lat=c(-10,10),
        select=NULL,FUN="exceedance",
        FUNX="sum",threshold=1,
        pattern="pr_Amon_ens_",verbose=FALSE)
DSensemble.mu(y,plot=TRUE,path="CMIP5.monthly/",
        rcp="rcp45",biascorrect=FALSE,
        predictor="ERA40_t2m_mon.nc",
        non.stationarity.check=FALSE,
        eofs=1:16,lon=c(-30,20),lat=c(-20,10),
        select=NULL,FUN="wetmean",
        FUNX="C.C.eq",threshold=1,
        pattern="tas_Amon_ens_",verbose=FALSE)

```

### Arguments

<code>y</code>	A station object.
<code>plot</code>	Plot intermediate results if TRUE.
<code>path</code>	The path where the GCM results are stored.
<code>rcp</code>	Which (RCP) scenario
<code>area.mean.expl</code>	When TRUE, subtract the area mean for the domain and use as a the first co-variate before the PCs from the EOF analysis.

### Value

A 'dsensemble' object - a list object holding DS-results.

### Author(s)

R.E. Benestad and A. Mezghani

### Examples

```

y <- station.metnod("Oslo - Blindern")
rcp4.5 <- DSensemble(subset(y,is=1),plot=TRUE)
plot(rcp4.5)

# Evaluation: (1) compare the past trend with downscaled trends for same
# interval by ranking and by fitting a Gaussian to the model ensemble;
# (2) estimate the probability for the counts outside the 90
# percent confidence interval according to a binomial distribution.

```

```
dstest <- diagnose(rcp4.5)
plot(dstest)
```

---

ele2param	<i>Dictionary and conversion tools between esd element identifier and variables names and specifications.</i>
-----------	---

---

## Description

Converts between esd element/parameter identifier and names from different data sources.

## Usage

```
ele2param(ele = 101, src = GHCND)
esd2ele(param=t2m,src=GHCND,verbose=FALSE)
```

## Arguments

param,ele	Parameter or element identifier. There are several core parameters or elements as well as a number of additional parameters. The parameters or elements are : PARAMETER LONGNAME ELE ID auto Automatic selection. prcp, pr, rr, precip Precipitation (mm) '601' tas, tavg, t2m, t2 2m-surface temperature (in degrees Celcius) '101' tmax, tasmax Maximum temperature (in degrees Celcius) '111' tmin, tasmin Minimum temperature (in degrees Celcius) '121' slp, mslp Mean sea level pressure (hPa) '401' cloud Cloud cover (%) '801' ...
src	A character string for the acronym of the data source. The data sources are : NACD : North Atlantic Climatological Dataset - Monthly NARP : North Atlantic Research Programme ? - Monthly NORDKLIM : Nordic co-operation within climate activities - Monthly GHCNM : Global historical climate network - Monthly ECAD : European Climate Assessment & Dataset- Daily GHCND : Global Historical Climate Network - Daily METNO : MET Norway climate network - Daily

## Value

A meta data matrix object with the glossary of the different variables or element identifiers as originally defined by each data source

## Author(s)

A. Mezghani, MET Norway

## Examples

```
## Not run:
# Eg.1 # Display the glossary of parameters or element identifiers for GHCND data source.
print(ele2param(ele=NULL,src=GHCND))
# Eg.2 # Display the glossary of parameters or element identifiers for all data sources.
print(ele2param())
# Eg.3 # Convert mean temperature parameter (param) to esd element (ele).
ele <- esd2ele(param=t2m)
print(ele)

## End(Not run)
```

---

 EOF

*Empirical Orthogonal Functions (EOFs).*


---

## Description

Computes EOFs (a type of principal component analysis) for combinations of data sets, typically from gridded data, reanalysis and climate models results.

[ref: Benestad (2001), "A comparison between two empirical downscaling strategies", *Int. J. Climatology*, **vol 21**, Issue 13, pp.1645-1668. DOI 10.1002/joc.703]. and `mixFields` prepares for mixed-field EOF analysis [ref. Bretherton et al. (1992) "An Intercomparison of Methods for finding Coupled Patterns in Climate Data", *J. Climate*, **vol 5**, 541-560; Benestad et al. (2002), "Empirically downscaled temperature scenarios for Svalbard", *Atm. Sci. Lett.*, doi.10.1006/asle.2002.0051].

Uncertainty estimates are computed according to North et al. (1982), "Sampling Errors in the Estimation of Empirical Orthogonal Functions", *Mon. Weather Rev.*, **vol 110**, 699-706.

The EOFs are based on `svd`.

See the course notes from Environmental statistics for climate researchers <http://www.gfi.uib.no/~nilsg/kurs/notes/course.html> for a discussion on EOF analysis.

The method PCA is similar to EOF, but designed for parallel station series (e.g. grouped together with `merge`). PCA does not assume gridded values and hence does not weigh according to grid area. PCA is useful for downscaling where the spatial covariance/coherence is important, e.g. involving different variables from same site, same variable from different sites, or a mix between these. For instance, PCA can be applied to the two wind components from a specific site and hence extract the most important wind directions/speeds.

## Usage

```
EOF(X, it=NULL, n=20, lon=NULL, lat=NULL, verbose=FALSE, ...)
EOF.default(X, it=NULL, n=20, lon=NULL, lat=NULL,
            area.mean.exp1=TRUE, verbose=FALSE, ...)
EOF.field(X, it=NULL, n=20, lon=NULL, lat=NULL,
          area.mean.exp1=TRUE, verbose=FALSE)
EOF.comb(X, it=NULL, n=20, lon=NULL, lat=NULL, area.mean.exp1=TRUE, verbose=FALSE)
eof2field(eof, is=NULL, lon=NULL, lat=NULL, anomaly=FALSE)
PCA(X, ...)
```

```
EOF.default(X,...)
PCA.station(X,na.action=fill,verbose=FALSE)
pca2station(X,lon=NULL,lat=NULL,anomaly=FALSE)
```

### Arguments

X	a 'field' or 'pca' object
it	see <a href="#">subset</a>
n	number of EOFs
is	Spatial subsetting - see <a href="#">subset.eof</a>
lon	set longitude range - see <a href="#">t2m.ERAINT</a>
lat	set latitude range
verbose	TRUE - clutter the screen with messages
area.mean.exp1	When TRUE, subtract the area mean for the domain and use as a the first co-variate before the PCs from the EOF analysis.
na.action	'fill' uses <a href="#">approx</a> to interpolate the NA-values before the PCA.

### Value

File containing an 'eof' object which is based on the 'zoo' class.

### Author(s)

R.E. Benestad

### Examples

```
# Simple EOF for annual mean SST:
sst <- sst.NCEP(lon=c(-90,20),lat=c(0,70))
SST <- aggregate(sst, year, mean, na.rm = FALSE)
eof.sst <- EOF(SST)
plot(eof.sst)

# EOF of July SST:
eof.sst7 <- EOF(sst,it=7)
plot(eof.sst7)

# common EOF for model
# Get some sample data, extract regions:
GCM <- t2m.NorESM.M()
gcm <- subset(GCM,is=list(lon=c(-50,60),lat=c(30,70)))
t2m.eraint <- t2m.ERAINT()
eraint <- subset(t2m.eraint,is=list(lon=c(-50,60),lat=c(30,70)))

OBS <- aggregate(eraint, by=year, mean, na.rm = FALSE)
GCM <- aggregate(gcm, by=year, mean, na.rm = FALSE)
OBSGCM <- combine(OBS,GCM,dimension=time)

ceof <- EOF(OBSGCM)
```

```

plot(ceof)

# Example for using PCA in downscaling
nacd <- station(src=nacd)
X <- annual(nacd)
nv <- function(x) sum(is.finite(x))
ok <- (1:dim(X)[2])[apply(X,2,nv) == dim(X)[1]]
X <- subset(X,is=ok)
pca <- PCA(X)
map(pca)

slp <- slp.NCEP(lon=c(-20,30),lat=c(30,70))
eof <- EOF(slp,it=1)
ds <- DS(pca,eof)
# ds is a PCA-object
plot(ds)

# Recover the station data:
Z <- pca2station(ds)
plot(Z)

```

---

iid.test

*iid test*


---

## Description

Test for whether a variable is independent and identically distributed (iid). Used in [daily.station.records](#).

Reference:

Benestad, R.E., 2003: How often can we expect a record-event? Climate Research. 23, 3-13 (pdf)

Benestad, R.E., 2004: Record values, nonstationarity tests and extreme value distributions, Global and Planetary Change, vol 44, p. 11-26

The papers are available in the pdf format from [http://regclim.met.no/results\\_iii\\_artref.html](http://regclim.met.no/results_iii_artref.html).

Note, gaps of missing data (NA) can bias the results and produce an under-count. The sign of non-iid behaviour is when the 'forward' analysis indicated higher number of record-events than the confidence region and the backward analysis gives lower than the confidence region.

Version 0.7: Added a test checking for dependencies based on an expected number from a binomial distribution and given the probability  $p1(n) = 1/n$ . This test is applied to the parallel series for one respective time (realisation), and is then repeated for all observation times. The check uses [qbinom](#) to compute a theoretical 95% confidence interval, and a number outside this range is marked with red in the 'ball diagram' (first plot). [pbinom](#) is used to estimate the p-value for the

## Usage

```

iid.test(x,plot=TRUE,Monte.Carlo=TRUE,N.test=200,reverse.plot.reverse=TRUE)
n.records(x)

```

**Arguments**

<code>x</code>	A data matrix or a vector.
<code>plot</code>	Flag: plot the diagnostics.
<code>Monte.Carlo</code>	Flag: for estimating confidence limits.
<code>N.test</code>	Number of Monre-Carlo runs.
<code>reverse.plot.reverse</code>	TRUE: plots reverse from right to left, else left to right..

**Value**

list: 'record.density' and 'record.density.rev' for the reverse analysis. The variables CI.95, p.val, and i.cluster (and their reverse equivalents '.rev') return the estimated 95% conf. int, p-value, and the location of the clusters (binomial).

**Author(s)**

R.E. Benestad

**Examples**

```
dat <- rnorm(100*30)
dim(dat) <- c(100,30)
iid.test(dat)
```

---

InfoGraphics

*InfoGraphics.*

---

**Description**

Wheel

Risk

prob - boxes with foreseen outcomes - area proportional to probability

conf - confidence intervals and uncertainty - clouds...

vis

diagram

cumugram

Usage

```
vis(x,...)
diagram(x,...)
diagram.dsensemble(x,it=0,...)
wheel(x,...)
wheel.station(x,new=TRUE,lwd=2,col=NULL,bg="grey90",...)
wheel.spell(x,new=TRUE,lwd=2,col=NULL...)
cumugram(x,it=NULL,...)
climvar(x,FUN=sd,plot=TRUE,...)
colscal(n=30,col="bwr",test=FALSE)
seasevol(x,...)
seasevol.station(x,it=NULL,nv=25,...)
```

Arguments

x                      a data object

Value

A field object

Author(s)

R.E. Benestad and A. Mezghanil

See Also

[map](#), [plot.station](#), [hist.spell](#)

Examples

```
data(bjornholt)
wheel(bjornholt)

z <- spell(bjornholt)
wheel(spell,dry=TRUE)
```

---

is	<i>Test for .</i>
----	-------------------

---

Description

Computes different formulas

Usage

```
is.T(x)
is.precip(x)
```



**Arguments**

x                      a data object

**Value**

Boolean

**Author(s)**

R. Benestad, MET Norway

**Examples**

```
data(ferder)
is.T(ferder)
```

---

map	<i>Plot maps for esd objects</i>
-----	----------------------------------

---

**Description**

Make map of geophysical data. These plot functions are S3 methods for esd objects.

**Usage**

```
map(x,it=NULL,is=NULL,new=TRUE,...)
map.default(x,it=NULL,is=NULL,new=TRUE,projection="lonlat",
            xlim=NULL,ylim=NULL,n=15,
            col=NULL,breaks=NULL,
            what=NULL,gridlines=FALSE,
            lonR=NULL,latR=-90,axiR=NULL,...)
map.matrix(x,new=TRUE,...)
map.comb(x,it=NULL,is=NULL,new=TRUE,xlim=NULL,ylim=NULL,
         pattern=1,n=15,
         projection="lonlat",col=NULL,breaks=NULL,
         lonR=NULL,latR=NULL,axiR=0,what=c("fill","contour"),
         gridlines=TRUE,...)
map.eof(x,it=NULL,is=NULL,new=TRUE,pattern=1,
        xlim=NULL,ylim=NULL,n=15,
        projection="lonlat",col=NULL,
        breaks=NULL,lonR=NULL,latR=NULL,axiR=0,
        what=c("fill","contour"),gridlines=TRUE,...)
map.ds(x,it=NULL,is=NULL,new=TRUE,xlim=xlim,ylim=ylim,
       what=c("fill","contour"),
       n=15,projection="lonlat",
       lonR=NULL,latR=NULL,axiR=0,gridlines=TRUE,
       col=NULL,breaks=NULL,...)
```

```

map.field(x,it=NULL,is=NULL,new=TRUE,xlim=NULL,ylim=NULL,
          what=c("fill","contour"),
          FUN=mean,n=15,projection="lonlat",
          lonR=NULL,latR=NULL,na.rm=TRUE,
          axiR=0,gridlines=FALSE,col=NULL,breaks=NULL,...)
map.corfield(x,new=TRUE,xlim=NULL,ylim=NULL,n=15,
             projection="lonlat",
             col=NULL,breaks=seq(-1,1,0.1),
             lonR=NULL,latR=NULL,axiR=0,what=c("fill","contour"),
             gridlines=TRUE,...)
map.trend(x,it=NULL,is=NULL,new=TRUE,xlim=NULL,ylim=NULL,n=15,
          projection="lonlat",
          col=NULL,breaks=NULL,
          lonR=NULL,latR=NULL,axiR=0,what=c("fill","contour"),
          gridlines=TRUE,...)
map.pca(x,new=TRUE,FUN=mean,pattern=1,...)
map.mvr(x,it=NULL,is=NULL,new=TRUE,xlim=NULL,ylim=NULL,
        n=15,projection="lonlat",
        col=NULL,breaks=NULL,
        lonR=NULL,latR=NULL,axiR=0,what=c("fill","contour"),
        gridlines=TRUE,...)
map.cca(x,it=NULL,is=NULL,new=TRUE,icca=1,xlim=NULL,ylim=NULL,
        what=c("fill","contour"),
        n=15,projection="lonlat",
        lonR=NULL,latR=NULL,
        axiR=0,gridlines=FALSE,col=NULL,breaks=NULL,...)
lonlatprojection(x,it=NULL,is=NULL,xlim=NULL,ylim=NULL,
                 n=15,col=NULL,breaks=NULL,geography=TRUE,
                 what=c("fill","contour"),gridlines=TRUE,
                 new=TRUE,...)
map.googleearth(x)
rotM(x=0,y=0,z=0)
gridbox(x,cols,density = NULL, angle = 45)
map2sphere(x,lonR=NULL,latR=NULL,axiR=0,
           what=c("fill","contour"),gridlines=TRUE,cols=NULL)

```

### Arguments

x	the object to be plotted
pattern	Which EOF pattern (mode) to plot
cols	Colour scales, either as an output from <a href="#">rbg</a> or a single character string 'bwr' (blue-white-red) og 'rwb' (red-white-blue')

### Value

A field object

**Author(s)**

R.E. Benestad

**See Also**[plotstation](#)**Examples**

```
# Example: use aggregate to compute annual mean temperature for Svalbard:
data(Svalbard)
year <- as.numeric( format(index(Svalbard), %Y) )
y <- aggregate(Svalbard, by=year, mean, na.rm = FALSE)
plot(y)
```

MVR

*Multi-variate regression***Description**

MVR solves the equation

$$Y = \Psi X$$

and estimates

$$\Psi$$

by inverting the equation. Predictions give the value of Y, given this matrix and some input. MVR is useful for data where Y contains several time series where the spatial coherence/covariance is important to reproduce. For instance, Y may be a combination of stations, the two wind components from one station, or a set of different elements from a group of stations.

**Usage**

```
MVR(Y,X,...)
MVR.default(Y,X,...)
MVR.field(Y,X,SVD=TRUE,LINPACK=FALSE)
MVR.pca(Y,X,SVD=TRUE,LINPACK=FALSE)
MVR.eof(Y,X,SVD=TRUE,LINPACK=FALSE)
predict.MVR(object, newdata=NULL, ...)
```

**Arguments**

Y	An object with climate data: field, eof, or pca.
X	Same as Y or any zoo object.
SVD	Use a singular value decomposition as a basis for the PCA.
i.eofs	Which EOFs to include in the CCA.
LINPACK	an option for <a href="#">svd</a> .
object	The result from CCA.
newdata	The same as X.

**Value**

A CCA object: a list containing a.m, b.m, u.k, v.k, and r, describing the Canonical Correlation variates, patterns and correlations. a.m and b.m are the patterns and u.k and v.k the vectors (time evolution).

**Author(s)**

R.E. Benestad

**Examples**

```
## Not run:
# Example for using EOF and MVR
slp <- slp.NCEP(lat=c(-40,40),anomaly=TRUE)
sst <- sst.NCEP(lat=c(-40,40),anomaly=TRUE)
eof.1 <- EOF(slp,mon=1)
eof.2 <- EOF(sst,mon=1)
mvr <- MVR(eof.1,eof.2)
plot(mvr)

# Example for using PCA and MVR
oslo <- station(src="NACD",loc="Oslo")
bergen <- station.nacd("Bergen")
stockholm <- station.nacd("Stockholm")
copenhagen <- station.nacd("Koebenhavn")
helsinki <- station.nacd("Helsinki")
reykjavik <- station.nacd("Stykkisholmur")
edinburgh <- station.nacd("Edinburgh")
debilt <- station.nacd("De_Bilt")
uccle <- station.nacd("Uccle")
tromso <- station.nacd("Tromsoe")
falun <- station.nacd("Falun")
stensele <- station.nacd("Stensele")
kuopio <- station.nacd("Kuopio")
valentia <- station.nacd("Valentia")
X <- combine(oslo,bergen,stockholm,copenhagen,helsinki,reykjavik,
             edinburgh,debilt,uccle,tromso,falun,stensele,kuopio,valentia)
pca <- PCA(X)
slp <- slp.NCEP(lon=c(-20,30),lat=c(30,70))
eof <- EOF(slp)
mvr <- MVR(pca,eof)
plot(mvr)

# Find the teleconnection pattern to the NAO
data("NAOI")
data("sunspots")
data("NINO3.4")
X <- merge(NAOI,sunspots,NINO3.4,all=FALSE)

mvr <- MVR(pca,X)

# Find the pattern for NAOI:
```

```
teleconnection <- predict(mvr,newdata= c(1,0,0))
map(teleconnection,cex=2)

## End(Not run)
```

plot.station

*Plot esd objects*

## Description

These plot functions are S3 methods for esd objects.

## Usage

```
nam2expr(x)
plot.station(x,plot.type="single",new=TRUE,
             lwd=3,type=1,pch=0,main=NULL,col=NULL,
             xlim=NULL,ylim=NULL,xlab="",ylab=NULL,...)
plot.eof(x,new=TRUE,xlim=NULL,ylim=NULL,pattern=1,what=c("pc","eof","var"),...)
plot.eof.field(x,new=TRUE,xlim=NULL,ylim=NULL,pattern=1,what=c("pc","eof","var"),...)
plot.eof.comb(x,new=TRUE,xlim=NULL,ylim=NULL,
              pattern=1,col=c("red"),what=c("pc","eof","var"),...)
plot.eof.var(x,new=TRUE,xlim=NULL,ylim=NULL,pattern=20,...)
plot.ds(x,plot.type="single",what=c("map","ts"),new=TRUE,
        lwd=3,type=b,pch=0,main=NULL,col=NULL,
        xlim=NULL,ylim=NULL,xlab="",ylab=NULL,...)
plot.CCA(x,icca=1)
plot.field(x,is=NULL,it=NULL,FUN="mean",...)
plot.spell(x)
plot.diagnose(x,...)
plot.diagnose.comb.eof(x,...)
plot.xval(x,...)
plot.dsensemble(x,pts=FALSE,showci=TRUE,showtrend=TRUE,legend=TRUE,it=0,
               envcol=c(1,0,0,0.2),...)
```

## Arguments

x	the object to be plotted
pattern	Which EOF pattern (mode) to plot
col	Colour
icca	Which CCA pattern to plot
is	For subsetting in space - See <code>link{subset}</code> , but can also be a station value and if provided, the plotting will involve an interpolation to the same coordinates as defined by is.
it	For subsetting in time - See <code>link{subset}</code> . 'it=0' returns the annual means (mean of DJF + MAM + JJA + SON)
FUN	function

**Value**

A field object

**Author(s)**

R.E. Benestad

**Examples**

```
# Example: use aggregate to compute annual mean temperature for Svalbard:
data(Svalbard)
year <- as.numeric( format(index(Svalbard), %Y) )
y <- aggregate(Svalbard, by=year, mean, na.rm = FALSE)
plot(y)

# Example with downscaling:
lon <- c(-12,37)
lat <- c(52,72)
t2m <- t2m.ERA40(lon=lon,lat=lat)
data(Oslo)
ds <- DS(Oslo,t2m)

# Plot the results for January month
plot(ds$Jan)

# Plot the residuals:
residual <- as.residual(ds)
obs <- as.anomaly(as.calibrationdata(ds))

plot.zoo(obs,lwd=2)
lines(residual,col="red")

print("Global climate model simulation NorESM")
T2m <- t2m.NorESM.M(lon=lon,lat=lat)

# Plot the global mean of the field:
plot(T2m)
# Plot area mean of a sub region
plot(T2m,is=list(lon=c(0,10),lat=c(60,70)))

# Plot interpolated results corresponding to ferder
data(ferder)
plot(T2m,ferder)

# Plot Hovmuller diagram:
plot(T2m,is=list(lon=0))

print("Extract a subset - the January month")
x <- subset(t2m,it=1)
X <- subset(T2m,it=1)

print("Combine the fields for computing common EOFs:")
```

```

XX <- combine(x,X)

print("Compute common EOFs")
eofxx <- EOF(XX)
plot(eofxx)

print("Downscale the January mean temperature")
ds.jan <- DS(Oslo,eofxx)
plot(ds.jan)

```

regrid

*Regrid*

## Description

Fast transform data from one longitude-latitude grid to another through bi-linear interpolation. The regridding is done by first calculating a set of weights

Let  $X(i,j)$  be a  $i$ - $j$  matrix containing the data on a grid with  $i$  longitudes and  $j$  latitudes. We want to transform this to a different grid with  $k$  longitudes and  $l$  latitudes:

$X(i,j) \rightarrow Y(k,l)$

First the routine computes a set of weight, then performs a matrix multiplication to map the original data onto the new grid. The weights are based on the distance between points, taking longitude & latitude and use `distAB()` to estimate the geographical distance in km.

The matrix operation is:  $Y = \text{beta} X$

beta is a matrix with dimensions  $(i*j,k*l)$

$(Y(1,1) \text{ } (beta(1,1), beta(2,1), beta(3,1), \dots) \text{ } (X(1,1) \text{ } (Y(1,2) \text{ } (beta(1,2), beta(2,2), beta(3,2), \dots) \text{ } (X(1,2) \text{ } (\dots) \text{ } (beta(1,3), beta(2,3), beta(3,3), \dots) \text{ } (X(1,3) \text{ } )$

Most of the elements in Beta are zero!

## Usage

```

regrid.weights(xo,yo,xn,yn,verbose)
sparseMproduct(beta,x)
regrid(x,is,...)
regrid.default(x,is,verbose=FALSE,...)
regrid.field(x,is,verbose=FALSE,...)
regrid.matrix(x,is,verbose=FALSE,...)
regrid.eof(x,is,verbose=FALSE)

```

## Arguments

xo	Old x-coordinates (longitudes)
yo	Old y-coordinates (latitudes)
xn	New x-coordinates (longitudes)

yn	New y-coordinates (latitudes)
beta	The matrix of interpolation weights
x	a field object.
is	A list holding the coordinates xn and yn, a field object, an eof object, or a station object - for the latter three, the field x is interpolated to the longitude/latitude held by is.
verbose	Clutter the screen.

**Value**

A field object

**Author(s)**

R.E. Benestad and A. Mezghanil

**Examples**

```
## Not run:
# Use regrid to interpolate to station location:
t2m <- retrieve.ncdf4("~/data/ERAINT/ERAINT_t2m_mon.nc", param="t2m")
data(Oslo)
z.oslo <- regrid(t2m, is=Oslo)
plot(Oslo)
lines(z.oslo)

# Regrid t2m onto the grid of the gcm
gcm <- t2m.NorESM.M()
Z <- regrid(t2m, gcm)
map(Z)

# Example using regrid on a matrix object:
t2m.mean <- as.pattern(t2m, FUN=mean)
z <- regrid(t2m.mean, is=list(seq(min(lon(t2m)), max(lon(t2m))), by=0.5),
              seq(min(lat(t2m)), max(lat(t2m)), by=0.5))
image(lon(z), lat(z), z)

## End(Not run)
```

---

retrieve

*Retrieve field data from a netcdf file.*

---

**Description**

Retrieve data from a netcdf file and return a zoo field object with attributes. [retrieve](#).



**Usage**

```

retrieve.default(ncfile,...)
retrieve.ncdf(ncfile = ncfile, path = path , param = "auto",
              lon = NULL, lat = NULL, lev = NULL, time = NULL,
              miss2na = TRUE, greenwich = TRUE , ncdf.check = TRUE,
              verbose = FALSE , plot = TRUE)
retrieve.ncdf4(ncfile = ncfile, path = path , param = "auto",
               lon = NULL, lat = NULL, lev = NULL, time = NULL,
               miss2na = TRUE, greenwich = TRUE , ncdf.check = TRUE,
               verbose = FALSE , plot = TRUE)

summary.ncdf4(ncfile, verbose=FALSE)

check.ncdf4(ncid = ncid, param = "auto" , verbose = FALSE)
check.ncdf(ncid = ncid, param = "auto" , verbose = FALSE)

```

**Arguments**

<code>ncfile</code>	A character string of full path netcdf file name (include the path if necessary) or any object of class 'ncdf' or 'ncdf4'.
<code>ncid</code>	An object of class 'ncdf' or 'ncdf4'.
<code>lon</code>	Numeric value of longitude for the reference point (in decimal degrees East) or a vector containing the range of longitude values in the form of <code>c(lon.min,lon.max)</code>
<code>lat</code>	Numeric value of latitude for the reference point (in decimal degrees North) or a vector containing the range of latitude values in the form of <code>c(lat.min,lat.max)</code>
<code>lev</code>	Numeric value of pressure levels or a vector containing the range of pressure level values in the form of <code>c(lev.min,lev.max)</code>
<code>time</code>	Numerical year values or date values of time or a vector containing the range of values in the form of <code>c(time.min,time.max)</code> . Date format should be in the form of "YYYY-MM-DD".
<code>param</code>	Parameter or element type. There are several core parameters or elements as well as a number of additional parameters. The parameters or elements are: <code>auto</code> = automatic selection. <code>prcp</code> , <code>pr</code> = Precipitation (mm) <code>tas</code> , <code>tavg</code> = 2m-surface temperature (in degrees Celcius) <code>tmax</code> , <code>tasmax</code> = Maximum temperature (in degrees Celcius) <code>tmin</code> , <code>tasmin</code> = Minimum temperature (in degrees Celcius)
<code>plot</code>	Logical value. if, TRUE provides a map.
<code>greenwich</code>	Logical value. If FALSE, convert longitudes to -180E/180E or centre maps on Greenwich meridian (0 deg E).
<code>ncdf.check</code>	Logical value. If TRUE, performs a quick check of the ncfile contents
<code>miss2na</code>	Logical value. If TRUE missing values are converted to "NA"
<code>verbose</code>	Logical value defaulting to FALSE. If FALSE, do not display comments (silent mode). If TRUE, displays extra information on progress.

**Value**

A "zoo" "field" object with additional attributes used for further processing.

**Author(s)**

A. Mezghani

**See Also**

[test.retrieve.ncdf4](#).

**Examples**

```
#\dontrun{
# Download air surface temperature (tas) for the NorESM1-ME model
# output prepared for CMIP5 RCP4.5 and for run r1i1p1 from the climate
# explorer web portal (http://climexp.knmi.nl) and store the file into the temporary folder /tmp (Size ~96Mb)
download.file(url="http://climexp.knmi.nl/CMIP5/monthly/tas/tas_Amon_NorESM1-ME_rcp45_000.nc",
destfile="/tmp/tas_Amon_NorESM1-ME_rcp45_000.nc", method = "auto", quiet = FALSE, mode = "w", cacheOK = TRUE)
# Retrieve the data into "gcm" object
gcm <- retrieve.ncdf4(ncfile="/tmp/tas_Amon_NorESM1-ME_rcp45_000.nc", param="tas", plot=TRUE)
# Download the air surface temperature (tas) for RCP 4.5 scenarios and
# NorESM1-ME model from the climate explorer and store it in destfile.
# Compute the anomalies
gcm.a <- as.anomaly(gcm, ref=c(1960:2001))
map(gcm.a, projection="sphere")
#}
```

---

spatial.avg.field	<i>Spatial Average of a Field Object.</i>
-------------------	---

---

**Description**

Computes the spatial average of a field object and return a zoo time series object.

**Usage**

```
spatial.avg.field(x, ...)
```

**Arguments**

x	A zoo field object with two (longitude, latitude) or three dimensions (longitude, latitude, time)
---	---

**Value**

A "zoo" "time series" object

**Author(s)**

A. Mezghani, MET Norway

**See Also**

[retrieve.ncdf4](#)

**Examples**

```
## Not run:
# Consider the "gcm" object from the e.g. in \link{retrieve.ncdf4}
# Compute the spatial average along lon and lat in gcm2
gcm2 <- spatial.avg.field(gcm)
# keep all attributes in gcm2
gcm2 <- attrcp(gcm,gcm2)
# Compute the annual mean
gcm.am <- as.annual(gcm2,FUN=mean,na.rm=TRUE)
# keep all attributes in gcm.am
gcm.am <- attrcp(gcm2,gcm.am)
year <- index(gcm.am)
# Compute the anomalies relative to the period 1986-2005
agcm.ave <- gcm.am-mean(gcm.am[is.element(as.numeric(year),c(1986:2005))])
agcm.ave <- attrcp(gcm.am,agcm.ave)
# plot anomaly time series of the global mean temperature
frame.metno(agcm.ave,col="black",cex.lab=0.75,cex.axis=0.75) ! Should be
  updated !
# Add vertical margin text with y-label
mtext("Anomaly values relative to 1986-2005",side=2,line=2,cex=0.75,las=3)

## End(Not run)
```

---

spell

*Spell statistics*


---

**Description**

Statistics of spell durations (consecutive wet and dry days), e.g. dry and wet periods or duration of extremes.

exceedance estimates statistics for peak-over-threshold, and nevents returns the number of events with exceeding values (e.g. the number of rainy days  $X > 1$  mm/day). wetfreq returns the wet-day frequency (a fraction) and wetmean wet-day mean.

**Usage**

```
spell(x, threshold, ...)
spell.default(x, threshold, upper=150, ...)
spell.station(x, threshold, upper=150, ...)
hist.spell(x, ...)
```

```

count(x, threshold=1, fraction=FALSE)
exceedance(x, threshold=1, fun=mean, ...)
exceedance.default(x, threshold=1, fun=mean, ...)
exceedance.station(x, threshold=1, fun=mean, ...)
exceedance.field(x, threshold=1, fun=mean, ...)
nevents(x, threshold=1)
wetfreq(x, threshold=1)
wetmean(x, threshold=1)
HDD(x, x0=18, na.rm=TRUE)
CDD(x, x0=22, na.rm=TRUE)
GDD(x, x0=10, na.rm=TRUE)

```

### Arguments

x	station or field object
threshold	threshold value
upper	upper limit for maximum length - ignore any above this because they are likely erroneous
fraction	TRUE: divide the number of counts by number of samples
fun	function

### Value

Station or field objects

### Author(s)

R.E. Benestad and A. Mezghanil

### See Also

plot

### Examples

```

# Example 1 :
precip <- station.metnod(stid="18700", param="precip")
x <- spell(precip, threshold=.1)
x.ann <- annual(x, FUN="max")
plot(x.ann, plot.type="multiple")
# Example 2 :
x11() ; plot(x)

# Growing degree days:
data(ferder)
plot(as.seasons(ferder, FUN=GDD))

```

---

station	<i>Retrieve meta data and data from observational weather stations.</i>
---------	---

---

## Description

Retrieve station record from a given data source.

## Usage

```
# Retrieve meta data
select.station(loc=NULL , param = NULL,  stid = NULL ,lon = NULL,
              lat = NULL, alt = NULL, cntr = NULL, src = NULL ,
              it = NULL , nmin = NULL , verbose=FALSE)

# Retrieve data
station(stid=NULL,...)

station.default(loc=NULL, param="t2m", src = c("GHCNM", "ECAD", "GHCND",
        "NACD","NARP","NORDKLIMA"), stid=NULL, lon=NULL, lat=NULL,
        alt=NULL, cntr=NULL, it= NULL,nmin=30,
        path=NULL, plot=FALSE,verbose=FALSE)

# Monthly weather stations
station.nordklim(...)
station.narp(...)
station.nacd(...)
station.ghcnm(...,path="data.GHCNM")
station.metnom(...)

#Daily weather stations
station.ecad(..., path="data.ECAD")
station.ghcnd(..., path="data.GHCND")
station.metnod(...)
```

## Arguments

loc	A string of characters as the name of the location (weather/climate station) or an object of class "stationmeta".
param	Parameter or element type or variable identifier. There are several core parameters or elements as well as a number of additional parameters. The parameters or elements are: prcp, pr = Precipitation (mm) tas, tavg = 2m-surface temperature (in degrees Celcius) tmax, tasmax = Maximum temperature (in degrees Celcius) tmin, tasmin = Minimum temperature (in degrees Celcius)
src	Source: limit the downscaling to a specific data set ("NARP", "NACD", "NORDKLIMA", "GHCNM", "METNOM", "ECAD", "GHCND" and "METNOD")

<code>stid</code>	A string of characters as an identifier of the weather/climate station.
<code>lon</code>	Numeric value of longitude (in decimal degrees East) for the reference point (e.g. weather station) as a single value or a vector containing the range of longitude values in the form of <code>c(lon.min,lon.max)</code>
<code>lat</code>	Numeric value of latitude for the reference point (in decimal degrees North) or a vector containing the range of latitude values in the form of <code>c(lat.min,lat.max)</code>
<code>alt</code>	Numeric value of altitude (in meters a.s.l.) used for selection. Positive value, select all stations above this altitude; for negative values, select all stations below this altitude.
<code>cntr</code>	A string or a vector of strings of the full name of the country: Select the stations from a specified country or a set of countries.
<code>it</code>	A single integer or a vector of integers or Dates. An integer in the range of [1:12] for months, an integer of 4 digits for years (e.g. 2014), or a vector of Dates in the form "2014-01-01").
<code>nmin</code>	Select only stations with at least <code>nmin</code> number of years, months or days depending on the class of object <code>x</code> (e.g. 30 years).
<code>plot</code>	Logical value. If, TRUE provides a plot.
<code>verbose</code>	Logical value defaulting to FALSE. If FALSE, do not display comments (silent mode). If TRUE, displays extra information on progress.
<code>path</code>	The path where the data are stored. Can be a symbolic link.

**Value**

A time series of "zoo" "station" class with additional attributes used for further processing.

**Author(s)**

A. Mezghani

**See Also**

[station.meta](#) and [map.station](#).

**Examples**

```
# \dontrun{
# Get daily and monthly mean temperature for "Oslo" station ("18700") from METNO data source
t2m.dly <- station.metnod(stid="18700",param="t2m")
t2m.mon <- station.metnom(stid="18700",param="t2m")

# Get daily data from the ECA&D data source:
# If called for the first time, the script will download a huge chunk of
# data and store it locally.
# select meta for "De Bilt" station into ss,
ss <- select.station(loc = "de bilt",param="t2m",src="ECAD")
# Retrieve the data from the local directory specified in path based on
# previous selected station
t2m.dly <- station.ecad(loc=ss,path="data.ECAD")
}
```

```

# or directly retrieve the data without a prior selection
t2m.dly <- station.ecad(loc = "oslo - blindern",param="t2m",path="data.ECAD")
plot(t2m.dly)
# Aggregate to monthly and annual mean temperature values and plot the results
t2m.mon <- as.monthly(t2m.dly, FUN="mean") ; plot(t2m.mon)
t2m.ann <- as.annual(t2m.mon, FUN = "mean") ; plot(t2m.ann)
# specify one station from ECAD, and this time get daily mean precipitation
precip.dly <- station.ecad(loc="Oxford",param="precip") ; plot(precip.dly)
# Aggregate to annual accumulated precipitation values and plot the result
precip.ann <- as.annual(precip.dly,FUN="sum") ; plot(precip.ann)

# Get daily data from the GHCND data source
# select the meta data of a subset of stations in ss and map the geographical location of the selected stations with a
ss <- select.station(cntr="NORWAY",param="precip",src="GHCND")
map(ss, xlim = c(-10,30) , ylim = c(50,70))
# Select a subset of stations across Norway with a minimum number of
# 130 years using "GHCND" as a data source, retrieve the data and show its
# structure.
ss <- select.station(cntr="NORWAY",param="precip",src="GHCND",nmin=130)
y <- station.ghcnd(loc=ss , path="data.GHCND",plot=TRUE)
str(y)
# Subselect one station and display the geographical location of both selected stations and highlight the subselected
y1 <- subset(y,is=2)
map(y, xlim = c(-10,30), ylim = c(50,70), cex=1, select=y1, cex.select=2, showall=TRUE)
#}

```

subset

*Subsetting esd objects*

## Description

The subset method tries to be 'intelligent', and if the list has no names, then the list contains two vectors of length 2, then this is interpreted as a region, e.g. argument `is = list( c(lon.min,lon.max),c(lat.min,lat.max) )`. If, on the other hand, `is = list( lon=1:50,lat=55:65 )`, then the function picks the longitudes and latitudes which match these. This makes it flexible so that one can pick any irregular sequence.

## Usage

```

subset(x,it=NULL,is=NULL,...)
subset.station(x,loc=NULL , param = NULL, stid = NULL ,lon = NULL,
               lat = NULL, alt = NULL, cntr = NULL, src = NULL , it = NULL ,
               nmin = NULL, is = NULL)
subset.eof(x,it=NULL,is=NULL,verbose=FALSE)
subset.cca(x,it=NULL,is=NULL)
subset.mvr(x,it=NULL,is=NULL)
subset.pca(x,it=NULL,is=NULL)
subset.trend(x,it=NULL,is=NULL)
subset.corfield(x,it=NULL,is=NULL)
subset.comb(x,it=NULL,is=NULL)

```

```

subset.field(x,it=NULL,is=NULL)
subset.spell(x,is=NULL,it=NULL)
subset.ds(x,it=NULL,is=NULL)
subset.trend(x,it=NULL,is=NULL)
subset.dsensemble(x,it=NULL,is=NULL)
matchdate(x,it)
station.subset(x,it=NULL,is=NULL)

```

### Arguments

x	Data object from which the subset is taken
it	A list or data.frame providing time index, e.g. month
is	A list or data.frame providing space index, e.g. station record
dimension	qualifier for field objects: tme or space?

### Value

A field object

### Author(s)

R.E. Benestad and A. Mezghanil

### Examples

```

data(Oslo)

# January months:
jan <- subset(Oslo,1)

# The last 10 years:
recent <- subset(Oslo,2003:2012)

gcm <- t2m.NorESM.M()
# Extract July months from a field:
gcm.jul <- subset(gcm,it=7)

# Extract a period from a field:
gcm.short <- subset(gcm.jul,it=1950:2030)

# Extract data for the region 0-50E/55-65N
X <- subset(gcm,is=list(c(0,50),c(55,65)))

# Extract data for a specific set of longitudes and latitudes
Z <- subset(gcm,is=list(lon=1:30,lat=58:63))

t2m <- t2m.NCEP(lon=c(-10,30),lat=c(50,70))
cal <- subset(t2m,it=c("1948-01-01","1980-12-31"))

# Example on how to split the data into two parts for
# split-sample test...

```



```

T2M <- as.annual(t2m.NCEP(lon=c(-10,30),lat=c(50,70)))
cal <- subset(T2M,it=c("1948","1980"))
pre <- subset(T2M,it=c("1981","2012"))
comb <- combine(cal,pre)
X <- EOF(comb)
plot(X)

data(ferder)
y <- as.annual(ferder)
z <- DS(y,X)
plot(z)

# Test of subset the commutative property of subset and combine:
T2M <- as.4seasons(t2m.NCEP(lon=c(-10,30),lat=c(50,70)))
GCM <- as.4seasons(t2m.NorESM.M(lon = c(-10, 30), lat = c(50, 70)))
XY <- combine(T2M,GCM)
X1 <- subset(XY,it=3)
X2 <- combine(subset(T2M,it=3),subset(GCM,it=3))
eof1 <- EOF(X1)
eof2 <- EOF(X2)
eof3 <- biasfix(eof2)
plot(merge(eof1[,1],eof2[,1],eof3[,1]),plot.type=single,
      col=c(red,blue,green),lty=c(1,1,2),lwd=c(4,2,2))
# OK - identical results

```

---

test.retrieve.ncdf4      *Test functions*


---

## Description

This routine contains a series of test functions which compute the global mean 2m-temperature anomalies and other predefined regions based on both CMIP3 and CMIP5 experiments. The main function is [test.retrieve.ncdf4](#). The others are specific cases for the "Scandinavian" and "Arctic" regions for both CMIP3 and CMIP5 projects

## Usage

```

test.retrieve.ncdf4(path="CMIP3.monthly/20c3m-sresa1b",param="auto",cntr= "Global",
                    lon=NULL,lat=NULL,time=NULL,lev=NULL,experiment="CMIP3",
                    climatology=c(1986,2005),fig=TRUE,saveinfile=TRUE,verbose=FALSE)

test.cmip3.arctic(...)
test.cmip5.arctic(...)
test.cmip3.global(...)
test.cmip5.global(...)
test.cmip3.scandinavia(...)
test.cmip5.scandinavia

```

```
test.cmip35.global()
```

### Arguments

path	Character vector of the path to the CMIP data.
param	Parameter or element type. There are several core parameters or elements as well as a number of additional parameters. The parameters or elements are <code>pr</code> (Abdelkader : We need to update this list): <code>auto</code> = automatic selection. <code>pr</code> = Precipitation (mm) <code>tas</code> , <code>tavg</code> = 2m-surface temperature (in degrees Celcius) <code>tmax</code> , <code>tasmax</code> = Maximum temperature (in degrees Celcius) <code>tmin</code> , <code>tasmin</code> = Minimum temperature (in degrees Celcius)
lon	Numeric value of longitude for the reference point (in decimal degrees East) or a vector containing the range of longitude values in the form of <code>c(lon.min,lon.max)</code>
lat	Numeric value of latitude for the reference point (in decimal degrees North) or a vector containing the range of latitude values in the form of <code>c(lat.min,lat.max)</code>
lev	Numeric value of pressure levels or a vector containing the range of pressure level values in the form of <code>c(lev.min,lev.max)</code>
time	Numerical year values or date values of time or a vector containing the range of values in the form of <code>c(time.min,time.max)</code> . Date format should be in the form of "YYYY-MM-DD".
saveinfile	Logical or a character value. The output filename is set automatically if not specified. Default value is "TRUE".
verbose	Logical value. If TRUE, do not display comments (silent mode)

### Value

A field object

### Author(s)

A. Mezghani

### Examples

```
## Not run:
# Eg.1 :
# Compute the global mean surface temperature anomalies from CMIP3 experiment
test.cmip3.global(...)
# Compute the global mean surface temperature anomalies from CMIP5 experiment
test.cmip5.global(...)
# Plot the Global t2m-temperature anomalies from both CMIP3 and CMIP5 experiments.
plot.cmip35.global()

# Eg.2 Compute the mean surface temperature anomalies from CMIP3 experiment over Arctic
test.cmip3.arctic(...)

# Eg.3 Compute the mean surface temperature anomalies from CMIP5 experiment over Scandinavia.
```

```
test.cmip5.scandinavia(...)  
  
## End(Not run)
```

---

transforms

*Various formulas, equations and transforms.*

---

## Description

Computes different formulas.

C.C.eq: Clapeyron-Clausius equation (saturation evaporation pressure) where x is a data object holding the temperature.

## Usage

```
C.C.eq(x)
```

## Arguments

x                      a data object

## Value

The right hand side of the equation

## Author(s)

R. Benestad, MET Norway

## Examples

```
t2m <- t2m.ERAINT(lon=c(-70,-10),lat=c(20,60))  
es <- C.C.eq(t2m)  
map(es)
```

---

trend	<i>Trending and detrending data</i>
-------	-------------------------------------

---

### Description

Trend analysis and de-trending of data.

### Usage

```
trend(x,result="trend",model="y ~ t",...)
trend.default(x,result="trend",model="y ~ t",...)
trend.one.station(x,result="trend",model="y ~ t",...)
trend.station(x,result="trend",model="y ~ t",...)
trend.eof(x,result="trend",model="y ~ t",...)
trend.field(x,result="trend",model="y ~ t",...)
trend.zoo(x,result="trend",model="y ~ t",...)
```

### Arguments

x	The data object
result	"trend" returns the trend; "residual" returns the residual
model	The trend model used by <a href="#">lm</a> .

### Value

Similar type object as the input object

### Author(s)

R.E. Benestad

### See Also

[link{climatology}](#), [link{anomaly}](#)

---

WG	<i>Weather generators for conditional simulation.</i>
----	---

---

## Description

Weather generators for conditional simulation of daily temperature and/or precipitation, given mean and/or standard deviation. The family of WG functions produce stochastic time series with similar characteristics as the station series provided (if none is provided, it will use either ferder or bjornholt provided by the esd-package). Here characteristics means similar mean value, standard deviation, and spectral properties. FTscramble takes the Fourier components (doing a Fourier Transform - FT) of a series and reassigns random phase to each frequency and then returns a new series through an inverse FT. The FT scrambling is used for temperature, but not for precipitation that is non-Gaussian and involves sporadic events with rain. For precipitation, a different approach is used, taking the wet-day frequency of each year and using the wet-day mean and randomly generated exponentially distributed numbers to provide similar aggregated annual statistics as the station or predicted through downscaling. The precipitation WG can also take into account the number of consecutive number-of-dry-days statistics, using either a Poisson or a geometric distribution.

The weather generator produces a series with similar length as the provided sample data, but with shifted dates according to specified scenarios for annual mean mean/standard deviation/wet-day mean/wet-day frequency.

WG.FT.day.t2m generates daily temperature from seasonal means and standard deviations. It is given a sample station series, and uses FTscramble to generate a series with random phase but similar (or predicted - in the future) spectral characteristics. It then uses a quantile transform to prescribe predicted mean and standard deviation, assuming the distributions are normal. The temporal structure (power spectrum) is therefore similar as the sample provided.

WG.fw.day.precip uses the annual wet-day mean and the wet-day frequency as input, and takes a sample station of daily values to stochastically simulate number consecutive wet days based on its annual mean number. If not specified, it's taken from the sample data after being phase scrambled (FTscramble). The number of wet-days per year is estimated from the wet-day frequency, it too taken to be phase scrambled estimates from the sample data unless specifically specified. The daily amount is taken from stochastic values generated with [rexp](#). The number of consecutive wet days can be approximated by a geometric distribution ([rgeom](#)), and the annual mean number was estimated from the sample series.

## Usage

```
FTscramble(x,interval=NULL,spell.stats=FALSE,wetfreq.pred=FALSE)
WG(x,...)
WG.station(x,option=default,...)
WG.FT.day.t2m(x=NULL,amean=NULL,asd=NULL,t=NULL,eofs=1:4,
              select=NULL,lon=c(-20,20),lat=c(-20,20),
              plot=TRUE,biascorrect=TRUE,verbose=FALSE)
WG.fw.day.precip(x=NULL,mu=NULL,fw=NULL,ndd=NULL,t=NULL,
                 threshold=1,select=NULL,
                 lon=c(-10,10),lat=c(-10,10),
                 plot=TRUE,biascorrect=TRUE,
                 method=rgeom)
WG.pca.day.t2m.precip(t2m=NULL,precip=NULL,threshold=1,select=NULL)
```

## Arguments

x                      station object

option	Define the type of WG
amean	annual mean values. If NULL, use those estimated from x; if NA, estimate using <a href="#">DSensemble.t2m</a> , or if provided, assume a 'dsensemble' object.
asd	annual standard deviation. If NULL, use those estimated from x; if NA, estimate using <a href="#">DSensemble.t2m</a> , or if provided, assume a 'dsensemble' object.
t	Time axis. If null, use the same as x or the last interval of same length as x from downscaled results.
eofs	passed on to <a href="#">DSensemble.t2m</a>
select	passed on to <a href="#">DSensemble.t2m</a>
lon	passed on to <a href="#">DSensemble.t2m</a>
lat	passed on to <a href="#">DSensemble.t2m</a>
plot	
biascorrect	passed on to <a href="#">DSensemble.t2m</a>
verbose	passed on to <a href="#">DSensemble.t2m</a>
mu	annual wet-mean values. If NULL, use those estimated from x; if NA, estimate using <a href="#">DSensemble.t2m</a> , or if provided, assume a 'dsensemble' object.
fw	annual wet-day frequency. If NULL, use those estimated from x; if NA, estimate using <a href="#">DSensemble.t2m</a> , or if provided, assume a 'dsensemble' object.
ndd	annual mean dry spell length. If NULL, use those estimated from x; if NA, estimate using <a href="#">DSensemble.t2m</a> , or if provided, assume a 'dsensemble' object.
threshold	Definition of a rainy day.
method	Assume a gemoetric or a poisson distribution. Can also define ownth methods.
t2m	station object with temperature
precip	station object with precipitation.

### Author(s)

R.E. Benestad

### Examples

```
data(ferder)
t2m <- WG(ferder)
data(bjornholt)
pr <- WG(bjornholt)
```

---

write2ncdf	<i>Saves climate data as netCDF.</i>
------------	--------------------------------------

---

### Description

Method to save station data as netCDF, making sure to include the data structure and meta-data (attributes). The code tries to follow the netCDF 'CF' convention. The method is built on the [ncdf4](#) package.

### Usage

```
write2ncdf(x,file,...)
write2ncdf.station(x,file,prec=short,missval=-99.9,offs=0,scalf=0.1,
                  torg=1899-12-31,verbose=FALSE)
```

### Arguments

x	data object
file	file name
prec	Precision: see <a href="#">ncvar_def</a>
missval	Missing value: see <a href="#">ncvar_def</a>
offs	Sets the attribute 'add_offset' which is added to the values stored (to save space may be represented as 'short').
scalf	Sets the attribute 'scale_factor' which is used to scale (multiply) the values stored (to save space may be represented as 'short').
torg	Time origin
verbose	TRUE - clutter the screen.

### Value

A "zoo" "field" object with additional attributes used for further processing.

### Author(s)

R.E. Benestad

### See Also

[test.retrieve.ncdf4.](#)

### Examples

```
nacd <- station(src=nacd)
X <- annual(nacd)
write2ncdf(X,file=test.nc)
```

# Index

- \*Topic **?**
  - retrieve, [40](#)
  - write2ncdf, [55](#)
- \*Topic **datasets**
  - Data, [16](#)
- \*Topic **hplot**
  - map, [33](#)
  - plot.station, [37](#)
- \*Topic **manip**
  - CCA, [10](#)
  - corfield, [14](#)
  - crossval, [15](#)
  - DSensemble, [25](#)
  - iid.test, [30](#)
  - MVR, [35](#)
  - WG, [52](#)
- \*Topic **models**
  - DS, [19](#)
- \*Topic **multivariate**
  - DS, [19](#)
  - EOF, [28](#)
- \*Topic **parameter , element**
  - DSE, [23](#)
  - spatial.avg.field, [42](#)
- \*Topic **parameter,element**
  - ele2param, [27](#)
  - is, [32](#)
  - transforms, [51](#)
- \*Topic **select.station**
  - station, [45](#)
- \*Topic **spatial**
  - DS, [19](#)
  - EOF, [28](#)
- \*Topic **ts**
  - DS, [19](#)
  - EOF, [28](#)
- \*Topic **utilities**
  - aggregate, [2](#)
  - annual, [3](#)
  - anomaly, [5](#)
  - as, [6](#)
  - combine, [12](#)
  - diagnose, [18](#)
  - InfoGraphics, [31](#)
  - regrid, [39](#)
  - spell, [43](#)
  - subset, [47](#)
  - test.retrieve.ncdf4, [49](#)
  - trend, [52](#)
- aggregate, [2](#)
- aggregate.station, [4](#)
- aggregate.zoo, [2](#), [4](#)
- annual, [3](#), [3](#), [17](#)
- anomaly, [5](#)
- approx, [29](#)
- as, [6](#)
- as.4seasons, [3](#), [17](#)
- as.annual, [4](#)
- as.anomaly, [6](#)
- as.climatology, [6](#)
- biasfix (DS), [19](#)
- bjornholt (Data), [16](#)
- C.C.eq (transforms), [51](#)
- Canonical correlation analysis (CCA), [10](#)
- CCA, [10](#), [19](#)
- CDD (spell), [43](#)
- clim2pca (anomaly), [5](#)
- climatology (anomaly), [5](#)
- climvar (InfoGraphics), [31](#)
- colscal (InfoGraphics), [31](#)
- combine, [12](#), [19](#)
- combine.ds, [21](#)
- cor, [14](#)
- corfield, [14](#)
- count (spell), [43](#)
- crossval, [15](#), [25](#)



- cumugram (InfoGraphics), 31
- daily.station.records, 30
- Data, 16
- day (annual), 3
- diagnose, 18, 20
- diagram (InfoGraphics), 31
- DS, 15, 19, 25
- DSE, 23
- DSensemble, 23, 24, 25
- DSensemble.t2m, 54
- ele2param, 27
- Empirical orthogonal Functions (EOF), 28
- EOF, 12, 19, 21, 25, 28
- eof.precip.ERAINT (Data), 16
- eof.slp.DNMI (Data), 16
- eof.slp.ERAINT (Data), 16
- eof.slp.MERRA (Data), 16
- eof.slp.NCEP (Data), 16
- eof.sst.DNMI (Data), 16
- eof.sst.NCEP (Data), 16
- eof.t2m.DNMI (Data), 16
- eof.t2m.ERA40 (Data), 16
- eof.t2m.ERAINT (Data), 16
- eof.t2m.MERRA (Data), 16
- eof.t2m.NCEP (Data), 16
- eof.t2m.NorESM.M (Data), 16
- eof2field (EOF), 28
- esd2ele (ele2param), 27
- exceedance (spell), 43
- ferder (Data), 16
- field, 2
- g2dl (combine), 12
- GDD (spell), 43
- geoborders (Data), 16
- glm, 21
- gridbox (map), 33
- HadCRUT4 (Data), 16
- HDD (spell), 43
- hist.spell, 32
- hist.spell (spell), 43
- iid.test, 30
- InfoGraphics, 31
- is, 32
- lm, 21, 52
- lonlatprojection (map), 33
- map, 16, 32, 33
- map.station, 46
- map2sphere (map), 33
- matchdate (subset), 47
- mean, 2, 4
- merge, 12, 28
- meta.dse, 24
- mixFields, 28
- month (annual), 3
- Multi-variate regression (MVR), 35
- MVR, 35
- n.records (iid.test), 30
- NACD (Data), 16
- nam2expr (plot.station), 37
- NAOI (Data), 16
- NARP (Data), 16
- ncdf4, 55
- ncvar\_def, 55
- nevents (spell), 43
- NINO3.4 (Data), 16
- Oslo (Data), 16
- pbinom, 30
- PCA, 19
- PCA (EOF), 28
- pca2station (EOF), 28
- pentad (annual), 3
- plot.cca (plot.station), 37
- plot.diagnose (plot.station), 37
- plot.ds (plot.station), 37
- plot.dsensemble (plot.station), 37
- plot.dsx (plot.station), 37
- plot.eof (plot.station), 37
- plot.field (plot.station), 37
- plot.MVR (MVR), 35
- plot.spell (plot.station), 37
- plot.station, 32, 37
- plot.xval (plot.station), 37
- plotstation, 35
- precip.ERAINT (Data), 16
- precip.NORDKLIM (Data), 16
- predict.CCA (CCA), 10
- predict.MVR (MVR), 35
- qbinom, 30

- rbg, 34
- regrid, 39
- retrieve, 40, 40
- retrieve.ncdf4, 43
- rexp, 53
- rgeom, 53
- rotM (map), 33
  
- sametimescale (DS), 19
- seasevol (InfoGraphics), 31
- season (annual), 3
- seasonal.name (annual), 3
- select.station (station), 45
- slp.DNMI (Data), 16
- slp.ERAINT (Data), 16
- slp.MERRA (Data), 16
- slp.NCEP (Data), 16
- softattr (combine), 12
- sp2np (combine), 12
- sparseMproduct (regrid), 39
- spatial (spatial.avg.field), 42
- spatial.avg.field, 3, 17, 42
- spell, 2, 43
- sst.DNMI (Data), 16
- sst.NCEP (Data), 16
- station, 2, 16, 45
- station.meta, 46
- station.meta (Data), 16
- station.subset (subset), 47
- step, 21
- subset, 18, 29, 47
- subset.eof, 29
- subset.field, 2
- sunspots (Data), 16
- Svalbard (Data), 16
- svd, 10, 11, 28, 35
  
- t2m.DNMI (Data), 16
- t2m.ERA40 (Data), 16
- t2m.ERAINT, 29
- t2m.ERAINT (Data), 16
- t2m.MERRA (Data), 16
- t2m.NCEP (Data), 16
- t2m.NORDKLIM (Data), 16
- t2m.NorESM.M (Data), 16
- test.cca (CCA), 10
- test.cmip3.arctic
  - (test.retrieve.ncdf4), 49
- test.cmip3.global
  - (test.retrieve.ncdf4), 49
- test.cmip3.scandinavia
  - (test.retrieve.ncdf4), 49
- test.cmip35.global
  - (test.retrieve.ncdf4), 49
- test.cmip5.arctic
  - (test.retrieve.ncdf4), 49
- test.cmip5.globa (test.retrieve.ncdf4),
  - 49
- test.cmip5.scandinavia
  - (test.retrieve.ncdf4), 49
- test.retrieve.ncdf4, 42, 49, 49, 55
- transforms, 51
- trend, 52
  
- vardo (Data), 16
- vis (InfoGraphics), 31
  
- Weather generators (WG), 52
- wetfreq (spell), 43
- wetmean (spell), 43
- WG, 52
- wheel (InfoGraphics), 31
- write2ncdf, 55
  
- year (annual), 3
  
- zeros (combine), 12