

Package ‘Rfdbk’

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Type Package

Title Handling NetCDF feedback files

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Description Collection of functions to handle NetCDF feedback files from DWD data assimilation. To get examples running make sure the 'examplesRfdbk' directory exists in your home.

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Depends RNetCDF,data.table,parallel,stringr,survival,grid,verification,reshape2,pcaPP

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afc	<i>Fast version of the 2AFC for continuous observations and forecasts The score is based on the rank correlation coefficient</i>
-----	--

Description

Fast version of the 2AFC for continuous observations and forecasts The score is based on the rank correlation coefficient

Usage

```
afc(obsv, fcst)
```

Arguments

obsv	observation vector
fcst	forecast vector

Value

afc score

Author(s)

Felix <felix.fundel@dwd.de>

agg_det_scores	<i>Aggregate deterministic scores</i>
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Description

Aggregate deterministic scores

Usage

```
agg_det_scores(SCORENAME = NULL, RMSE = NULL, ME = NULL, MSE = NULL,  
SD = NULL, MAE = NULL, LEN = NULL)
```

Arguments

SCORENAME	score name string
RMSE	rmse scores of data subsets
ME	me scores of data subsets
MSE	mse scores of data subsets
SD	sd scores of data subsets
MAE	mae scores of data subsets
LEN	length of forecast-observation pairs in subsets

Value

pooled score value

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
x      = runif(1000) fnames    = system("ls ~/examplesRfdbk/icon/synop/*", intern=T)
y      = rnorm(1000)
x1     = x[1:10]; x2=x[11:300]; x3=x[301:1000]
y1     = y[1:10]; y2=y[11:300]; y3=y[301:1000]
rmse   = function(x, y) {return(sqrt(mean((x-y)^2)))}
rmse(x, y)
agg_det_scores("RMSE", RMSE=c(rmse(x1, y1), rmse(x2, y2), rmse(x3, y3)), LEN=c(length(x1), length(x2), length(x3)))
```

comparableRows

Find comparable rows in DT for two or more attributes

Description

Find comparable rows in DT for two or more attributes

Usage

```
comparableRows(DT, splitCol, splitVal, compareBy)
```

Arguments

DT	data.table
splitCol	Dt column name that contains the attributes that should be compared
splitVal	two or more values of splitCol that should be compared
compareBy	other column names that should be used two decide if a comparable row exists for both splitVals

Value

indices of DT that show which rows should be retained (TRUE) i.e. rows that have a counterpart in each of the two splitVals

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
## Delete rows in DT that have no counterpart for GME/ICON concerning the attributes: "ve

require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/*/synop/verSYNOP.2014*", intern=T)
cond        = list(verno="verno%in%c(3,4)", veri_description="grepl('forecast', v
columnnames = c("obs", "veri_data", "verno", "veri_model", "veri_forecast_time", "ve
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
keepind     = comparableRows(DT, splitCol="veri_model", splitVal=unique(DT$veri_m
DT          = DT[keepind]
DT[, .N, by=c("verno", "veri_model")]
DT$verno    = verno_to_name(DT$verno)
strat       = c("verno", "veri_forecast_time", "veri_model")
scores      = fdbk_dt_verif_continuous(DT, strat)
p = ggplot(scores, aes(x=veri_forecast_time, y=scores, group=interaction(scorename, verno, ve
  geom_line(size=.7) + geom_point(size=1.5) + facet_wrap(~scorename, scales = "free") +
  theme_bw()+theme(axis.text.x = element_text(angle=70, hjust = 1))

p
```

fdbk_dt

Fdbk file content (as obtained from read_fdbk(_f)) is converted into a data.table. Therefore a lot of data overhead is created as most data will be duplicated. However, data.tables offer a lot of extra functionality.

Description

Fdbk file content (as obtained from read_fdbk(_f)) is converted into a data.table. Therefore a lot of data overhead is created as most data will be duplicated. However, data.tables offer a lot of extra functionality.

Usage

```
fdbk_dt(fdbk)
```

Arguments

fdbk output from read_fdbk

Value

a data.table of the feedback file data section

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```

fdbk = read_fdbk("~/examplesRfdbk/icon/synop/verSYNOP.2014120112")
format(object.size(fdbk), "Mb")
DT    = fdbk_dt(fdbk)
format(object.size(DT), "Mb")
DT

```

```

fdbk_dt_add_obs_ini

```

Update a feedback file data.table with observations valid at initialization (helpful for calculation of tendency correlations or persistence scores)

Description

Update a feedback file data.table with observations valid at initialization (helpful for calculation of tendency correlations or persistence scores)

Usage

```

fdbk_dt_add_obs_ini(DT, fileNames, vars = c("ident", "varno"), cond = "")

```

Arguments

DT	data.table with feedback file content, minimum requires "veri_forecast_time", "obs", "statid", "level", "varno" and "veri_initial_date" as YYYYmmddHHMM numeric
fileNames	vector of filenames (including path) of feedback files that should be valid at times needed to fill DT (e.g. files of past 7 days to fill DT for a model of 7 day forecast range)

Value

DT with an additional columns "obs_ini"

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```

# obsolete
fdbkDir  = "~/examplesRfdbk/icon/synop"
fileName = tail(dir(fdbkDir, full.names=T), 1)
refDate  = fdbk_refdate(fileName)
vars     = c("obs", "veri_data", "veri_forecast_time", "statid", "level", "varno", "lon", "lat")
cond     = list(veri_forecast_time="veri_forecast_time>300")
DT       = fdbk_dt_multi_large(fileName, condition=cond, vars=vars, cores=1)
fileNames = tail(dir(fdbkDir, full.names=T), 50)
DT = fdbk_dt_add_obs_ini(DT, fileNames, cond)
na.omit(DT[varno==3, list(TCC=cor(veri_data-obs_ini, obs-obs_ini, use="pair"))], by=c("varno",

```

fdbk_dt_binning	<i>Bin a data.table column into user defined bins and replace it with the bin center value. If breaks can be provided (e.g. no gaps between bins) try to use 'cut' instead.</i>
-----------------	---

Description

Bin a data.table column into user defined bins and replace it with the bin center value. If breaks can be provided (e.g. no gaps between bins) try to use 'cut' instead.

Usage

```
fdbk_dt_binning(DT, varToBin = "level", binLower, binUpper)
```

Arguments

DT	data.table
varToBin	variable that should be binned (and will be replaced by the binned version)
binLower	number/vector lower bins limits
binUpper	number/vector upper bins limits

Value

data.table with varToBin replaced by factorized mid-bin values (NA if variable falls in none of the bins)

Author(s)

Felix <felix.fundel@dwd.de>

See Also

[cut](#)

Examples

```
#plot scores accross binned levels
require(ggplot2)
fnames      = "~/examplesRfdbk/icon/temp/verTEMP.2014120112"
cond        = list(obs="!is.na(obs)", varno="varno%in%c(2,3,4,29)")
columnnames = c("obs", "veri_data", "varno", "state", "level")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 1)
binUpper    = seq(100000, 1000, by=-5000)+1500
binLower    = seq(100000, 1000, by=-5000)-1500
DT          = fdbk_dt_binning(DT, "level", binLower, binUpper)
DT          = DT[!is.na(level), , ]
DT$varno    = varno_to_name(DT$varno)
strat       = c("varno", "level")
scores      = fdbk_dt_verif_continuous(DT, strat)
setkey(scores, scorename, varno, level)
scores      = scores[!is.na(scores), ]
p = ggplot(scores, aes(x=scores, y=level, group=interaction(varno, scorename))) +
```

```
geom_path() + facet_wrap(~varno~scorename,scales="free_x",ncol = 6)+
theme_bw()+theme(axis.text.x = element_text(angle=70,hjust = 1))+scale_y_reverse()
p
```

fdbk_dt_brier	<i>Calculate the brier score (and decomposition and skill score) for one threshold per variable</i>
---------------	---

Description

Calculate the brier score (and decomposition and skill score) for one threshold per variable

Usage

```
fdbk_dt_brier(DT, thresholds = "", by = "")
```

Arguments

DT	data.table (columns 'veri_ens_member','obs' and 'veri_data' plus all variables to make forecasts distinguishable are required!!!)
thresholds	list of threshold for variable names in DT (if "" uses obs median)
by	stratify crps by (e.g. c('varno','veri_forecast_time'))

Value

data.table with columns as defined in 'by' plus scorename plus score

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
require(ggplot2)
fnames = system("/bin/ls ~/examplesRfdbk/eps/*12/verSYNOP*",intern=T)
condition = list(veri_description="grepl('member',veri_description)",
                 state="state%in%c(0,1)",
                 statid="!is.na(as.numeric(statid)) & !duplicated(statid)",
                 veri_forecast_time="veri_forecast_time>=1200")
columns = c("obs","veri_data","varno","veri_ens_member","veri_forecast_time","statid",
DT = fdbk_dt_multi_large(fnames,condition,columns,5)
PROBS = fdbk_dt_brier(DT,by=c("varno","veri_forecast_time"))

ggplot(PROBS,aes(x=veri_forecast_time,y=score,color=scorename,group=scorename))+
  geom_line()+geom_point()+facet_wrap(~varno,scale="free_y",ncol=2)+
  theme_bw()+scale_colour_discrete("lead-time")
```

`fdbk_dt_contscores` *Calculates most common contingency scores*

Description

Calculates most common contingency scores

Usage

```
fdbk_dt_contscores (CONTTABLE, by)
```

Arguments

<code>CONTTABLE</code>	data.table with columns hit,miss,corrneg,false and additional columns (output of <code>fdbk_dt_conttable(_2thrs)</code>)
<code>by</code>	stratify contingency entries by these columns

Value

data.table with one column of score names and one column of scores values

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/*/synop/verSYNOP.*", intern=T)
cond        = list(veri_description="grepl('forecast', veri_description)",
                    veri_forecast_time="veri_forecast_time%in%c(2400,4800,7200,9600)")
columnnames = c("obs", "veri_data", "varno", "veri_model", "veri_forecast_time", "score")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
thrs        = list('29'=list('lower'=c(.8, .6), 'upper'=c(Inf, .9)),
                    '3'=list('lower'=c(-5, 0, 5), 'upper'=c(Inf, Inf, Inf)))
CONTTABLE   = fdbk_dt_conttable_2thrs(DT, thrs, by=c("veri_model", "veri_forecast_time"))
SCORES      = fdbk_dt_contscores(CONTTABLE, by=c("veri_model", "veri_forecast_time"))
ggplot(SCORES, aes(x=veri_forecast_time, y=scores, color=thr, linetype=veri_model)) +
  geom_line() +
  geom_point() +
  facet_grid(scorename~varno, scale="free_y") +
  theme_bw()
```

fdbk_dt_conttable	<i>Calculates stratified contingency table entries (above threshold) for a data table</i>
-------------------	---

Description

Calculates stratified contingency table entries (above threshold) for a data table

Usage

```
fdbk_dt_conttable(DT, vars = NULL, thrs = NULL, by = NULL, cores = 1)
```

Arguments

DT	data.table with relevant information
vars	character vector of varnos (if NULL take from DT)
thrs	list of vectors of thresholds for each varno (if NULL threshold are generated from quantiles)
by	stratify contingency entries by these DT columns
cores	number of CPU cores to split the calculation (helps for larger data tables)

Value

data.table with columns varno,thr, hits,false,miss,corrneg and the arguments of 'by'

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE (CSI for quantile thresholds)
require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/*/synop/verSYNOP.*", intern=T)
cond        = list(veri_description="grepl('forecast', veri_description)",
                    veri_forecast_time="veri_forecast_time%in%c(2400,4800,7200,9600)")
columnnames = c("obs", "veri_data", "varno", "veri_model", "veri_forecast_time", "st")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
vars        = c('1', '3', '4', '29')
thrs        = list('1'=c(50, 60), '3'=c(-5, 0, 5), '4'=c(-5, 0, 5), '29'=c(.4, .6, .8))
xx          = fdbk_dt_conttable(DT, vars=vars, thrs=thrs, by=c("veri_model", "veri_forecast_time"))
CSI         = xx[, list(csi = (hit) / (hit + miss + false) ), by=c("veri_forecast_time", "veri_model")]
CSI[, varno:=varno_to_name(varno, T)]
ggplot(CSI, aes(x=thr, y=csi, color=factor(veri_forecast_time), linetype=factor(veri_model), group=factor(veri_model))) +
  geom_line() +
  ggtitle("CSI") +
  facet_wrap(~varno, scales="free_x")
```

```
fdbk_dt_conttable_2thrs
```

Calculates stratified contingency table entries (above or between thresholds) for a data table

Description

Calculates stratified contingency table entries (above or between thresholds) for a data table

Usage

```
fdbk_dt_conttable_2thrs(DT, thrs, by, cores = 1, incores = 1)
```

Arguments

DT	data.table with relevant information (at least varno, obs and veri_data)
thrs	list of variable having each a list of lower/upper thresholds (set upper to Inf if only one threshold is required)
by	stratify contingency entries by these DT columns
cores	computing cores for the outer loop (splits computation by varnos)
incores	computing cores for the outer loop (splits computation by thresholds)(available cores have to be of number cores x incores)

Value

data.table with columns varno,thr, hits,false,miss,corrneg and the arguments of 'by'

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE (CSI for quantile thresholds)
require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/*/synop/verSYNOP.*", intern=T)
cond        = list(veri_description="grepl('forecast', veri_description)",
                   veri_forecast_time="veri_forecast_time%in%c(2400,4800,7200,9600)",
                   veri_model="grepl('GEM', veri_model)")
columnnames = c("obs", "veri_data", "varno", "veri_model", "veri_forecast_time", "st")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
thrs        = list('29'=list('lower'=c(.5, .8), 'upper'=c(Inf, .9)),
                   '3'=list('lower'=c(-5, 0, 5), 'upper'=c(Inf, Inf, Inf)))
xx          = fdbk_dt_conttable_2thrs(DT, thrs, by=c("veri_model", "veri_forecast_time"))
CSI         = xx[,list(csi = (hit) / (hit + miss + false) ), by=c("veri_forecast_time", "veri_model")]
CSI[,varno:=varno_to_name(varno, T)]
ggplot(CSI, aes(x=veri_forecast_time, y=csi, group=interaction(veri_model, thr), linetype=veri_model)) +
  geom_line() +
  facet_grid(~varno) +
  ggtitle("CSI")
```

fdbk_dt_crps	<i>Calculate CRPS(crps, crpsPot,Reli) from data.table applied on selected parts of the table (Caution, double check results! DT sorting might be modified!)</i>
--------------	---

Description

Calculate CRPS(crps, crpsPot,Reli) from data.table applied on selected parts of the table (Caution, double check results! DT sorting might be modified!)

Usage

```
fdbk_dt_crps(DT, by)
```

Arguments

DT	data.table (columns 'veri_ens_member','obs' and 'veri_data' plus all variables to make forecasts distinguishable are required!!!)
by	stratify crps by (e.g. 'varno')

Value

data.table with columns as defined in 'by' plus scorename plus score

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE 1 (CRPS for each varno)
fnames      = system("ls ~/examplesRfdbk/talagrand/*SYNOP*",intern=T)
cond        = list(veri_description="grepl('first guess ensemble member',veri_d",
                   obs="!is.na(obs)",
                   statid="!is.na(as.numeric(statid)) & !duplicated(statid)",
                   veri_forecast_time="veri_forecast_time==100",
                   state="state%in%c(0,1,5)")
columnnames = c("veri_data", "varno", "obs", "veri_ens_member", "veri_initial_date")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 10)
DT[, varno:=varno_to_name(varno)]
fdbk_dt_crps(DT, by="varno")

#EXAMPLE 2 (CRPS decomosition for forecasts at SYNOP stations)
require(ggplot2)
fnames      = system("/bin/ls ~/examplesRfdbk/eps/*12/verSYNOP*",intern=T)
condition   = list(veri_description="grepl('member',veri_description)",
                   state="state%in%c(0,1)",
                   statid="round(as.numeric(statid)/1000)==10 & !duplicated(statid)",
                   veri_forecast_time="veri_forecast_time>=1200")
columns     = c("obs", "veri_data", "varno", "veri_ens_member", "veri_forecast_time", "statid", "F")
DT          = fdbk_dt_multi_large(fnames, condition, columns, 5)
CRPS       = fdbk_dt_crps(DT, by=c("varno", "veri_forecast_time"))
CRPS[, varno:=varno_to_name(varno), F]
```

```

ggplot (CRPS,aes (x=veri_forecast_time,y=score))+geom_line()+geom_point()+facet_grid(~varno)

#EXAMPLE 3 (slow...) (CRPS decomosition for european forecasts at TEMP stations)
require(ggplot2)
fnames      = system("/bin/ls ~/examplesRfdbk/eps/*12/verTEMP*",intern=T)
condition    = list (veri_description="grepl ('member',veri_description)",
                     state="state%in%c(0,1)",
                     level="level%in%c(100000,92500,85000,75000,70000,50000,40000,30000,25000)",
                     statid="round(as.numeric(statid)/1000)<=10 & !duplicated(statid)",
                     veri_forecast_time="veri_forecast_time>=1200",
                     varno="varno!=1")
columns      = c("obs","veri_data","varno","level","veri_ens_member","veri_forecast_time","v
DT           = fdbk_dt_multi_large(fnames,condition,columns,5)
CRPS         = fdbk_dt_crps(DT,by=c("varno","level","veri_forecast_time"))
CRPS[,varno:=varno_to_name(varno,F)]
ggplot (CRPS,aes (x=score,y=level,color=factor(veri_forecast_time),group=veri_forecast_time)
  geom_path()+facet_wrap (~varno~scorename,scale="free_x",ncol=3)+
  scale_y_reverse()+theme_bw()+scale_colour_discrete("lead-time")

```

fdbk_dt_crps_norm	<i>Calculate CRPS and Ignorance score from data.table with EPS mean/spread, assuming a normally distributed EPS</i>
-------------------	---

Description

Calculate CRPS and Ignorance score from data.table with EPS mean/spread, assuming a normally distributed EPS

Usage

```
fdbk_dt_crps_norm(DT, by)
```

Arguments

DT	data.table (columns 'veri_description','obs' and 'veri_data' are required!!!) values of veri_description have to be "mean" or "spread"
by	stratify crps by (e.g. 'varno')

Value

data.table with columns as defined in 'by' plus scorename plus score

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```

require(ggplot2)
fnames      = system("/bin/ls ~/examplesRfdbk/eps/*12/verTEMP*",intern=T)
condition    = list (
                     veri_description="grepl ('first guess',veri_description)",
                     veri_description="grepl ('ensemble',veri_description)",

```

```

state="state%in%c(0,1)",
level="level%in%c(100000,92500,85000,75000,70000,50000,40000,30000)",
veri_forecast_time="veri_forecast_time>=1200",
varno="varno!=1")
vars      = c("obs","veri_data","varno","level","veri_description","veri_forecast_time")
DT        = fdbk_dt_multi_large(fnames,condition,vars,5)
DT[grepl("mean",veri_description),veri_description:="mean"]
DT[grepl("spread",veri_description),veri_description:="spread"]
by=c("varno","level","veri_forecast_time")
CRPS = fdbk_dt_crps_norm(DT,by)
CRPS[,varno:=varno_to_name(varno,F)]
CRPS[scorename=="IGN" & score>10000,score:=NA]
ggplot(CRPS,aes(x=score,y=level,color=factor(veri_forecast_time),group=veri_forecast_time))
  geom_path()+geom_point()+facet_wrap(~scorename~varno,scale="free_x",ncol=4)+
  scale_y_reverse()+theme_bw()+scale_colour_discrete("lead-time")

```

fdbk_dt_hits_uncert

Calculates stratified hit rates for uncertain obs/fcst

Description

Calculates stratified hit rates for uncertain obs/fcst

Usage

```
fdbk_dt_hits_uncert(DT, thrs, by, cores = 1, incores = 1)
```

Arguments

DT	data.table with relevant information (at least varno, obs and veri_data)
thrs	list of variable having each a list of lower/upper thresholds (set upper to Inf if only one threshold is required)
by	stratify contingency entries by these DT columns
cores	computing cores for the outer loop (splits computation by varnos)
incores	computing cores for the outer loop (splits computation by thresholds)(available cores have to be of number cores x incores)

Value

data.table with columns varno,interval, hits, total and the arguments of 'by'

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
fnames      = system("ls ~/examplesRfdbk/icon/synop/verSYNOP.*", intern=T)
cond        = "varno%in%c(3,4) & !is.na(obs) "
columnnames = c("obs", "veri_data", "varno", "veri_forecast_time")
DT          = fdbk_dt_multi(fnames, cond, columnnames, 4)
DT
```

```
fdbk_dt_multi_large
```

Function to load one or many fdbk Files and transform them to a data.table. Faster than fdbk_dt_multi and able to handle very large files, however, be as restrictive as possible, use the cond/columnnames argument select only the data you need for your problem. Note: Using conditions on veri_data in the cond argument is not possible and may cause an error!!! Solution: filter veri_data in the returned data.table

Description

Function to load one or many fdbk Files and transform them to a data.table. Faster than fdbk_dt_multi and able to handle very large files, however, be as restrictive as possible, use the cond/columnnames argument select only the data you need for your problem. Note: Using conditions on veri_data in the cond argument is not possible and may cause an error!!! Solution: filter veri_data in the returned data.table

Usage

```
fdbk_dt_multi_large(fnames, condition = "", vars = "", cores = 1)
```

Arguments

fnames	vector of feedback filename(s)
cores	use multiple cores for parallel file loading
cond	list of strings of conditions (all of the list entries are connected with the "&" operator!)
columnnames	attribute names to keep in the data table

Value

a data.table of merged feedback file contents

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE 1 (1x1 deg.) bias of satellite data (channel 921 from METOP-1)
require(ggplot2)
fnames      = system("/bin/ls ~/examplesRfdbk/example_monRad/monRAD_*.nc",intern=T)
condition    = list(obs="!is.na(obs)",
                    level="level%in%c(921)",
                    statid="statid=='METOP-1'",
                    veri_forecast_time="veri_forecast_time==0",
                    veri_run_type="veri_run_type==3",
                    veri_ens_member="veri_ens_member==1")
columnnames = c("obs","veri_data","lon","lat","veri_initial_date")
DT          = fdbk_dt_multi_large(fnames,condition,columnnames,cores=1)
DT
DT[,lon:=round(lon)]
DT[,lat:=round(lat)]
scores = DT[,list(ME=mean(obs-veri_data)),by=c("lon","lat")]
outlines = as.data.table(map("world", plot = FALSE)[c("x","y")])
worldmap = geom_path(aes(x, y), inherit.aes = FALSE, data = outlines, alpha = 0.8, show_g
p = ggplot(scores,aes(x=lon,y=lat,fill=cut(ME,seq(-100,100,20))))+geom_raster()+
  scale_fill_manual("ME",values=tim.colors(10),drop = FALSE)+
  worldmap
p

#EXAMPLE 2 TEMP EPS plot for one station on reversed-log-y scale
require(ggplot2)
require(scales)
fname="~/examplesRfdbk/eps/2013111112/verTEMP.nc"
condition      = list(veri_description="grepl('first guess vv',veri_description)",
                    veri_description="grepl('member',veri_description)",
                    state="state%in%c(0,1)",
                    statid="statid=='01028'")
columns        = c("obs","veri_data","varno","level","veri_description","veri_foreca
DT             = fdbk_dt_multi_large(fname,condition,columns,1)
DT$veri_description = as.numeric(substr(DT$veri_description,29,32))
setnames(DT,"veri_description","member")
DT[,varno:=varno_to_name(varno,F)]
reverselog_trans <- function(base = exp(1)) {
  trans <- function(x) -log(x, base)
  inv <- function(x) base^(-x)
  trans_new(paste0("reverselog-", format(base)), trans, inv,
            log_breaks(base = base),
            domain = c(1e-100, Inf))
}

# plot only even members for clearness+ obs as black line
ggplot(DT[DT$member%%2==0,],aes(x=veri_data,y=level,color=factor(member)))+geom_path()+ge
  scale_y_continuous(trans=reverselog_trans(10))+
  geom_point(data =DT[member==1], aes(x=obs,y=level), colour = "black")+
  geom_path(data =DT[member==1], aes(x=obs,y=level), colour = "black")+
  ggtitle(paste("EPS TEMP for station",unique(DT$statid)))

#EXAMPLE 3 SATELLITE RADIATION plot verification scores as function of channel and stael
require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/example_monRad/monRAD_*.nc",intern=T)
condition    = list(obs="!is.na(obs)",
                    level="level>100 & level<6000",
```



```

      veri_forecast_time="veri_forecast_time==0",
      veri_run_type="veri_run_type==3",
      veri_ens_member="veri_ens_member==1")
DT      = fdbk_dt_multi_large(fnames, condition, c("obs", "veri_data", "level", "statid"), 1)
scores   = fdbk_dt_verif_continuous(DT, c("level", "statid"))
ggplot(scores, aes(x=level, y=scores, color=statid, group=statid)) + geom_line() + geom_point() + f

```

```
fdbk_dt_reliability_diagram
```

Calculate the reliability diagram statistics

Description

Calculate the reliability diagram statistics

Usage

```
fdbk_dt_reliability_diagram(DT, thresholds = "", by = "", breaks = "")
```

Arguments

DT	data.table (columns 'veri_ens_member', 'obs' and 'veri_data' plus all variables to make forecasts distinguishable are required!!!)
thresholds	list of threshold for variable names in DT (if "" uses obs median)
by	stratify crps by (e.g. c('varno', 'veri_forecast_time'))
breaks	breaks used to bin the forecast probabilities

Value

data.table with columns forecast bin and observed frequency for each varno/threshold

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```

require(ggplot2)
fnames      = system("/bin/ls ~/examplesRfdbk/eps/*12/verSYNOP*", intern=T)
condition   = list(veri_description="grepl('member', veri_description)",
                   state="state%in%c(0,1)",
                   statid="!is.na(as.numeric(statid)) & !duplicated(statid)",
                   veri_forecast_time="veri_forecast_time>=1200")
columns     = c("obs", "veri_data", "varno", "veri_ens_member", "veri_forecast_time", "statid", "fbin")
DT          = fdbk_dt_multi_large(fnames, condition, columns, 5)
ATTR       = fdbk_dt_reliability_diagram(DT, thresholds="", by=c("varno", "veri_forecast_time"))
ggplot(ATTR, aes(x=fbin, y=obin, color=factor(veri_forecast_time), group=veri_forecast_time))

```

fdbk_dt_uv2drc	<i>Calculate wind direction from u and v wind components in a data.table</i>
----------------	--

Description

Calculate wind direction from u and v wind components in a data.table

Usage

```
fdbk_dt_uv2drc(DATATABLE, col = c("obs", "veri_data"))
```

Arguments

DATATABLE	data table containing the columns "varno" with elements 3 and 4, and e.g. "obs", "obs_ini", "veri_data" or combinations of it
fcst	forecast vector

Value

data.table with same columns as DATATABLE and varno=111

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
fnames = system("ls ~/examplesRfdbk/icon/synop/*", intern=T)[1:5]
cond = list(obs = "!is.na(obs)",
            veri_run_class = "veri_run_class%in%c(0,2)",
            veri_run_type = "veri_run_type%in%c(0,4)",
            state = "state%in%c(0,1,5)",
            statid = "!is.na(as.numeric(statid))",
            statid = "!duplicated(statid)",
            varno = "varno%in%c(3,4)")
colnames = c("obs", "veri_data", "veri_forecast_time", "veri_initial_date", "lat", "lon", "var")
DT = fdbk_dt_multi_large(fnames, cond, colnames, cores=5)
DRC = fdbk_dt_uv2drc(DT)
.rbind.data.table(DT, DRC)
```

fdbk_dt_uv2spd	<i>Calculate wind speed from u and v wind components in a data.table</i>
----------------	--

Description

Calculate wind speed from u and v wind components in a data.table

Usage

```
fdbk_dt_uv2spd(DATATABLE, col = c("obs", "veri_data"))
```

Arguments

DATATABLE data table containing the columns "varno" with elements 3 and 4, and e.g. "obs", "obs_ini", "veri_data" or combinations of it

fcst forecast vector

Value

data.table with same columns as DATATABLE and varno=112

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
fnames = system("ls ~/examplesRfdbk/icon/synop/*", intern=T) [1:5]
cond = list(obs = "!is.na(obs) ",
             veri_run_class = "veri_run_class%in%c(0,2) ",
             veri_run_type = "veri_run_type%in%c(0,4) ",
             state = "state%in%c(0,1,5) ",
             statid = "!is.na(as.numeric(statid)) ",
             statid = "!duplicated(statid) ",
             varno = "varno%in%c(3,4) ")
colnames = c("obs", "veri_data", "veri_forecast_time", "veri_initial_date", "lat", "lon", "var")
DT = fdbk_dt_multi_large(fnames, cond, colnames, cores=5)
SPD = fdbk_dt_uv2spd(DT)
.rbind.data.table(DT, SPD)
```

fdbk_dt_verif_continuous

Deterministic scores for data.tables from feedback files, returns 5-95 confidence intervals if needed.

Description

Function returns a score data.table with ME,MAE,RMSE,SD,R2 and length of verification data pairs. Additionally 5th and 95th confidence interval from bootstrap resampling can be returned. (Do not use to verify e.g. wind direction or similarly strange data types (as ordinary differences make no sense))

Usage

```
fdbk_dt_verif_continuous(DT, strat, bootscores = F, R = 100)
```

Arguments

DT the data table (obs and veri_data are required)

strat list of variables to stratify for

bootscores logical if bootstrap confidence intervals are required (5-95)

R number of bootstrap iterations (default 100)

Value

a data.table of stratified continuous verification scores (ME,SD,RMSE,R2,LEN)(CI_L,CI_U if bootstrap)

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE 1 (continuous scores by lead-time)
require(ggplot2)
fnames = system("ls ~/examplesRfdbk/*/synop/*", intern=T)
cond = list(verno="verno%in%c(3,4)", veri_description="grepl('forecast', v")
columnnames = c("obs", "veri_data", "verno", "veri_model", "veri_forecast_time")
DT = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
DT$verno = verno_to_name(DT$verno)
strat = c("verno", "veri_forecast_time", "veri_model")
scores = fdbk_dt_verif_continuous(DT, strat)
p = ggplot(scores, aes(x=veri_forecast_time, y=scores, group=interaction(scorename, verno, ve
  geom_line(size=.7) + geom_point(size=1.5) + facet_wrap(~scorename, scales = "free")+
  theme_bw()+theme(axis.text.x = element_text(angle=70,hjust = 1))

p

#EXAMPLE 2 (talagrand diagram for each variable)
require(ggplot2)
fnames = system("ls ~/examplesRfdbk/talagrand/*SYNOP*", intern=T)
cond = list(veri_description="grepl('Talagrand', veri_description)")
columnnames = c("veri_data", "verno")
DT = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
DT$verno = verno_to_name(DT$verno)
p = ggplot(DT, aes(x=veri_data)) +
  geom_histogram(binwidth=1, colour="black", fill="white") +
  facet_wrap(~verno)+theme_bw()

p

#EXAMPLE 3 (TEMP verification)
require(ggplot2)
fnames=system("ls ~/examplesRfdbk/fof/*", intern=T)
cond = list(obs="!is.na(obs)", level="level%in%c(100000,92500,85000,70000,50000,40000,30000)")
columnnames = c("obs", "veri_data", "verno", "level")
DT = fdbk_dt_multi_large(fnames, cond, columnnames, cores=20)
DT$verno = verno_to_name(DT$verno)
strat = c("verno", "level")
scores = fdbk_dt_verif_continuous(DT, strat)
setkey(scores, scorename, verno, level)
scores = scores[!scorename%chin%c("LEN"),]
p = ggplot(scores, aes(x=scores, y=level, group=interaction(verno, scorename)))+
  geom_path() + facet_wrap(~scorename~verno, scales="free_x")+
  theme_bw()+theme(axis.text.x = element_text(angle=70,hjust = 1))+scale_y_reverse()

p

#EXAMPLE 4 (SATOB verification)
require(ggplot2)
fnames = system("ls ~/examplesRfdbk/gme/satob/*", intern=T)
cond = list(obs="!is.na(obs)")
```

```

columnnames      = c("veri_data", "varno", "obs", "veri_forecast_time", "statid", "lat", "lon")
DT               = fdbk_dt_multi_large(fnames, cond, columnnames, 10)
DT[, lon:=cut(lon, seq(-180, 180, by=10), labels=seq(-175, 175, by=10), include.lowest=T), ]
DT[, lat:=cut(lat, seq(-90, 90, by=10), labels=seq(-85, 85, by=10), include.lowest=T), ]
strat            = c("varno", "veri_forecast_time", "statid", "lon", "lat")
scores           = fdbk_dt_verif_continuous(DT, strat)
scores[, lon:=as.numeric(levels(lon)) [lon]]
scores[, lat:=as.numeric(levels(lat)) [lat]]
scores[, varno:=varno_to_name(varno)]
scores           = scores[!is.na(scores), ]
p = ggplot(droplevels(scores[varno=="U" & veri_forecast_time=="10800" & scorename=="R2",
  facet_wrap(~varno~statid~scorename)+
  scale_fill_manual(breaks=seq(0, 1, by=.1), values=tim.colors(10), drop = FALSE)+borders(1)))
p

#EXAMPLE 5 (SYNOP score time series)
require(ggplot2)
fnames = system("ls ~/examplesRfdbk/*/synop/verSYNOP.*", intern=T)
cond = list(obs="!is.na(obs)",
  veri_description="grepl('forecast', veri_description)",
  veri_forecast_time="veri_forecast_time%in%c(1200, 16800)",
  state="state%in%c(0, 1)",
  statid="!is.na(as.numeric(statid))")

colnames = c("obs", "veri_data", "veri_forecast_time", "veri_initial_date", "varno", "veri_model")
DT = fdbk_dt_multi_large(fnames, cond, colnames, cores=20)
keep = comparableRows(DT, splitCol="veri_model", splitVal=c("GME", "ICON"))
DT = DT[keep]
gc()

scores = fdbk_dt_verif_continuous(DT, strat=c("veri_forecast_time", "veri_initial_date", "varno"))
scores$veri_initial_date = as.POSIXct(scores$veri_initial_date, format="%Y%m%d%H")
scores$varno = varno_to_name(scores$varno)

p = ggplot(scores[varno=="RH"&scorename=="RMSE", ], aes(x=veri_initial_date, y=scores, color=veri_model)) +
  geom_line() +
  facet_grid(~scorename~varno~veri_forecast_time, scales="free")
p

#EXAMPLE 6 (TEMP time series)
require(ggplot2)
require(RColorBrewer)
fnames = system("/bin/ls ~/examplesRfdbk/*/temp/verTEMP.*", intern=T)
LEVELS = c(100000, 92500, 85000, 70000, 50000, 40000, 30000, 25000, 20000, 15000, 10000, 7000, 5000)
cond = list(statid="!is.na(as.numeric(statid))",
  obs="!is.na(obs)",
  state="state%in%c(0, 1, 5)",
  veri_run_type="veri_run_type%in%c(0, 4)",
  statid="round(as.numeric(statid)/1000)<=10",
  level="level%in%c(100000, 92500, 85000, 70000, 50000, 40000, 30000, 25000, 20000, 15000, 10000, 7000, 5000)",
  veri_forecast_time="veri_forecast_time%in%c(0, 4800, 9600, 14400, 16800)")
columnnames = c("obs", "veri_data", "veri_forecast_time", "veri_initial_date", "level", "varno", "valid_date")
DT = fdbk_dt_multi_large(fnames, cond, columnnames, cores=10)
DT[, valid_date:=as.POSIXct(veri_initial_date, format="%Y%m%d%H%M")+veri_forecast_time*3600]
SCORES = fdbk_dt_verif_continuous(DT, strat=c("veri_forecast_time", "level", "varno", "valid_date"))
SCORES[, varno:=varno_to_name(varno)]
x11(width=18, height=6)

```

```

ggplot(SCORES[scorename=="ME" & varno=="T"], aes(x=valid_date, y=as.numeric(factor(level))),
       geom_raster(limits=c(-20,20)) +
       facet_wrap(~veri_model~veri_forecast_time~varno, ncol=5) +
       scale_y_reverse(breaks = seq(length(LEVELS), 1, by=-1), labels=rev(LEVELS)) +
       scale_fill_manual("ME", values=rev(brewer.pal(9, "RdYlBu")), drop=F) +
       theme_bw())

#EXAMPLE 7 (continuous scores by lead-time plus confidence intervals)
require(ggplot2)
fnames      = system("ls ~/examplesRfdbk/*/synop/verSYNOP.*", intern=T)[1:10]
cond        = list(varno="varno%c(3,4)", veri_description="grepl('forecast', v
columnnames = c("obs", "veri_data", "varno", "veri_forecast_time")
DT          = fdbk_dt_multi_large(fnames, cond, columnnames, 20)
DT$varno    = varno_to_name(DT$varno)
strat       = c("varno", "veri_forecast_time")
scores      = fdbk_dt_verif_continuous(DT, strat, bootscores=T, R=100)
ggplot(scores, aes(x=veri_forecast_time, y=scores, color=varno)) +
  geom_errorbar(aes(ymin=CI_L, ymax=CI_U), width=.1) +
  geom_line() +
  geom_point() +
  theme_bw() +
  facet_wrap(~scorename, scale="free_y", ncol = 6)

```

fdbk_dt_verif_continuous_windDir

Deterministic scores for wind direction in degrees with bootstrap confidence intervals if required

Description

Deterministic scores for wind direction in degrees with bootstrap confidence intervals if required

Usage

```
fdbk_dt_verif_continuous_windDir(DT, strat, bootscores = F, R = 100)
```

Arguments

DT	data table (obs and veri_data are required, only for wind direction in degrees!)
strat	list of variables to stratify for
bootscores	logical if bootstrap confidence intervals are required (5-95)
R	number of bootstrap iterations (default 100)

Value

a data.table of stratified continuous verification scores (ME,SD,RMSE,R2,LEN)

Author(s)

Felix <felix.fundel@dwd.de>

fdbk_refdate	<i>Get reference date(s) from feedback file(s)</i>
--------------	--

Description

Get reference date(s) from feedback file(s)

Usage

```
fdbk_refdate(filenamees)
```

Arguments

filenamees filename(s) fo feedback file(s) including path

Value

vector of reference dates YYYYmmddHHMM

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
filenamees = system("ls ~/examplesRfdbk/icon/synop/*", intern=T)
fdbk_refdate(filenamees)
```

multiplot	<i>Multiple plot function</i>
-----------	-------------------------------

Description

description ggplot objects can be passed in ..., or to plotlist (as a list of ggplot objects) If the layout is something like matrix(c(1,2,3,3), nrow=2, byrow=TRUE), then plot 1 will go in the upper left, 2 will go in the upper right, and 3 will go all the way across the bottom.

Usage

```
multiplot(..., plotlist = NULL, cols = 1, layout = NULL)
```

Arguments

cols: Number of columns in layout
 layout: A matrix specifying the layout. If present, 'cols' is ignored.

References

http://www.cookbook-r.com/Graphs/Multiple_graphs_on_one_page_%28ggplot2%29/

read_fdbk	<i>Load the entire content of a fdbk file</i>
-----------	---

Description

Load the entire content of a fdbk file

Usage

```
read_fdbk(filename)
```

Arguments

filename	NetCDF fdbk filename including path
----------	-------------------------------------

Value

a list of entries from the given fdbk file

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
fdbk = read_fdbk("~/examplesRfdbk/icon/synop/verSYNOP.2014120112")
str(fdbk)
```

read_fdbk_f	<i>Load the entire content of a fdbk file or only some specified variables (faster and more resource friendly)</i>
-------------	--

Description

Load the entire content of a fdbk file or only some specified variables (faster and more resource friendly)

Usage

```
read_fdbk_f(filename, vars = "")
```

Arguments

filename	NetCDF fdbk filename including path
vars	vector of variables that should be retained if not specified or "" all variables are loaded

Value

a list of entries from the given fdbk file

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
fdbk = read_fdbk_f("~/examplesRfdbk/icon/synop/verSYNOP.2014120112", c("obs", "veri_data"))
str(fdbk)
```

read_fdbk_large	<i>Load one fdbk file and return as list of lists of.... condition and vars arguments help to discard data you do not need</i>
-----------------	--

Description

Load one fdbk file and return as list of lists of.... condition and vars arguments help to discard data you do not need

Usage

```
read_fdbk_large(fname, condition = "", vars = "")
```

Arguments

fname	feedback filename (including path)
condition	list of strings of conditions (all of the list entries are connected with the "&" operator!)
vars	vector of variable names that should be retained if not specified or "" all variables are loaded

Value

a data.table with fdbk file content

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
#EXAMPLE 1 (1x1 deg.) bias of satellite data (channel 921 from METOP-1)
fnames      = "~/examplesRfdbk/example_monRad/monRAD_2014092406.nc"
condition    = list(obs="!is.na(obs)",
                    level="level%in%c(921)",
                    statid="statid=='METOP-1'",
                    veri_forecast_time="veri_forecast_time==0",
                    veri_run_type="veri_run_type==3",
                    veri_ens_member="veri_ens_member==1")
fdbk        = read_fdbk_large(fnames, condition, c("lon", "lat", "obs"))
x11(width=12,height=7.5)
scatterplot(fdbk$DATA$lon$values, fdbk$DATA$lat$values, fdbk$DATA$obs$values, pch=20, cex=.5,
```

rowSds	<i>Standard deviation on rows of array (faster than using 'apply')</i>
--------	--

Description

Standard deviation on rows of array (faster than using 'apply')

Usage

```
rowSds(a, na.rm = F)
```

Arguments

a	2d array
---	----------

Value

standard deviation on rows

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
a = array(rnorm(1e5), dim=c(1000, 50))
system.time(rowSds(a))
system.time(apply(a, 1, sd))
# Results agree besides some numerical precision errors
identical(round(rowSds(a), 12), round(apply(a, 1, sd), 12))
```

scatterplot	<i>Scatterplot with colored points</i>
-------------	--

Description

Scatterplot with colored points

Usage

```
scatterplot(x, y, z, zlim = NULL, ncol = 10, cpal = c("red", "white",
"blue"), ...)
```

Arguments

x	numeric vector
y	numeric vector
z	numeric vector
zlim	plot color range (default z range)
ncol	number of colors (default 10)
cpal	color palette (default red,white,blue)

Value

a plot

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
condition = list(obs="!is.na(obs)", level="level%in%c(921)", statid="statid=='METOP-1'"
DT        = fdbk_dt_multi_large("~/examplesRfdbk/example_monRad/monRAD_2014092406.nc", co
x11(width=12,height=7.5)
DT[, scatterplot(lon, lat, obs, pch=20, cpal=tim.colors(), ncol=20, cex=.5)]
world(add=T, col="gray", fill=T)
```

statid_to_wmoregion

Convert WMO station-id to region

Description

Convert WMO station-id to region

Usage

```
statid_to_wmoregion(ident)
```

Arguments

ident numeric vector of station ID as integer (see variable "ident" in feedback file)

Value

vector of same length wiith id replaced by region shortcut

Author(s)

Felix <felix.fundel@dwd.de>

varno_to_name	<i>Convert variable number (varno) to long or short variable name and reverse</i>
---------------	---

Description

Convert variable number (varno) to long or short variable name and reverse

Usage

```
varno_to_name(varno, short = T, rev = F)
```

Arguments

short	short or long name (boolean)
rev	TRUE: from varno to name, FALSE: from short name to varno
varno(s)	or short name(s)

Value

long or short variable name(s)

Author(s)

Felix <felix.fundel@dwd.de>

Examples

```
varno_to_name(c(3,4), short=T, rev=F)
varno_to_name(c(3,4), short=F, rev=F)
varno_to_name(c("RH", "TS"), short=T, rev=T)
varno_to_name(c("RH", "TS"), short=F, rev=T)
```

windBias	<i>Difference in wind direction (based un U. Pfl<c3><bc>gers code)</i>
----------	--

Description

Difference in wind direction (based un U. Pfl<c3><bc>gers code)

Usage

```
windBias(ang_pred, ang_obs)
```

Arguments

ang_pred	forecast wind direction
ang_obs	observed wind direction

Value

wind direction difference in degree

Author(s)

Felix <felix.fundel@dwd.de>

windDir	<i>Convert u,v wind in wind direction in degrees</i>
---------	--

Description

Convert u,v wind in wind direction in degrees

Usage

```
windDir(u, v)
```

Arguments

u	u wind vector
v	v wind vector

Value

wind direction in degree (0 - <360), 360 is set to 0, if u&v=0 then return NA

Author(s)

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Examples

```
u = c( 10,  0,  0, -10,  10,  10, -10, -10,  0)
v = c(  0,  10, -10,  0,  10, -10,  10, -10,  0)
windDir(u,v)
```

windSpeed	<i>Convert u,v wind in wind speed</i>
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Description

Convert u,v wind in wind speed

Usage

```
windSpeed(u, v)
```

Arguments

u	u wind vector
v	v wind vector

Value

wind speed

Author(s)

Felix <felix.fundel@dwd.de>

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