Package ‘RFOC’

February 7, 2026

Type Package

Title Graphics for Spherical Distributions and Earthquake Focal Mechanisms

Version 3.4-14

Date 2026-02-07

Depends R (>= 3.1.0)

Imports RPMG, GEOmap, RSEIS, MASS, fields, rpanel

Suggests maps

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Description Graphics for statistics on a sphere, as applied to geological fault data, crystallography, earthquake focal mechanisms, radiation patterns, ternary plots and geographical/geological maps. Non-double couple plotting of focal spheres and source type maps are included for statistical analysis of moment tensors.

License GPL (>= 2)

NeedsCompilation no

Repository CRAN

Date/Publication 2026-02-07 16:50:02 UTC

Contents

`RFOC-package` *Calculates and plot Earthquake Focal Mechanisms*

Description

Graphics for statistics on a sphere, as applied to geological fault data, crystallography, earthquake focal mechanisms, radiation patterns, ternary plots and geographical/geological maps. Given strike-dip-rake or a set of fault planes, focal planes, RFOC creates structures for manipulating and plotting earthquake focal mechanisms as individual plots or distributed spatially maps.

RFOC can be used for analysis of plane orientation, geologic structure, distribution of stress and strain analyses.

Details

Visualize focal mechanisms in a number of modes, including: beachball plots, radiation plots, fault planes and ternary diagrams. Shows spatial distribution of spherically distributed data.

Author(s)

Jonathan M. Lees Maintainer: Jonathan M. Lees <jonathan.lees@unc.edu>

References

J. M. Lees. Geotouch: Software for three and four dimensional GIS in the earth sciences. *Computers and Geosciences* , 26(7):751–761, 2000.

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

Snyder, John P., 1987, Map Projections-a working manual, USGS-Professional Paper, 383p.

C. Frohlich. Triangle diagrams: ternary graphs to display similarity and diversity of earthquake focal mechanisms. *Physics of the Earth and Planetary Interiors*, 75:193-198, 1992.

See Also

RSEIS, GEOmap, zoeppritz

Examples

```
#############  plot one focal mechanism:
M = SDRfoc(-25, 34, 16,u = FALSE, ALIM = c(-1, -1, +1, +1), PLOT=TRUE)


#############  plot many P-axes:
paz = rnorm(100, mean=297, sd=100)
pdip = rnorm(100, mean=52, sd=20)
net()
focpoint(paz, pdip, col='red',  pch=3, lab="", UP=FALSE)

#############

#### Show many Focal mechanisms on a plot:

Z1 = c(159.33,51.6,206,18,78,
161.89,54.5,257,27,133,
170.03,53.57,-44,13,171,
154.99,50.16,-83,19,-40,
151.09,47.15,123,23,-170,
176.31,51.41,-81,22,122,
153.71,46.63,205,28,59,
178.39,51.21,-77,16,126,
178.27,51.1,-86,15,115,
177.95,51.14,-83,25,126,
178.25,51.18,215,16,27
)

MZ = matrix(Z1, ncol=5, byrow=TRUE)

plot(MZ[,1], MZ[,2], type='n', xlab="LON", ylab="LAT", asp=1)

for(i in 1:length(MZ[,1]))
{
paste(MZ[i,3], MZ[i,4], MZ[i,5])
```

```
MEC =  SDRfoc(MZ[i,3], MZ[i,4], MZ[i,5], u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
fcol =  foc.color(foc.icolor(MEC$rake1), pal=1)
justfocXY(MEC, x=MZ[i,1], y =MZ[i,2] , focsiz=0.5, fcol =fcol , fcolback = "white", xpd = TRUE)


}
```

---

addmecpoints *Add points to Focal Mech*

Description

Add a standard set of points to a Focal Mechanism

Usage

```
addmecpoints(MEC, pch = 5)
```

Arguments

MEC	MEC structure list
pch	plotting character

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

SDRfoc, focpoint

Examples

```
MEC= SDRfoc(12,34,-120)
addmecpoints(MEC)
```

addPT — *Add P-T Axis to focal plot*

Description

Add Pressure and tension Axes to focal mechanism

Usage

```
addPT(MEC, pch = 5)
```

Arguments

MEC	MEC structure
pch	plotting character

Value

Graphical Side Effect

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

addPTarrows

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
Beachfoc(MEC)
addPT(MEC, pch = 5)
```

addPTarrows — *Add fancy 3D arrows*

Description

Illustrate Pressure and Tension axis on Focal Plot using 3D arrows

Usage

```
addPTarrows(MEC)
```

Arguments

`MEC`	Mechanism Structure

Value

Graphical Side Effects

Note

This function looks better when plotting the upper hemisphere

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

focpoint, BOXarrows3D,Z3Darrow

Examples

```
 MEC = SDRfoc(65,25,13, u=TRUE, ALIM=c(-1,-1, +1, +1), PLOT=TRUE)

addPTarrows(MEC)
```

`addsmallcirc` *Small Circle on Stereonet*

Description

Calculate and plot small circle on Stereo net at arbitrary azimuth, orientation and conical angle

Usage

```
addsmallcirc(az, iang, alphadeg, BALL.radius = 1, N = 100, add = TRUE, ...)
```

Arguments

`az`	Azimuth of axis
`iang`	angle of dip, degrees
`alphadeg`	width of cone in degrees
`BALL.radius`	size of sphere
`N`	NUmber of points to calculate
`add`	logical, TRUE=add to existing plot
`...`	graphical parameters

Details

Given the azimuth and dip of a vector, plot the small circle around the pole with conical angle alphadeg

Value

LIST:

x	x-coordinates
y	y-coordinates

Note

alphadeg is the radius of the conic projection

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

net

Examples

```
net()
addsmallcirc(65, 13, 20, BALL.radius = 1, N = 100, add = TRUE)
addsmallcirc(165, 73, 5.6, BALL.radius = 1, N = 100, add = TRUE)
```

AlongGreat *Get Points Along Great Circle*

Description

Using a Starting LAT-LON, return points along an azimuth

Usage

```
AlongGreat(LON1, LAT1, km1, ang,  EARTHRAD= 6371)
```

Arguments

LON1	Longitude, point
LAT1	Latitude, point
km1	Kilometers in direction ang
ang	Direction from North
EARTHRAD	optional earth radius, default = 6371

Details

Returns LAT-LON points along a great circle, so many kilometers away in a specified direction

Value

LIST:

lat	Latitude, destination point
lon	Longitude, destination point
distdeg	distance in degrees
distkm	distance in km

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
london = c(51.53333, -0.08333333)

AlongGreat(london[2], london[1], 450, 56)
```

---

alpha95 *95 percent confidence for Spherical Distribution*

Description

Calculates conical projection angle for 95% confidence bounds for mean of spherically distributed data.

Usage

```
alpha95(az, iang)
```

Arguments

az	vector of azimuths, degrees
iang	vector of dips, degrees

Details

Program calculates the cartesian coordinates of all poles, sums and returns the resultant vector, its azimuth and length (R). For N points, statistics include:

$$K = \frac{N-1}{N-R}$$

$$S = \frac{81^\circ}{\sqrt{K}}$$

$$\kappa = \frac{log(\frac{\epsilon_1}{\epsilon_2})}{log(\frac{\epsilon_2}{\epsilon_3})}$$

$$\alpha_{95} = cos^{-1}\left[1 - \frac{N-R}{R}\left(20^{\frac{1}{N-1}} - 1\right)\right]$$

where ϵ's are the relevant eigenvalues of matrix MAT and angles are in degrees.

Value

LIST:

Ir	resultant inclination, degrees
Dr	resultant declination, degrees
R	resultant sum of vectors, normalized
K	K-dispersion value
S	spherical variance
Alph95	95% confidence angle, degrees
Kappa	log ratio of eignevectors
E	Eigenvactors
MAT	matrix of cartesian vectors

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Davis, John C., 2002, Statistics and data analysis in geology, Wiley, New York, 637p.

See Also

addsmallcirc

Examples

```
paz = rnorm(100, mean=297, sd=10)
pdip = rnorm(100, mean=52, sd=8)
ALPH = alpha95(paz, pdip)

#########  draw stereonet
net()
############  add points
focpoint(paz, pdip, col='red',  pch=3, lab="", UP=FALSE)
###############  add 95 percent confidence bounds
addsmallcirc(ALPH$Dr, ALPH$Ir, ALPH$Alph95, BALL.radius = 1, N = 25,
add = TRUE, lwd=1, col='blue')

############  second example:
paz = rnorm(100, mean=297, sd=100)
pdip = rnorm(100, mean=52, sd=20)
ALPH = alpha95(paz, pdip)

net()
focpoint(paz, pdip, col='red',  pch=3, lab="", UP=FALSE)

addsmallcirc(ALPH$Dr, 90-ALPH$Ir, ALPH$Alph95, BALL.radius = 1, N = 25,
add = TRUE, lwd=1, col='blue')
```

AXpoint *Extract Axis pole on Stereonet*

Description

Interactive extract axis point on Stereonet

Usage

```
AXpoint(UP = TRUE, col=2, n=1)
```

Arguments

UP	logical, TRUE=upper hemisphere
col	plotting color
n	maximum number to locate, default=unlimited

Details

Program uses locator to create a vector of poles. Points outside the focal sphere (r>1) are ignored. If n is missing, locator continues until stopped (middle mouse in linux, stop in windows).

Value

phiang	azimuth angle, degrees
dip	dip angle, degrees
x	x-coordinate of cartesian vector
y	y-coordinate of cartesian vector
z	z-coordinate of cartesian vector
gx	x-coordinate of prjection
gy	y-coordinate of prjection

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

locator, qpoint, EApoint

Examples

```
####################  this is interactive
if(interactive()){
net()
Z = AXpoint(UP = TRUE)


##  click in steronet
Z
}
```

---

bang — *Angle between two 2D normalized vectors*

Description

Calculates the angle between two 2D normalized vectors using dot and cross product

Usage

```
bang(x1, y1, x2, y2)
```

Arguments

x1	x coordinate of first normalized vector
y1	y coordinate of first normalized vector
x2	x coordinate of second normalized vector
y2	y coordinate of second normalized vector

Details

The sign of angle is determined by the sign of the cross product of the two vectors.

Value

angle in radians

Note

Vectors must be normalized prior to calling this routine. Used mainly for vectors on the unit sphere.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
v1 = c(5,3)
v2 = c(6,1)

a1 = c(5,3)/sqrt(v1[1]^2+v1[2]^2)
a2 = c(6,1)/sqrt(v2[1]^2+v2[2]^2)

plot(c(0, v1[1],v2[1] ) , c(0, v1[2],v2[2]), type='n', xlab="x", ylab="y" )
text(c(v1[1],v2[1]) , c(v1[2],v2[2]), labels=c("v1", "v2"), pos=3, xpd=TRUE)

arrows(0, 0, c(v1[1],v2[1] ), c(v1[2],v2[2]))

B  = 180*bang(a1[1], a1[2], a2[1], a2[2])/pi
title(paste(sep=" ", "Angle from V1 to V2=",format(B, digits=2)) )
```

Beachfoc *Plot a BeachBall Focal Mechanism*

Description

Plots a focal mechanism in beachball style

Usage

```
Beachfoc(MEC, fcol = gray(0.9), fcolback = "white", ALIM = c(-1, -1, +1, +1))
```

Arguments

`MEC`	Mechanism Structure
`fcol`	color for the filled portion of the beachball
`fcolback`	color for the background portion of the beachball, default='white'
`ALIM`	Bounding box for beachball, default=c(-1, -1, +1, +1)

Details

Beachfoc is run after MEC is set using SDRfoc. Options for plotting the beachball in various modes are controlled by flags set in MEC

Value

Used for its graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K. Aki and P. G. Richards. *Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002. Keiiti Aki, Paul G. Richards. ill. ; 26 cm.

See Also

CONVERTSDR, SDRfoc, justfocXY

Examples

```
MEC = SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=TRUE)

Beachfoc(MEC, fcol=MEC$fcol, fcolback="white")
```

`Bfocvec` *Angles for Ternary plot*

Description

Calculates Angles for determining ternary distribution of faults based on P-T axis orientation.

Usage

```
Bfocvec(Paz, Pdip, Taz, Tdip)
```

Arguments

`Paz`	vector of azimuths, degrees
`Pdip`	vector of dips, degrees
`Taz`	vector of azimuths, degrees
`Tdip`	vector of dips, degrees

Details

This calculation is based on Froelich's paper.

Value

LIST:

`Bdip`	azimuths, degrees
`Baz`	dips, degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

C. Frohlich. Triangle diagrams: ternary graphs to display similarity and diversity of earthquake focal mechanisms. Physics of the Earth and Planetary Interiors, 75:193-198, 1992.

See Also

ternfoc.point

Examples

```
Msdr = CONVERTSDR(55.01, 165.65,  29.2   )
 MEC = MRake(Msdr$M)
  MEC$UP = FALSE
   az1 = Msdr$M$az1
  dip1 = Msdr$M$d1
  az2 = Msdr$M$az2
  dip2 = Msdr$M$d2
  BBB = Bfocvec(az1, dip1,  az2,  dip2)
  V = ternfoc.point(BBB$Bdip, Msdr$M$pd, Msdr$M$td )
```

BOXarrows3D *Create a 3D Arrow structure*

Description

Create and project and plot 3D arrows with viewing Matrix.

Usage

```
BOXarrows3D(x1, y1, z1, x2, y2, z2, aglyph = NULL, Rview = ROTX(0),
col = grey(0.5), border = "black", len = 0.7, basethick = 0.05,
headlen = 0.3, headlip = 0.02)
```

Arguments

`x1`	x-coordinates of base of arrows
`y1`	y-coordinates of base of arrows
`z1`	z-coordinates of base of arrows
`x2`	x-coordinates of head of arrows
`y2`	y-coordinates of head of arrows
`z2`	z-coordinates of head of arrows
`aglyph`	glyph structure, default is Z3Darrow
`Rview`	Viewing matrix
`col`	fill color
`border`	Border color
`len`	Length
`basethick`	thickness of the base
`headlen`	thickness of the head
`headlip`	width of the overhanging lip

Details

Arrows point from base to head.

Value

Used for graphical side effects.

Note

Any 3D glyph strucutre can be used

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

Z3Darrow

Examples

```
if(interactive()){
#### animate 10 random arrow vectors


 L   = list(x1 = runif(10, min=-2, max=2),
    y1 = runif(10, min=-2, max=2),
    z1=runif(10, min=-4, max=4),
    x2 = runif(10, min=-2, max=2),
    y2 = runif(10, min=-2, max=2),
    z2=runif(10, min=-4, max=4)
    )
  headlen = .3
  len = .7
  basethick = 0.05
  headlip = .02
  aglyph = Z3Darrow(len = len , basethick =basethick , headlen =headlen , headlip=headlip )

  r1 = 8
  theta = seq(from=0, to=2*360, length=200)
  mex = r1*cos(theta*pi/180)
  mey = r1*sin(theta*pi/180)
  mez = seq(from=r1, to =0 , length=length(mex))
  ##  mez=rep(r1, length=length(mex))

  angz = atan2(mey, mex)*180/pi
  angx = atan2(sqrt(mex^2+mey^2), mez)*180/pi
  pal=c("red", "blue", "green")

##  aglyph = gblock

  for(j in 1:length(angz))
    {
      Rview  =    ROTZ(angz[j])
      plot(c(-4,4), c(-4,4), type='n', asp=1); grid()

      BOXarrows3D(L$x1,L$y1,L$z1, L$x2,L$y2,L$z2,  aglyph=aglyph,  Rview=Rview, col=pal)

      Sys.sleep(.1)
    }
}
```

---

circtics *Draw circular ticmarks*

Description

Draw circular ticmarks

Usage

```
circtics(r = 1, dr = 0.02, dang = 10, ...)
```

Arguments

`r`	radius
`dr`	length of tics
`dang`	angle between tics
`...`	graphical parameters

Value

graphical side effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
phi = seq(from =0, to = 2 * pi, length=360)
   x = cos(phi)
   y = sin(phi)
   plot(x, y, col = 'blue', asp=1, type='l')
  circtics(r = 1, dr = 0.02, dang = 10, col='red')
```

`CONVERTSDR` *Convert Strike-Dip-Rake to MEC structure*

Description

Takes Strike-Dip-Rake and creates planes and pole locations for MEC structure

Usage

```
CONVERTSDR(strike, dip, rake)
```

Arguments

strike	angle, degrees, strike of down dip directin
dip	angle, degrees, dip is measured from the horizontal NOT from the NADIR
rake	angle, degrees

Details

input is strike dip and rake in degrees

Value

LIST:

strike	strike
dipdir	dip
rake	rake
F	list(az, dip) of F-pole
G	list(az, dip) of G-pole
U	list(az, dip) of U-pole
V	list(az, dip) of V-pole
P	list(az, dip) of P-pole
T	list(az, dip) of T-pole
M	list(az1=0, d1=0, az2=0, d2=0, uaz=0, ud=0, vaz=0, vd=0, paz=0, pd =0, taz=0, td=0)

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

BeachFoc

Examples

```
s=65
d=25
r=13

  mc = CONVERTSDR(s,d,r )
```

`cross.prod` *Vector Cross Product*

Description

Vector Cross Product with list as arguments and list as values

Usage

```
cross.prod(B, A)
```

Arguments

`B`	list of x,y,z
`A`	list of x,y,z

Value

LIST

`x, y, z`	vector of cross product

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

RSEIS::xprod

Examples

```
B1 = list(x=4, y=9, z=2)
B2 = list(x=2,y=-5,z=4)

cross.prod(B1, B2)
```

CROSSL *Vector Cross Product*

Description

returns cross product of two vectors in list format

Usage

```
CROSSL(A1, A2)
```

Arguments

A1	list x,y,z
A2	list x,y,z

Value

List

x, y, z	input vector
az	azimuth, degrees
dip	dip, degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

RSEIS::xprod

Examples

```
A1 = list(x=1,y=2, z=3)
A2 = list(x=12,y=-2, z=-5)

N = CROSSL(A1, A2)
```

`doNonDouble` *Plot Non-double Couple Moment*

Description

Plot Non-double Couple Moment

Usage

```
doNonDouble(moments, sel = 1, col=rgb(1, .75, .75))
```

Arguments

`moments`	list of moments: seven elements. See details.
`sel`	integer vector, index of moments to plot
`col`	color, either a single color, rgb, or a color palette

Details

Plot, sequentially the moments using the CLVD (non-double couple component. The first element of the list is the integer index of the event. The next six elements are the moments in the following order, c(Mxx, Myy, Mzz, Mzy, Mxz, Mxy) .

If the data is in spherical coordinates, one must switch the sign of the Mrp and Mtp components, so:

```
Mrr = Mzz
Mtt = Mxx
Mpp = Myy
Mrt = Mxz
Mrp = -Myz
Mtp = -Mxy
```

Value

Side effects

Note

If events are read in using spherical rather than cartesian coordinates need a conversion:

```
Mrr = Mzz
Mtt = Mxx
Mpp = Myy
Mrt = Mxz
Mrp = -Myz
Mtp = -Mxy
```

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Ekstrom, G.; Nettles, M. and DziewoDski, A. The Global CMT Project 2004-2010: centroid-moment tensors for 13,017 earthquakes Physics of the Earth and Planetary Interiors, 2012.

See Also

MapNonDouble, ShadowCLVD, angles, nodalLines, PTaxes

Examples

```
mo = list(n=1, m1=1.035675e+017, m2=-1.985852e+016,
m3=-6.198052e+014, m4=1.177936e+017, m5=-7.600627e+016,
m6=-3.461405e+017)

moments = cbind(mo$n, mo$m1, mo$m2, mo$m3, mo$m4, mo$m5, mo$m6)

doNonDouble(moments)
```

`EApoint` *Equal-area point stereonet*

Description

Interactive locator to calculate x,y orientation, dip coordinates and plots on an equalarea stereonet

Usage

```
EApoint()
```

Details

Used for returning a set of strike/dip angles on Equal-area stereonet plot.

Value

LIST:

`phi`	orientation, degrees
`iang`	angle of dip, degrees
`x`	x-coordinate
`y`	y-coordinate

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

qpoint, focpoint

Examples

```
####################  this is interactive

###  collect points with locator()

if(interactive()){
net()
eps = EApoint()

###  plot results
net()
qpoint(eps$phi , eps$iang)
}
```

---

egl *Tungurahua Cartesian Moment Tensors*

Description

Cartesian moment tensors from Tungurahua Volcano, Ecuador

Usage

```
data(egl)
```

Format

A list of 84 moment tensors, each elelment consists of: lam1, lam2, lam3, vec1, vec2,vec3, ratio, force.

Source

See below

References

Kim, K., Lees, J.M. and Ruiz, M., (2014) Source mechanism of Vulcanian eruption at Tungurahua Volcano, Ecuador, derived from seismic moment tensor inversions, *J. Geophys. Res.*, February, 2014. Vol. 119(2): pp. 1145-1164.

Examples

```
data(egl)

typl1=c(2,4,7,12,13,16,17,18,19,20,24,25,26,27,
28,29,30,31,33,34,35,36,37,38,40,43,50,
59,62,73,74,77,8,79,80,81,83,84)
typl2=c(5,6,8,9,10,11,14,15,22,42,46,47,48,49,
51,52,53,54,55,56,57,58,60,61,63,72,82)

evtns=1:84

par(mfrow=c(1,2))
T1 = TapeBase()
TapePlot(T1)


for(i in 1:length(egl))
{
i1 = egl[[i]]

E1 = list(values=c(i1$lam1, i1$lam2, i1$lam3),
vectors = cbind(i1$vec1, i1$vec2, i1$vec3))

testrightHAND(E1$vectors)

E1$vectors = forcerighthand(E1$vectors)

mo=sort(E1$values,decreasing=TRUE)
# M=sum(mo)/3
# Md=mo-M
h = SourceType(mo)
h$dip = 90-h$phi

h1 = HAMMERprojXY(h$dip*pi/180, h$lam*pi/180)

if(i %in% typl1) { col="red" }else{col="blue" }
points(h1$x, h1$y,  pch=21, bg=col )

}

par(mai=c(0,0,0,0))
hudson.net()
for(i in 1:length(typl1))
{
egv=egl[[typl1[i]]]
m=c(egv$lam1,egv$lam2,egv$lam3)
col='red'
hudson.plot(m=m,col=col)
}

for(i in 1:length(typl2))
```

```
{
egv=egl[[typl2[i]]]
m=c(egv$lam1,egv$lam2,egv$lam3)
col='blue'
hudson.plot(m=m,col=col,lwd=2)
}
```

---

fancyarrows *Make fancy arrows*

Description

Create and plot fancy arrows. Aspect ratio must be set to 1-1 for these arrows to plot correctly.

Usage

```
fancyarrows(x1, y1, x2, y2, thick = 0.08,
     headlength = 0.4, headthick = 0.2, col = grey(0.5),
     border = "black")
```

Arguments

x1	x tail coordinate
y1	y tail coordinate
x2	x head coordinate
y2	y head coordinate
thick	thickness of arrow
headlength	length of head
headthick	thickness of head
col	fill color
border	color of border

Value

Graphical side effects.

Note

fancyarrows only work if te aspect ratio is set to 1. See example below.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

TEACHFOC

Examples

```
   thick = 0.01; headlength = 0.2; headthick = 0.1

x = runif(10, -1, 1)
y = runif(10, -1, 1)

############   MUST set asp=1 here
plot(x,y, asp=1)

fancyarrows(rep(0, 10) , rep(0, 10) ,x, y,
thick =thick , headlength =  headlength,
headthick =headthick)
```

---

faultplane — *fault plane projection on focal sphere*

Description

given azimuth and dip of fault mechanism, calculate and plot the fault plane.

Usage

```
faultplane(az, dip, col = par("col"), PLOT = TRUE, UP = FALSE,lwd=2, lty=1, ...)
```

Arguments

az	degrees, strike of the plane (NOT down dip azimuth)
dip	degrees, dip from horizontal
col	color for line
PLOT	option for adding to plot
UP	upper or lower hemisphere
lwd	Line Width
lty	Line Type
...	graphical parameters

Details

Azimuth is the strike in degrees, not the down dip azimuth as described in other routines.

Value

list of points along fault plane

x	coordinates on focal sphere
y	coordinates on focal sphere

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

Beachfoc

Examples

```
gcol='black'
border='black'
ndiv=36
phi = seq(0,2*pi, by=2*pi/ndiv);
  x = cos(phi);
  y = sin(phi);

plot(x,y, type='n', asp=1)
  lines(x,y, col=border)
  lines(c(-1,1), c(0,0), col=gcol)
  lines(c(0,0), c(-1,1), col=gcol)

faultplane(65, 34)
```

FixDip *Fix Dip Angle*

Description

Fix az, dip angles so they fall in correct quadrant.

Usage

```
FixDip(A)
```

Arguments

List:

A	**az** azimuthm angle, degrees **dip** dip angle, degrees

Details

Quadrants are determined by the sine and cosine of the dip angle: `co = cos(dip)` `si = sin(dip)` `quad[co>=0 & si>=0] = 1` `quad[co<0 & si>=0] = 2` `quad[co<0 & si<0] = 3` `quad[co>=0 & si<0] = 4`

Value

List:

`az`	azimuthm angle, degrees
`dip`	dip angle, degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

RPMG::fmod

Examples

```
B = list(az=231, dip = -65)

FixDip(B)
```

`flipnodal` *Flip Nodal Fault Plane*

Description

Switch a focal mechanism so the auxilliary plane is the nodal plane.

Usage

```
flipnodal(s1, d1, r1)
```

Arguments

`s1`	Strike
`d1`	Dip
`r1`	Rake

Details

Fuunction is used for orienting a set of fault planes to line up according to a geologic interpretation.

Value

List:

s1	Strike
d1	Dip
r1	Rake

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

Examples

```
s=65
d=25
r=13

  mc = CONVERTSDR(s,d,r )

  mc2 = flipnodal(s, d, r)
```

---

foc.color *Get color of Focal Mechansim*

Description

Based on the rake angle, focal styles are assigned an index and assigned a color by foc.color

Usage

```
foc.color(i, pal = 0)
```

Arguments

i	index to list of focal rupture styles
pal	vector of colors

Details

Since the colors used by focal programs are arbitrary, this routines allows one to change the coloring scheme easily.

foc.icolor returns an index that is used to get the color associated with that style of faulting

Value

Color for plotting, either a name or HEX RGB

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

foc.icolor

Examples

```
fcolors=c("DarkSeaGreen", "cyan1","SkyBlue1" , "RoyalBlue" ,"GreenYellow","orange","red")
        foc.color(3, fcolors)
```

---

foc.icolor *Get Fault Style*

Description

Use Rake Angle to determine style of faulting

Usage

```
foc.icolor(rake)
```

Arguments

rake	degrees, rake angle of fault plane

Details

The styles are determined by the rake angle

strikeslip abs(rake) <= 15.0 or abs((180.0 - abs(rake))) <= 15.0

rev-obl strk-slp (rake >= 15.0 and rake < 45) or (rake >= 135 and rake < 165)

oblique reverse (rake >= 45.0 and rake < 75) or (rake >= 105 and rake < 135)

reverse rake >= 75.0 and rake < 105.0

norm-oblq strkslp (rake < -15.0 and rake >= -45) or (rake < -135 and rake >= -165)

oblq norm (rake < -45.0 and rake >= -75) or (rake < -105 and rake >= -135)

normal rake < -75.0 and rake >= -105

Value

index (1-6)

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

foc.color

Examples

```
foc.icolor(25)
```

FOCangles *Angles for focal planes*

Description

Angles for focal planes

Usage

```
FOCangles(m)
```

Arguments

m	moment tensor

Details

Used in MapNonDouble and doNonDouble

Value

vector of 6 angles, 3 for each plane

Note

Lower Hemisphere.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

MapNonDouble, doNonDouble, PTaxes, nodalLines

Examples

```
mo = list(n=1, m1=1.035675e+017, m2=-1.985852e+016,
  m3=-6.198052e+014, m4=1.177936e+017,
  m5=-7.600627e+016, m6=-3.461405e+017)


moments = cbind(mo$n, mo$m1, mo$m2, mo$m3, mo$m4, mo$m5, mo$m6)

 di = dim(moments)
    number.of.events = di[1]
moment_11 = moments[,2]
moment_22 = moments[,3]
moment_33 = moments[,4]
moment_23 = moments[,5]
moment_13 = moments[,6]
moment_12 = moments[,7]


i = 1
m=matrix( c(moment_11[i],moment_12[i],moment_13[i],
       moment_12[i],moment_22[i],moment_23[i],
       moment_13[i],moment_23[i],moment_33[i]), ncol=3, byrow=TRUE)

   angles.all = FOCangles(m)
print(angles.all)
```

`focleg` *Fault style descriptor*

Description

Get character string describing type of fault from its style index

Usage

```
focleg(i)
```

Arguments

`i`	index to vector of focal styles

Value

character string used for setting text on plots

Note

String of characters:

STRIKESLIP Strike slip fault

REV-OBL STRK-SLP Reverse Oblique strike-slip fault

REVERSE Reverse fault

NORM-OBLQ STRKSLP Normal Oblique strike-slip fault

OBLQ NORM Oblique Normal fault

NORMAL Formal fault

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

foc.icolor, foc.color

Examples

```
focleg(2)
```

`focpoint` *add point on focal sphere*

Description

Add points on equal-area focal plot

Usage

```
focpoint(az1, dip1, col = 2, pch = 5, lab = "", cex=1,  UP = FALSE, PLOT = TRUE, ...)
```

Arguments

`az1`	degrees, azimuth angle
`dip1`	degrees, dip angle
`col`	color
`pch`	plot character for point
`lab`	text lable for point
`cex`	Character Size
`UP`	upper or lower hemisphere
`PLOT`	logical, PLOT=TRUE add points to current plot
`...`	graphical parameters

Value

List of x,y coordinates on the plot

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

Beachfoc, addmecpoints

Examples

```
###  create focal mech
ALIM=c(-1,-1, +1, +1)
s=65
d=25
r=13
mc = CONVERTSDR(s,d,r )
  MEC = MRake(mc$M)
  MEC$UP = FALSE
  MEC$icol =  foc.icolor(MEC$rake1)
  MEC$ileg =  focleg(MEC$icol)
  MEC$fcol =   foc.color(MEC$icol)
  MEC$CNVRG = NA
  MEC$LIM = ALIM

###  plot focal mech
Beachfoc(MEC, fcol=MEC$fcol, fcolback="white")

###  now add the F anf G axes
focpoint(MEC$F$az, MEC$F$dip, pch=5, lab="F", UP=MEC$UP)
    focpoint(MEC$G$az, MEC$G$dip, pch=5, lab="G", UP=MEC$UP)
```

`forcerighthand` *Force Right-Hand System*

Description

Force Right-Hand System

Usage

```
forcerighthand(U)
```

Arguments

U	3 by 3 matrix

Details

Flip vectors so they form a right handed system

Value

matrix

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

testrightHAND

Examples

```
Mtens = c(-0.412, 0.084, 0.328 ,0.398, -1.239, 1.058)
M1 = matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4], Mtens[2],
Mtens[6], Mtens[5],Mtens[6], Mtens[3]), ncol=3, nrow=3, byrow=TRUE)
E1 = eigen(M1)
testrightHAND(E1$vectors)

E1$vectors = forcerighthand(E1$vectors)

testrightHAND(E1$vectors)
```

---

getCMT *Read CMT*

Description

Read and reformat CMT solutions downloaded from the web.

Usage

```
getCMT(fn, skip=1)
```

Arguments

`fn`	character file name
`skip`	number of lines to skip (e.g. header)

Details

Data can be extracted from web site: http://www.globalcmt.org/CMTsearch.html

The file must be cleaned prior to scanning - on download from the web site there are extra lines on top and bottom of file. Delete these. Leave one line on the top that describesthe columns. Data is separated by blanks. The files have a mixture of dates - some with 7 component dates (YYMMDD and others with 14 components YYYYMODDHHMM these are read in separately. Missing hours and minutes areset to zero.

Value

list of CMT solution data:

`lon`	lon of epicenter
`lat`	lat of epicenter
`str1`	strike of fault plane
`dip1`	dip of fault plane
`rake1`	rake of fault plane
`str2`	strike of auxilliary plane
`dip2`	dip of auxilliary plane
`rake2`	rake of auxilliary plane
`sc`	scale?
`iexp`	exponent?
`name`	name, includes the date
`Elat`	exploding latitude, set to lat initially
`Elon`	exploding longitude, set to lon initially
`jd`	julian day
`yr`	year
`mo`	month
`dom`	day of month

Note

Use ExplodeSymbols or explode to get new locations for expanding the plotting points.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

http://www.globalcmt.org/CMTsearch.html

G. Ekstrom. Rapid earthquake analysis utilizes the internet. Computers in Physics, 8:632-638, 1994.

See Also

ExplodeSymbols, spherefocgeo, ternfocgeo

Examples

```
fn =  tempfile("temp", fileext = ".cmt")

cat(file=fn, c('-175.70 51.68 225 24 63 74 68 101 5.910 24 010677B',
'-168.18 52.40 221 27 62 72 66 103 1.780 25 032677A',
'-168.28 52.73 213 26 59 67 68 104 12.910 23 051577B') , sep="\n")

g = getCMT(fn)

pg = prepFOCS(g)

plot(range(pg$LONS), range(pg$LATS), type = "n", xlab = "LON",
    ylab = "LAT", asp = 1)


 for (i in 1:length(pg$LATS)) {
    mc = CONVERTSDR(g$str1[i], g$dip1[i], g$rake1[i])
     MEC <- MRake(mc$M)
MEC$UP = FALSE
     Fcol <- foc.color(foc.icolor(MEC$rake1), pal = 1)
     justfocXY(MEC, x = pg$LONS[i], y = pg$LATS[i], focsiz = 0.4,
     fcol = Fcol, xpd = FALSE)
 }
```

`GetRake` *Calculate Rake angles*

Description

Calculates rake angles for fault and auxilliary planes

Usage

```
GetRake(az1, dip1, az2, dip2, dir)
```

Arguments

`az1`	azimuth in degrees of fault plane 1
`dip1`	dip in degrees of fault plane 1
`az2`	azimuth in degrees of auxilliary plane 2
`dip2`	dip in degrees of auxilliary plane 2
`dir`	polarity

Details

uses output of CONVERTSDR or MEC structure

Value

list of angles for fault plane and auxiallary plane

`az1`, `dip1`, `rake1`, `dipaz1`
: strike, dip rake and downdip direction for plane 1

`az2`, `dip2`, `rake2`, `dipaz2`
: strike, dip rake and downdip direction for plane 2

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

GetRakeSense, CONVERTSDR, Beachfoc, justfocXY

Examples

```
GetRake(345.000000, 25.000000, 122.000000, 71.000000, 1)
```

GetRakeSense — *Get Rake Sense*

Description

Get the sense of the focal mechanism rake, from the U, V, P, T vectors

Usage

```
GetRakeSense(uaz, upl, vaz, vpl, paz, ppl, taz, tpl)
```

Arguments

`uaz`	Azimuth of U vector
`upl`	dip of U vector
`vaz`	Azimuth of V vector
`vpl`	dip of V vector
`paz`	Azimuth of P vector
`ppl`	dip of P vector
`taz`	Azimuth of T vector
`tpl`	dip of T vector

Value

1, 0 to make sure the region of the T-axis is shaded and the P-axis is blank.

Note

The convention is for the T-axis to be shaded, so this subroutine determines the order of the polygons to be plotted so that the appropriate regins are filled.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

GetRake

Examples

```
mc =CONVERTSDR(65,25,13)


angsense = GetRakeSense(mc$U$az, mc$U$dip, mc$V$az, mc$V$dip,mc$P$az, mc$P$dip,mc$T$az, mc$T$dip)
```

---

getUWfocs *Get UW focals*

Description

Get UW focal mechansims from a file. These are often called A and M cards

Usage

```
getUWfocs(amfile)
```

Arguments

`amfile`	character, file name

Details

UW focal mechanisms are stored as A and M cards. The A card described the hypocenter the M card describes the focal mechanism.

Value

List:

`lon`	numeric, longitude
`lat`	numeric, latitude
`str1`	numeric, strike of plane 1
`dip1`	numeric, dip of plane 1
`rake1`	numeric, rake of plane 1
`str2`	numeric, strike of plane 2
`dip2`	numeric, dip of plane 2
`rake2`	numeric, rake of plane 2
`sc`	character, some GMT info for scale
`iexp`	character, some GMT info for scale
`name`	character, name
`yr`	numeric, year
`mo`	numeric, month
`dom`	numeric, day of month
`jd`	numeric, julian day
`hr`	numeric, hour
`mi`	numeric, minute
`se`	numeric, second
`z`	numeric, depth
`mag`	numeric, magnitude

Note

Uses UW2 format, so full 4 digit year is required

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

http://www.unc.edu/~leesj/XM_DOC/xm_hypo.doc.html

See Also

getCMT

Examples

```
#####  uwpickfile is an ascii format file from University of Washington

data(GH, package='RSEIS')

pf = GH$pickfile$PF

### save only the A and M cards to temp file:
fn =  tempfile("temp", fileext = ".UW")
cat(file=fn, c(pf[1], pf[34]) , sep='\n')

G1 = getUWfocs(fn)

plot(G1$lon, G1$lat)

 MEKS = list(lon=G1$lon, lat=G1$lat, str1=G1$str1,
dip1=G1$dip1, rake1=G1$rake1, dep=G1$z, name=G1$name)

##   utm projection
 PROJ = GEOmap::setPROJ(type=2, LAT0=mean(G1$lat) , LON0=mean(G1$lon) )

     XY = GEOmap::GLOB.XY(G1$lat, G1$lon, PROJ)

     plot(range(XY$x), range(XY$y), type='n', asp=1)

     plotmanyfoc(MEKS, PROJ, focsiz=0.5)
```

HAMMERprojXY *Hammer Projection*

Description

Hammer Equal Area projection

Usage

```
HAMMERprojXY(phi, lam)
```

Arguments

phi	Latitude, radians
lam	Longitude, radians

Value

list:

x	coordinate for plotting
y	coordinate for plotting

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

Examples

```
HAMMERprojXY(-25*pi/180, -16*pi/180)
```

---

hudson.net *Hudson Net Plot*

Description

Plot a Hudson plot as preparation for plotting T-k values for focal mechanisms.

Usage

```
hudson.net(add = FALSE, POINTS = TRUE, TEXT = TRUE,
     colint = "grey", colext = "black")
```

Arguments

add	logical, TRUE=add to existing plot
POINTS	logical, TRUE=add points
TEXT	logical, TRUE=add points
colint	color for interior lines
colext	color for exterior lines

Details

Draws a T-k plot for moment tensors

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Hudson, J.A., Pearce, R.G. and Rogers, R.M., 1989. Source time plot for inversion of the moment tensor, J. Geophys. Res., 94(B1), 765-774.

See Also

hudson.plot

Examples

```
hudson.net()

Mtens <- c(-0.412, 0.084, 0.328 ,0.398, -1.239, 1.058)

M1 <-  matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4],
Mtens[2], Mtens[6], Mtens[5],Mtens[6], Mtens[3]), ncol=3, nrow=3,
byrow=TRUE)

E1 <-  eigen(M1)

hudson.plot(E1$values)
```

---

hudson.plot *Hudson Source Type Plot*

Description

Hudson Source Type Plot

Usage

```
hudson.plot(m, col = "red", pch = 21, lwd = 2, cex = 1, bg="white")
```

Arguments

m	vector of eigen values, sorted
col	color
pch	plotting char
lwd	line width
cex	character expansion
bg	background color for filled symbols

Details

Add to existing Hudson net

Value

Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Hudson, J.A., Pearce, R.G. and Rogers, R.M., 1989. Source time plot for inversion of the moment tensor, J. Geophys. Res., 94(B1), 765-774.

See Also

hudson.net

Examples

```
hudson.net()

Mtens <- c(-0.412, 0.084, 0.328 ,0.398, -1.239, 1.058)

M1 <- matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4],
Mtens[2], Mtens[6], Mtens[5],Mtens[6],
Mtens[3]), ncol=3, nrow=3, byrow=TRUE)

E1 <-  eigen(M1)

hudson.plot(E1$values)
```

`imageP` *P-wave radiation pattern*

Description

Amplitude of P-wave radiation pattern from Double-Couple earthquake

Usage

```
imageP(phiS, del, lam, SCALE = FALSE, UP = FALSE, col = NULL)
```

Arguments

`phiS`	strike
`del`	dip
`lam`	lambda
`SCALE`	logical, TRUE=add scale on side of plot
`UP`	upper/lower hemisphere
`col`	color

Details

This program calls radP to calculate the radiation pattern and it plots the result using the standard image function

Value

Used for the graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radP, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
imageP(MEC$az1, MEC$dip1, MEC$rake1, SCALE=TRUE, UP=MEC$UP, col=rainbow(100) )
```

`imageSCALE` *add scale on sice of image*

Description

add scale to side of an image plot

Usage

```
imageSCALE(z, col, x, y = NULL, size = NULL, digits = 2,
labels = c("breaks", "ranges"), nlab = 10)
```

Arguments

z	elevation matrix
col	palette for plotting
x	x location on plot
y	y location on plot
size	length of scale
digits	digits on labels
labels	breaks to be plotted
nlab	number of breaks to be plotted

Value

Used for graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
data(volcano)
image(volcano, col=rainbow(100) )

imageSCALE(volcano, rainbow(100), 1.015983, y = 0.874668,
size = .01, digits =
2, labels = "breaks", nlab = 20)
```

---

imageSH *P-wave radiation pattern*

Description

Amplitude of SH-wave radiation pattern from Double-Couple earthquake

Usage

```
imageSH(phiS, del, lam, SCALE = FALSE, UP = FALSE, col = NULL)
```

Arguments

phiS	strike
del	dip
lam	lambda
SCALE	logical, TRUE=add scale on side of plot
UP	upper/lower hemisphere
col	color

Details

This program calls radP to calculate the radiation pattern and it plots the result using the standard image function

Value

Used for the graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radSH, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
imageSH(MEC$az1, MEC$dip1, MEC$rake1, SCALE=TRUE, UP=MEC$UP, col=rainbow(100) )
```

---

imageSV *P-wave radiation pattern*

Description

Amplitude of SV-wave radiation pattern from Double-Couple earthquake

Usage

```
imageSV(phiS, del, lam, SCALE = FALSE, UP = FALSE, col = NULL)
```

Arguments

`phiS`	strike
`del`	dip
`lam`	lambda
`SCALE`	logical, TRUE=add scale on side of plot
`UP`	upper/lower hemisphere
`col`	color

Details

This program calls radP to calculate the radiation pattern and it plots the result using the standard image function

Value

Used for the graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radSV, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
imageSV(MEC$az1, MEC$dip1, MEC$rake1, SCALE=TRUE, UP=MEC$UP, col=rainbow(100) )
```

`inverseTAPE` *Inverse Moment Tensor*

Description

Inverse moment tensor from Tape angles.

Usage

```
inverseTAPE(GAMMA, BETA)
```

Arguments

GAMMA Longitude, degrees

BETA CoLatitude, degrees

Details

Uses Tape and Tape lune angles to estimate the moment tensor. This function is the inverse of the SourceType calculation. There are two solutions to the systems of equations.

Vectors are scaled by the maximum value.

Value

Moment tensor list:

Va vector, First solution

Vb vector, First solution

Note

The latitude is the CoLatitude.

Either vector can be used as a solution.

Orientation of moment tensor is not preserved int he lune plots.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Tape, W.,and C.Tape(2012), A geometric comparison of source-type plots for moment tensors, Geophys. J. Int., 190, 499-510.

See Also

SourceType

Examples

```
lats = seq(from = -80, to = 80, by=10)
    lons = seq(from=-30, to=30, by=10)

i = 3
j = 3
 u =  inverseTAPE( lons[i], 90-lats[j] )
```

jimbo *Moment Tensors from the Harvard CMT*

Description

Moment Tensors from the Harvard CMT

Usage

```
data(jimbo)
```

Format

A list of 9 moment tensors from the Kamchatka region.

Source

http://www.globalcmt.org/CMTsearch.html

References

Ekstrom, G.; Nettles, M. & DziewoDski, A. The Global CMT Project 2004-2010: centroid-moment tensors for 13,017 earthquakes Physics of the Earth and Planetary Interiors, 2012.

JMAT *Vertical Rotation matrix*

Description

Vertical Rotation matrix

Usage

```
JMAT(phi)
```

Arguments

phi	angle, degrees

Details

First rotate to plan, then within plane rotate to view angle.

Value

3 by 3 matrix

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

ROTX, ROTZ, ROTY

Examples

```
phi = 18

MAT = JMAT(phi)

v1 = c(1,1,0)

v2 = MAT
```

`justfocXY` *Plot focal mechanism*

Description

Add simple focal mechanisms to plot

Usage

```
justfocXY(MEC, x = x, y = y, focsiz=1 , fcol = gray(0.9),
          fcolback = "white", xpd = TRUE)
```

Arguments

`MEC`	MEC structure
`x`	x-coordinate of center
`y`	y-coordinate of center
`focsiz`	size of focal sphere in inches
`fcol`	color of shaded region
`fcolback`	color of background region
`xpd`	logical, whether to extend the plot beyond, or to clip

Details

This routine can be used to add focal mechanisms on geographic map or other plot.

Value

Used for graphical side effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

SDRfoc, foc.color

Examples

```
#### read in some data:


Z1 = c(159.33,51.6,206,18,78,
161.89,54.5,257,27,133,
170.03,53.57,-44,13,171,
154.99,50.16,-83,19,-40,
151.09,47.15,123,23,-170,
176.31,51.41,-81,22,122,
153.71,46.63,205,28,59,
178.39,51.21,-77,16,126,
178.27,51.1,-86,15,115,
177.95,51.14,-83,25,126,
178.25,51.18,215,16,27
)

MZ = matrix(Z1, ncol=5, byrow=TRUE)

plot(MZ[,1], MZ[,2], type='n', xlab="LON", ylab="LAT", asp=1)

for(i in 1:length(MZ[,1]))
{
paste(MZ[i,3], MZ[i,4], MZ[i,5])


MEC =  SDRfoc(MZ[i,3], MZ[i,4], MZ[i,5], u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
fcol =  foc.color(foc.icolor(MEC$rake1), pal=1)
justfocXY(MEC, x=MZ[i,1], y =MZ[i,2] , focsiz=.5, fcol =fcol , fcolback = "white", xpd = TRUE)


}
```

KAMCORN *SDR data from the Harvard CMT catalog*

Description

Strike-Dip-Rake and Locations of Harvard CMT catalog for the intersection of the Kamchataka and Aleutian arcs

Usage

```
data(KAMCORN)
```

Format

The format is: chr "KAMCORN"

Details

The data is selected fromt eh CMT catalog. Parameters are extracted from the normal distribution. Format of the list of data save in KAMCORN is: list(LAT=0 , LON =0 , DEPTH=0 , STRIKE=0 , DIP=0 , RAKE=0)

Source

http://www.globalcmt.org/CMTsearch.html

References

G. Ekstrom. Rapid earthquake analysis utilizes the internet. Computers in Physics, 8:632-638, 1994.

Examples

```
data(KAMCORN)
plot(KAMCORN$LON, KAMCORN$LAT, xlab="LON", ylab="LAT" ,
          main="Kamchatka-Aleutian Inersection", asp=1)
######
Paz =vector()
Pdip =vector()
Taz =vector()
Tdip =vector()
h = vector()
v = vector()

IFcol = vector()
Fcol = vector()

for(i in 1:10)
  {
```

```
    Msdr = CONVERTSDR(KAMCORN$STRIKE[i],
          KAMCORN$DIP[i], KAMCORN$RAKE[i]   )
  MEC = MRake(Msdr$M)
  MEC$UP = FALSE
  IFcol[i] = foc.icolor(MEC$rake1)
    Fcol[i] = foc.color(IFcol[i], 1)

      az1 = Msdr$M$az1
  dip1 = Msdr$M$d1
  az2 = Msdr$M$az2
  dip2 = Msdr$M$d2
  BBB = Bfocvec(az1, dip1,  az2,  dip2)
  V = ternfoc.point(BBB$Bdip, Msdr$M$pd, Msdr$M$td )
 Paz[i] = Msdr$M$paz
  Pdip[i] = Msdr$M$pd
  Taz[i] = Msdr$M$taz
  Tdip[i] = Msdr$M$td
  h[i] = V$h
  v[i] = V$v

     justfocXY( MEC, fcol = Fcol[i], KAMCORN$LON[i],
          KAMCORN$LAT[i] , focsiz = 0.4 )
  }
```

`lowplane` *Plot one Fault plane on stereonet*

Description

takes azimuth and dip and projects the greaat circle on the focla sphere

Usage

```
lowplane(az, dip, col = par("col"), UP = FALSE, PLOT = TRUE)
```

Arguments

az	degrees, azimuth of strike of plane
dip	degrees, dip
col	color of plane
UP	upper/lower hemisphere
PLOT	add to plot

Details

Here azimuth is measured from North, and represents the actual strike of the fault line.

Value

list of x,y coordinates of plane

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

net

Examples

```
net()
lowplane(65,23)
```

`m2tk` *Moment tensor to T-k*

Description

Moment tensor to T-k

Usage

```
m2tk(m0)
```

Arguments

`m0`	moment tensor eigenvalues, sorted decending

Details

Convert 3 eigen values of a moment tensor to T-k coordinates

Value

list(t, k)

Author(s)

Keehoon Kim<keehoon@live.unc.edu> Jonathan M. Lees<jonathan.lees@unc.edu>

References

Hudson

See Also

tk2uv, hudson.net, hudson.plot

Examples

```
v = c(2,-1,-1)
m2tk(v)
```

---

makeblock3D *Make a 3D block Structure*

Description

Given vertices of a 3D block, create a glyph structure (faces and normals)

Usage

```
makeblock3D(block1)
```

Arguments

block1	matrix of vertices

Value

glyph structure list

aglyph	list of faces (x,y,z)
anorm	Normals to faces

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

ROTZ, ROTY, ROTX, BOXarrows3D, Z3Darrow, TRANmat

Examples

```
  block1 = matrix(c(0,0,0,
      1,0,0,
      1,0.5,0,
      0,0.5,0,
      0,0,-2,
      1,0,-2,
      1,0.5,-2,
      0,0.5,-2), byrow=TRUE, ncol=3)

    Bblock1 = makeblock3D(block1)
```

`makenet` *Equal-Angle Stereonet*

Description

Creates but does not plot an Equal-Angle (Schmidt) Stereonet

Usage

```
makenet()
```

Value

list of x,y, values for drawing lines

`x1`	x-coordinate start of lines
`y1`	y-coordinate start of lines
`x2`	x-coordinate end of lines
`y2`	y-coordinate end of lines

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Snyder, John P., 1987, Map Projections-a working manual, USGS-Professional Paper, 383p. pages 185-186

See Also

net, pnet

Examples

```
MN = makenet()

  pnet(MN)
```

MapNonDouble *Map moment tensors*

Description

Plot moment tensors on map

Usage

```
MapNonDouble(Locs, moments, sel = 1, siz = 0.2,
col=rgb(1, .75, .75), PLANES = TRUE, add = FALSE, LEG=FALSE)
```

Arguments

Locs	Locations, x,y
moments	list of moments: seven elements. See details.
sel	integer, index of which to plot
siz	size to plot, inches
col	color, either a single color, rgb, or a color palette.
PLANES	logical, whether to add nodal planes, default=TRUE
add	logical, whether to add to plot, default=FALSE
LEG	logical, whether to add focal mech legend based on color coding, default=FALSE

Details

Moment tensors are added to an existing plot. The first element of the list is the integer index of the event. The next six elements are the moments in the following order, c(Mxx, Myy, Mzz, Mzy, Mxz, Mxy) .

If the data is in spherical coordinates, one must switch the sign of the Mrp and Mtp components, so:

```
Mrr = Mzz
Mtt = Mxx
Mpp = Myy
Mrt = Mxz
Mrp = -Myz
Mtp = -Mxy
```

A color palette can be provided for some details of the radiation patterns, e.g. col=rainbow(12). If col is NULL, the colors will be chosen according to focal.color from RFOC, based on rake of first nodal plane.

If col is NULL, then the colors are set by foc.color and it is appropriate to add a legend.

Value

list:

FOC	matrix, focal mechanism angles (strike, dip rake)
LAB	matrix, x-y location for labels

Note

If events are read in using spherical rather than cartesian coordinates need a conversion:

```
Mrr = Mzz
Mtt = Mxx
Mpp = Myy
Mrt = Mxz
Mrp = -Myz
Mtp = -Mxy
```

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Ekstrom, G.; Nettles, M. & DziewoDski, A. The Global CMT Project 2004-2010: centroid-moment tensors for 13,017 earthquakes Physics of the Earth and Planetary Interiors, 2012.

See Also

doNonDouble, ShadowCLVD, angles, nodalLines, PTaxes, focal.color, foc.icolor

Examples

```
 if(requireNamespace("maps")){
    library(maps)
    library(GEOmap)
    ##########  load the data
    data(widdenMoments)
    #################   to read in the data from a file,
    ##   GG = scan("widdenMoments.txt",sep=" ",
    ## what=list(ID=0,Event="",Lat=0,Long=0,Depth=0,Mw=0,ML=0,DC=0,
    ## CLVD=0,ISO=0,VR=0,nsta=0,Mxx=0,Mxy=0,Mxz=0,
    ##  Myy=0,Myz=0,Mzz=0,Mo=0,Ftest=0) )
    GG = widdenMoments
    Locs = list(y=GG$Lat,x=GG$Long)
    ef = 1e20
    moments = cbind(GG$ID, ef*GG$Mxx, ef*GG$Myy,
    ef*GG$Mzz, ef*GG$Myz, ef*GG$Mxz,ef*GG$Mxy)
    UTAH =  map('state', region = c('utah'), plot=FALSE )
    mlon = mean(UTAH$x, na.rm=TRUE)
    mlat = mean(UTAH$y, na.rm=TRUE)
Gutah   = maps2GEOmap(UTAH)
############   for mercator projection
```

```
PROJ =  GEOmap::setPROJ(type = 1, LAT0 = mlat , LON0 = mlon)
Glocs = GEOmap::GLOB.XY(Locs$y, Locs$x, PROJ       )
############   for UTM projection
PROJ =  GEOmap::setPROJ(type = 2, LAT0 = mlat , LON0 = mlon)
Glocs = GEOmap::GLOB.XY(Locs$y, Locs$x, PROJ       )
LIMlat = expandbound(Gutah$POINTS$lat)
LIMlon = expandbound(Gutah$POINTS$lon)
PLAT =  pretty(LIMlat)
 PLON  = pretty(LIMlon)
###############  plot the map
########  Utah is a little rectangular
###       dev.new(width=9, height=12)
plotGEOmapXY(Gutah,
LIM = c(min(PLON), min(PLAT) , max(PLON) , max(PLAT)) ,
             PROJ=PROJ, axes=FALSE, xlab="", ylab="" )
### add tic marks
kbox = GEOmap::GLOB.XY(PLAT,PLON, PROJ)
      sqrTICXY(kbox , PROJ, side=c(1,2,3,4), LLgrid=TRUE, col=grey(.7) )
########  add focal mechs
siz = 0.2
MapNonDouble(Glocs, moments,col=NULL,  add=TRUE, LEG=TRUE)
  up = par("usr")
    ui = par("pin")
    ratx = (up[2] - up[1])/ui[1]
    raty = (up[4] - up[3])/ui[2]
usizx = siz * ratx
AXY = NoOverlap(Glocs$x,Glocs$y, usizx )
 MapNonDouble(AXY, moments,col=NULL,  add=TRUE, LEG=TRUE)
####  MapNonDouble(NXY, moments,col=NULL,  add=TRUE, LEG=TRUE)

}
```

---

mc2cart *Convert azimuth, dip to Cartesian Coordinates*

Description

takes the pole information from a steroplot and returns the cartesian coordinates

Usage

```
mc2cart(az, dip)
```

Arguments

az	degrees, orientation angle, from North
dip	degrees, dip of pole

Value

list of x,y,z values

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
v1  = mc2cart(65,32)
v2  = mc2cart(135,74)
```

`mijsdr` *Moment Tensor to Strike-Dip-Rake*

Description

Convert a normalized moment tensor from the CMT catalog to Strike-Dip-Rake.

Usage

```
mijsdr(mxx, myy, mzz, mxy, mxz, myz)
```

Arguments

mxx	moment tensor 1,1
myy	moment tensor 2,2
mzz	moment tensor 3,3
mxy	moment tensor 1,2
mxz	moment tensor 1,3
myz	moment tensor 2,3

Details

the coordinate system is modified to represent a system centered on the source.

Value

Focal Mechanism list

Note

This code will convert the output of the website, http://www.globalcmt.org/CMTsearch.html when dumped in the psmeca (GMT v>3.3) format.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

http://www.globalcmt.org/CMTsearch.html

See Also

getCMT

Examples

```
mijsdr(-1.96, 1.07, 0.89, 0.51, 0.08, -0.68)
```

MomentDist *Distance Between Moment Tensors*

Description

Calculate the distance between moment tensors based on quaternions.

Usage

```
MomentDist(E1, E2)
```

Arguments

E1	Moment tensor
E2	Moment tensor

Details

Moment tensors should be right handed.

Value

angle in degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Tape and Tape, 2012

See Also

forcerighthand, testrightHAND

Examples

```
Mtens = c(-0.412, 0.084, 0.328 ,0.398, -1.239, 1.058)
M1 = matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4], Mtens[2],
Mtens[6], Mtens[5],Mtens[6], Mtens[3]), ncol=3, nrow=3, byrow=TRUE)



Mtens = c(5.054, -2.235, -2.819, -0.476, 5.420, 5.594)
M2 = matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4], Mtens[2],
Mtens[6], Mtens[5],Mtens[6], Mtens[3]), ncol=3, nrow=3, byrow=TRUE)

E1 = eigen(M1)

###  make sure these are a right handed system,
###   ie x1 cross x2 = x3


E2 = eigen(M2)

###  make sure these are a right handed system,
###   ie x1 cross x2 = x3
testrightHAND(E1$vectors)
testrightHAND(E2$vectors)

E1$vectors = forcerighthand(E1$vectors)

E2$vectors = forcerighthand(E2$vectors)


testrightHAND(E1$vectors)
testrightHAND(E2$vectors)

MomentDist(E1, E2)
```

`MRake` *Rake Calculation*

Description

Calculate various parameters associated with the Rake or Slip of an earthquake

Usage

```
MRake(M)
```

Arguments

`M`	list(uaz, ud, vaz, vd, paz, pd, taz, td)

Details

This routine takes the four poles U, V, P, T, and returns a MEC structure. (uaz, ud) = U pole azimuth and dip (vaz, vd)= V pole azimuth and dip (paz, pd)= P pole azimuth and dip (taz, td)= T pole azimuth and dip

Value

returns a MEC structure

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

CONVERTSDR, GetRakeSense, GetRake

Examples

```
 mc = CONVERTSDR(329, 8, 110 )
    MEC = MRake(mc$M)
```

`net` *EqualArea Stereonet*

Description

Plot Equal Area Stereo-Net. Lambert azimuthal Equal-Area (Schmidt) from Snyder p. 185-186

Usage

```
net(add = FALSE, col = gray(0.7), border = "black", lwd = 1, LIM = c(-1, -1, +1, +1))
```

Arguments

`add`	logical, TRUE=add to existing plot
`col`	color of lines
`border`	color of outer rim of stereonet
`lwd`	linewidth of lines
`LIM`	bounding area for a new plot

Value

Used for graphical side effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Snyder, John P., 1987, Map Projections-a working manual, USGS-Professional Paper, 383p. pages 185-186

See Also

pcirc

Examples

```
net(FALSE, col=rgb(.8,.7,.7) ,border='blue' )
```

---

nipXY *Fault-Slip vector plot*

Description

Plots a fault plane and the slip vector. Used for geographic representation of numerous focal spheres.

Usage

```
nipXY(MEC, x = x, y = y, focsiz=1, fcol = gray(0.9), nipcol = "black", cex = 0.4)
```

Arguments

MEC	MEC structure
x	coordinate on plot
y	coordinate on plot
focsiz	size in inches
fcol	color for plotting
nipcol	color of slip point
cex	character expansion for slip point

Details

Slip vector is the cross product of the poles to the fault plane and auxilliary planes.

Value

LIST

Q	output of qpoint
N	slip vector

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

qpoint, CROSSL, lowplane, TOCART

Examples

```
set.seed(2015)
N = 20
lon=runif(20, 268.1563 , 305)
lat=runif(20, 7.593004,  25.926045)
str1=runif(20,50,100)
dip1=runif(20,10, 80)
rake1=runif(20,5, 180)

dep=runif(20,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)

 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm

XY = GEOmap::GLOB.XY(lat, lon, PROJ)

plot(range(XY$x), range(XY$y), type='n', asp=1, xlab='km', ylab='km' )
for(i in 1:length(XY$x))
{
  Msdr = CONVERTSDR(MEKS$str1[i], MEKS$dip1[i],MEKS$rake1[i])
     MEC = MRake(Msdr$M)
       MEC$UP = FALSE

         jcol =  foc.color(foc.icolor(MEC$rake1), pal=1)



nipXY(MEC, x = XY$x[i], y = XY$y[i], focsiz=0.5, fcol = jcol, nipcol = 'black' , cex = 1)
}
```

nodalLines *Nodal Lines*

Description

Add nodal planes to focal mechanism

Usage

```
nodalLines(strike, dip, rake, PLOT=TRUE)
```

Arguments

strike	numeric, strike of fault
dip	numeric, dip of fault
rake	numeric, rake of fault
PLOT	logical, add lines to plot, default=TRUE

Details

Lower Hemisphere focal plane.

Value

Side effects

Note

Lower Hemisphere based on FOCangles.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

doNonDouble, MapNonDouble, FOCangles

Examples

```
mo <- list(n=1, m1=1.035675e+017,
   m2=-1.985852e+016, m3=-6.198052e+014,
   m4=1.177936e+017, m5=-7.600627e+016, m6=-3.461405e+017)
moments <- cbind(mo$n, mo$m1, mo$m2, mo$m3, mo$m4, mo$m5, mo$m6)
doNonDouble(moments)
```

normal.fault *Normal Fault Cartoon*

Description

Illustrate a normal fault using animation

Usage

```
normal.fault(ANG = (45), anim = seq(from = 0, to = 1, by = 0.1),
            KAPPA = 4, Light = c(45, 45))
```

Arguments

ANG	Angle of dip
anim	animation vector
KAPPA	Phong parameter for lighting
Light	lighting point

Details

Program will animate a normal fault for educational purposes. Animation must be stopped by halting execution.

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

strikeslip.fault, thrust.fault

Examples

```
normal.fault(45, anim=0, KAPPA=4, Light=c(-20, 80))

if(interactive()){
#### execute a stop command to stop this animation
anim= seq(from=0, to=1, by=.1)

 normal.fault(45, anim=anim, KAPPA=4, Light=c(-20, 80))
 }
```

pcirc *Circle Plot*

Description

Add a circle to a plot, with cross-hairs

Usage

```
pcirc(gcol = "black", border = "black", ndiv = 36)
```

Arguments

gcol	color of crosshairs
border	border color
ndiv	number of divisions for the circle

Value

no return values, used for side effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

net

Examples

```
net()
pcirc(gcol = "green", border = "purple", ndiv = 36)
```

pglyph3D *Plot a 3D body on an existing graphic*

Description

rotates a body in 3D and plots projection on existing plot

Usage

```
pglyph3D(aglyph, M = diag(1, nrow = 4), M2 = diag(1, nrow = 4),
         anorms = list(), zee = c(0, 0, 1), col = "white", border = "black")
```

Arguments

`aglyph`	glyph structure describing the vertices and normal vectors of a 3D body
`M`	rotation matrix 1
`M2`	rotation matrix 2
`anorms`	up vector
`zee`	up vector
`col`	coor of body
`border`	color of border

Details

Hidden sides are removed and phong shading is introduced to create 3D effect.

The input consists of an object defined by a list structure, list(aglyph, anorm) where aglyph is list of 3D polygons (faces) and anorm are outward normals to these faces.

Value

Used for side effect on plots

Note

For unusual rotations or bizarre bodies, this routine may produce strange looking shapes.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Rogers and Adams, 1990, Mathematical Elements for Computer Graphics, McGraw-Hill, 611p.

See Also

Z3Darrow, ROTX, ROTY, ROTZ

Examples

```
### create the 3D object
len = .7
basethick=.05
headlip=.02
headlen=.3

####  create a 3D glyph structure
aglyph = Z3Darrow(len = len , basethick =basethick , headlen =headlen ,
headlip=headlip )

#### define the up vector
```

```
myzee = matrix(c(0,0,1, 1), nrow=1, ncol=4)

##### set rotation angles:
gamma =12
beta =39
alpha = 62

########  set up rotation matrix
R3 = ROTZ(gamma)

R2 = ROTY(beta)

R1 = ROTZ(alpha)

###  create rotation matrix
M =      R1

M2 =       R1


plot(c(-1,1), c(-1,1))

 pglyph3D(aglyph$aglyph, anorms=aglyph$anorm  , M=M, M2=M2, zee=myzee ,
col=rgb(.7, 0,0) )
```

---

phong3D *Phong shading for a 3D body*

Description

Create phong shading for faces showing on the 3D block

Usage

```
phong3D(aglyph, M = diag(1, nrow = 4), M2 = diag(1, nrow = 4),
           Light = c(45, 45), anorms = list(), zee = c(0, 0, 1),
          col = "white", border = "black")
```

Arguments

`aglyph`	3-D body list of faces and normals
`M`	Rotation Matrix
`M2`	Viewing Matrix
`Light`	light source direction
`anorms`	normals to faces

zee	Up vector for Body
col	color for faces
border	border color for sides

Details

Uses a standard phong shading model based ont eh dot product of the face normal vector and direction of incoming light.

Value

Graphical Side effect

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Watt, Alan. Fundamentals of Three-dimensional Computer Graphics, Addison-Wesley, 1989, 430p.

See Also

makeblock3D, BOXarrows3D, PROJ3D, Z3Darrow, pglyph3D

Examples

```
###########  create a block and rotation matrix, then color it
ANG=(45)
DEGRAD = pi/180

y1 = 1.5

  y2 = y1 - 1/tan((ANG)*DEGRAD)


  z1 = 1
  x1 = 1


Ablock1 = matrix(c(0,0,0,
    1,0,0,
    1,y1,0,
    0,y1,0,
    0,0,-1,
    1,0,-1,
    1,y2,-1,
    0,y2,-1), byrow=TRUE, ncol=3)
```

```
Nblock1 = makeblock3D(Ablock1)
Light=c(45,45)
angz = -45
angx = -45

R1 = ROTZ(angz)
R2 = ROTX(angx)

   M =    R1

Z2 = PROJ3D(Nblock1$aglyph, M=M,  anorms=Nblock1$anorm ,  zee=c(0,0,1))
RangesX = range(attr(Z2, "RangesX"))

  RangesY = range(attr(Z2, "RangesY"))


plot( RangesX, RangesY, type='n', asp=1, ann=FALSE, axes=FALSE)

phong3D(Nblock1$aglyph, M=M,  anorms=Nblock1$anorm , Light = Light,
zee=c(0,0,1), col=rgb(.7,.5, .5)  , border="black")
```

PKAM *P and T-axes data from the Harvard CMT catalog*

Description

P and T-axes and Locations of Harvard CMT catalog for the intersection of the Kamchataka and Aleutian arcs

Usage

```
data(PKAM)
```

Format

The format is: chr "PKAM"

Details

The data is selected from the CMT catalog. Parameters are extracted from the standard web distribution. Format of the list of data save in PKAM is:

- Paz P-axis azimuth angle
- Pdip P-axis dip angle
- Taz T-axis azimuth angle
- Tdip T-axis dip angle

- h horizontal point to plot on ternary plot
- v vertical point to plot on ternary plot
- fcols colors, not used
- LATS Latitude
- LONS Longitude
- IFcol integer pointer to internal color
- yr year, not used
- JDHM Julian Day, hour, minute, not used
- JDHMS Julian Day, hour, minute, seconds

Source

http://www.globalcmt.org/CMTsearch.html

References

G. Ekstrom. Rapid earthquake analysis utilizes the internet. Computers in Physics, 8:632-638, 1994.

Examples

```
data(PKAM)
##

######  plot the locations:
plot( RPMG::fmod(PKAM$LONS, 360), PKAM$LATS)
######

  PlotTernfoc(PKAM$h,PKAM$v,x=0, y=0, siz=1, fcols='black', add=FALSE,
LAB=TRUE)

######  change the colors for the plot

acols = rainbow(7)
fcols = acols[PKAM$IFcol]

######


 PlotTernfoc(PKAM$h,PKAM$v,x=0, y=0, siz=1, fcols=fcols, add=FALSE,
LAB=TRUE)
```

plotfoc	*Plot Focal Radiation Patterns*

Description

Takes a MEC structure and plots all three radiation patterns.

Usage

```
plotfoc(MEC)
```

Arguments

`MEC`	MEC list

Details

Plot makes three figures after calling par(mfrow=c(3,1)).

Value

Graphical Side Effects.

Note

Basic MEC List Structure

az1	azimuth angle plane 1, degrees
dip1	dip angle plane 1, degrees
az2	azimuth angle plane 2, degrees
dip2	dip angle plane 2, degrees
dir	0,1 to determine which section of focal sphere is shaded
rake1	rake angle plane 1, degrees
dipaz1	dip azimuth angle plane 1, degrees
rake2	rake angle plane 2, degrees
dipaz2	dip azimuth angle plane 2, degrees
P	pole list(az, dip) P-axis
T	pole list(az, dip) T-axis
U	pole list(az, dip) U-axis
V	pole list(az, dip) V-axis
F	pole list(az, dip) F-axis
G	pole list(az, dip) G-axis
sense	0,1 to determine which section of focal sphere is shaded
M	list of focal parameters used in some calculations
UP	logical, TRUE=upper hemisphere
icol	index to suite of colors for focal mechanism
ileg	Kind of fault
fcol	color of focal mechanism

CNVRG	Character, note on convergence of solution
LIM	vector plotting region (x1, y1, x2, y2)

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

SDRfoc, Mrake, Pradfoc, radiateSH, radP, radSV, SVradfoc, radiateP, radiateSV, radSH, SHradfoc, imageP, imageSH, imageSV

Examples

```
M = SDRfoc(-25, 34, 16,u = FALSE, ALIM = c(-1, -1, +1, +1), PLOT=FALSE)
plotfoc(M)
```

`plotmanyfoc` *Plot Many Focals*

Description

Plot a long list of focal mechanisms

Usage

```
plotmanyfoc(MEK, PROJ, focsiz = 0.5, foccol = NULL,
UP=TRUE, focstyle=1, PMAT = NULL, LEG = FALSE, DOBAR = FALSE)
```

Arguments

`MEK`	List of Focal Mechanisms, see details
`PROJ`	Projection
`focsiz`	focal size, inches
`foccol`	focal color
`UP`	logical, UP=TRUE means plot upper hemisphere (DEFAULT=TRUE)
`focstyle`	integer, 1=beach ball, 2=nipplot, 3=strike-slip, 4=P-T, 5=P, 6=T
`PMAT`	Projection Matrix from persp
`LEG`	logical, TRUE= add focal legend for color codes
`DOBAR`	add strike dip bar at epicenter

Details

Input MEK list contains

MEKS = list(lon=0, lat=0, str1=0, dip1=0, rake1=0, dep=0, name="", Elat=0, Elon=0)

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Lees, J. M., Geotouch: Software for Three and Four Dimensional GIS in the Earth Sciences, Computers & Geosciences, 26, 7, 751-761, 2000.

See Also

justfocXY

Examples

```
set.seed(2015)
N = 20
lon=runif(20, 268.1563 , 305)
lat=runif(20, 7.593004,  25.926045)
str1=runif(20,50,100)
dip1=runif(20,10, 80)
rake1=runif(20,5, 180)

dep=runif(20,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)

 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm

XY = GEOmap::GLOB.XY(lat, lon, PROJ)

plot(range(XY$x), range(XY$y), type='n', asp=1)

plotmanyfoc(MEKS, PROJ, focsiz=0.5)
```

`plotMEC` *Plot a Focal Mechanism*

Description

Plot a Focal Mechanism

Usage

```
plotMEC(x, detail = 0, up = FALSE)
```

Arguments

x	Mechanism list
detail	level of detail
up	logical, Upper or lower hemisphere

Value

Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

Examples

```
 mc = CONVERTSDR(65, 32, -34 )
plotMEC(mc, detail=2, up=FALSE)
```

`PlotPlanes` *Plot Fault an Auxilliary Planes*

Description

Plot both fault and auxilliary planes

Usage

```
PlotPlanes(MEC, col1 = 1, col2 = 3)
```

Arguments

MEC	MEC structure
col1	color for plane 1
col2	color for plane 2

Details

Given MEC structure and focal mechanism plot both planes. This code adds to existing plot, so net() should be called.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

net, lowplane

Examples

```
net()

MFOC1 = SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
PlotPlanes(MFOC1, 'green', 'red' )
```

PlotPTsmooth *Plot Smooth PT-axes*

Description

Project PT axes on the sphere and smooth the image. This function requires function kde2d, from the MASS library.

Usage

```
PlotPTsmooth(paz, pdip, x = 0, y = 0, siz = 1, bcol = "white", border ="black",
        IMAGE = TRUE, CONT = TRUE, cont.col = "black",
         pal = terrain.colors(100), LABS = FALSE, add = FALSE, NCP=50, NIP=200)
```

Arguments

`paz`	vector of Axis azimuths, degrees
`pdip`	vector of dip angles, degrees
`x`	x-location of plot center in user coordinates
`y`	y-location of plot center in user coordinates
`siz`	siz of plot in user coordinates
`bcol`	color
`border`	border color
`IMAGE`	logical, TRUE=create an image plot
`CONT`	logical, TRUE=add contour lines
`cont.col`	color of contour lines
`pal`	pallete for image plot
`LABS`	text Label for image
`add`	logical, TRUE=add to plot
`NCP`	integer, Number of points to use for calculating smoothed contours, default=50
`NIP`	integer, Number of points to use for calculating smoothed image, default=200

Details

Program requires MASS libary for 2D smoothing routine kde2d.

For calculating contours the kde2d program creates a smoothed 2D image using NCP points per side. For the images, NIP points are used. To reduce the size of plots, or, if the subplots are very small, reduce NIP to a smaller value for faster plotting.

Value

Graphical Side Effect

Note

Points that fall on the opposite hemisphere are reflected through the origin.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

kde2d

Examples

```
plot(c(-1,1), c(-1,1), asp=1, type='n')

paz = rnorm(100, mean=297, sd=10)
 pdip = rnorm(100, mean=52, sd=8)

PlotPTsmooth(paz, pdip, x=0.5, y=.5, siz=.3, border=NA, bcol='white' ,
LABS=FALSE, add=FALSE, IMAGE=TRUE, CONT=FALSE)

taz = rnorm(100, mean=138, sd=10)
 tdip = rnorm(100, mean=12, sd=8)

 PlotPTsmooth(taz, tdip, x=-.5, y=.4, siz=.3, border=NA, bcol='white' ,
LABS=FALSE, add=FALSE, IMAGE=TRUE, CONT=TRUE)

###########  put them together
plot(c(-1,1), c(-1,1), asp=1, type='n')
PlotPTsmooth(paz, pdip, x=0, y=, siz=1, border=NA, bcol='white' ,
LABS=FALSE, add=FALSE, IMAGE=TRUE, CONT=FALSE)
PlotPTsmooth(taz, tdip, x=0, y=, siz=1, border=NA, bcol='white' ,
LABS=FALSE, add=TRUE, IMAGE=FALSE, CONT=TRUE)
```

PlotTernfoc *Ternary Distribution of focal mechanisms*

Description

Create and plot a ternary diagram using rake angle to distribute focal mechanisms on a ternary diagram.

Usage

```
PlotTernfoc(h, v, x = 0, y = 0, siz = 1, fcols = "black", LABS = FALSE, add = FALSE)
```

Arguments

h	x-coordinate on ternary plot
v	y-coordinate of ternary plot
x	x Location of center of Ternary plot
y	y Location of center of Ternary plot
siz	size of plot in user coordinates
fcols	vector of colors associated with each focal mechanism
LABS	logical, TRUE=add labels at vertices of Ternary plot
add	logical, add to plot=TRUE

Value

Used for graphical side effect.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

J. M. Lees. Geotouch: Software for three and four dimensional gis in the earth sciences. Computers & Geosciences, 26(7):751–761, 2000

See Also

ternfoc.point, Bfocvec

Examples

```
Z1 = c(159.33,51.6,206,18,78,
161.89,54.5,257,27,133,
170.03,53.57,-44,13,171,
154.99,50.16,-83,19,-40,
151.09,47.15,123,23,-170,
176.31,51.41,-81,22,122,
153.71,46.63,205,28,59,
178.39,51.21,-77,16,126,
178.27,51.1,-86,15,115,
177.95,51.14,-83,25,126,
178.25,51.18,215,16,27
)

MZ = matrix(Z1, ncol=5, byrow=TRUE)

h = vector()
v = vector()
Fcol = vector()
for(i in 1:length(MZ[,3]))
  {
    Msdr = CONVERTSDR(MZ[i,3], MZ[i,4], MZ[i,5])
MEC = MRake(Msdr$M)
  MEC$UP = FALSE

 az1 = Msdr$M$az1
  dip1 = Msdr$M$d1
  az2 = Msdr$M$az2
  dip2 = Msdr$M$d2
  BBB = Bfocvec(az1, dip1,  az2,  dip2)
  V = ternfoc.point(BBB$Bdip, Msdr$M$pd, Msdr$M$td )

  h[i] = V$h
  v[i] = V$v
Fcol[i] = foc.color(foc.icolor(MEC$rake1), pal=1)
```

```
}


PlotTernfoc(h,v,x=0, y=0, siz=1, fcols=Fcol, add=FALSE, LAB=TRUE)

MFOC1 = SDRfoc(65,90,1, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
    Fcol1 = foc.color(foc.icolor(MFOC1$rake1), pal=1)
 MFOC2 = SDRfoc(135,45,-90, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
    Fcol2 = foc.color(foc.icolor(MFOC2$rake1), pal=1)
 MFOC3 = SDRfoc(135,45,90, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
    Fcol3 = foc.color(foc.icolor(MFOC3$rake1), pal=1)

justfocXY( MFOC3, fcol = Fcol3, 1.2, -0.9, focsiz = 0.4 )
justfocXY( MFOC2, fcol = Fcol2, -1.2, -0.9,  focsiz = 0.4  )
justfocXY( MFOC1, fcol = Fcol1, 0, 1.414443+.2,  focsiz = 0.4  )
```

PLTcirc *Circle Plot with Cross Hairs*

Description

Plot an arc of a circle with cross-hairs.

Usage

```
PLTcirc(gcol = "black", border = "black", ndiv = 36,
         angs = c(-pi, pi), PLOT = TRUE, add = FALSE)
```

Arguments

gcol	cross hairs color
border	border color
ndiv	number of divisions
angs	vector from angs[1] to angs[2] in radians
PLOT	logical, if TRUE plot
add	logical, if TRUE add to existing plot

Value

list used for plotting:

x	x coordinates
y	y coordinates
phi	angles, radians

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

Examples

```
PLTcirc(gcol = "purple", border = "black", ndiv = 36, angs = c(-pi, pi), PLOT = TRUE, add = FALSE)

PLTcirc(gcol = NULL, border = "green" , ndiv = 36, angs = c(-pi/4, pi/4), PLOT = TRUE, add = TRUE)
```

---

pnet *plot stereonet*

Description

Plots stereonet created by makenet

Usage

```
pnet(MN, add = FALSE, col = gray(0.7), border = "black", lwd = 1)
```

Arguments

`MN`	Net strucutre created by makenet
`add`	TRUE= add to existing plot
`col`	color of lines
`border`	color for outside border
`lwd`	line width

Value

Used Graphical Side Effects.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Snyder, John P., 1987, Map Projections-a working manual, USGS-Professional Paper, 383p. pages 185-186

See Also

net, pnet

Examples

```
MN = makenet()

  pnet(MN)
```

---

polyfoc *Polt the focal mechanism polygon*

Description

Calculate the projection of the focal mechanism polygon

Usage

```
polyfoc(strike1, dip1, strike2, dip2, PLOT = FALSE, UP = TRUE)
```

Arguments

`strike1`	strike of plane 1, degrees
`dip1`	dip of plane 1, degrees
`strike2`	strike of plane 1, degrees
`dip2`	dip of plane 2, degrees
`PLOT`	logical, TRUE = add to plot
`UP`	upper/lower hemisphere

Value

List of coordinates of polygon

`Px`	x-coordinates of polygon
`Py`	y-coordinates of polygon

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

faultplane

Examples

```
MEC = SDRfoc(13,59,125, PLOT=FALSE)

net()
ply = polyfoc(MEC$az1, MEC$dip1, MEC$az2, MEC$dip2, PLOT = TRUE, UP = TRUE)
```

Pradfoc *Plot P-wave radiation*

Description

Plot P-wave radiation with information from the pickfile and waveform data

Usage

```
Pradfoc(A, MEC, GU, pscale, col)
```

Arguments

`A`	Pickfile structure
`MEC`	MEC structure
`GU`	Waveform Event Structure
`pscale`	logical (not used)
`col`	color palette

Details

Image plot of the P radiation pattern

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

imageP

Examples

```
MEC = SDRfoc(65, 32, -34, u=TRUE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)

Pradfoc(NULL, MEC , NULL, TRUE, rainbow(100) )
```

`Preflect` *Reflect a pole through to the lower hemisphere*

Description

Takes a vector to a pole and reflects it to the lower hemisphere

Usage

```
Preflect(az, dip)
```

Arguments

`az`	azimuth angle, degrees
`dip`	dip in degrees

Value

list

`az`	azimuth angle, degrees
`dip`	dip in degrees

...

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

REFLECT

Examples

```
z = Preflect(65, -23)
z = Preflect(265, -23)
```

`prepFOCS` *Prepare Focals*

Description

Prepare Focals for plotting. Program cycles through data and prepares a relevant data for further plotting and analysis.

Usage

```
prepFOCS(CMTSOL)
```

Arguments

`CMTSOL`	see getCMT for the format for the input here.

Details

Used internally in spherefocgeo and ternfocgeo.

Value

List:

`Paz`	P-axis azimuth
`Pdip`	P-axis dip
`Taz`	T-axis azimuth
`Tdip`	T-axis dip
`h`	horizontal distance on ternary plot
`v`	vertical distance on ternary plot
`fcols`	focal color
`LATS`	latitudes
`LONS`	longitudes
`IFcol`	index of color
`yr`	year
`JDHM`	character identification
`JDHMS`	character identification

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

getCMT, spherefocgeo, ternfocgeo

`printMEC` *Print focal mechanism*

Description

Print focal mechanism

Usage

```
printMEC(x, digits = max(3, getOption("digits") - 3), ...)
```

Arguments

`x`	Mechanism list
`digits`	digits for numeric information
`...`	standard printing parameters

Value

Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

Examples

```
 mc = CONVERTSDR(65, 32, -34 )

printMEC(mc)
```

`PROJ3D` *Project 3D*

Description

Project a 3D body after rotation and translation

Usage

```
PROJ3D(aglyph, M = diag(1, nrow = 4), M2 = diag(1, nrow = 4),
             anorms = list(), zee = c(0, 0, 1))
```

Arguments

aglyph	glyph structure
M	rotation matrix
M2	rotation matrix
anorms	normals to structure
zee	Up direction of body

Details

This function takes a 3D body, rotates it and projects it for plotting. An example glyph is found in Z3Darrow.

Value

Glyph structure

x, y, z	coordinates of rotated body faces
xp	rotated normal vectors
zd	depth mean value of each face

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

makeblock3D, ROTZ, ROTY, ROTX, BOXarrows3D, Z3Darrow, TRANmat

Examples

```
  block1 = matrix(c(0,0,0,
      1,0,0,
      1,0.5,0,
      0,0.5,0,
      0,0,-2,
      1,0,-2,
      1,0.5,-2,
      0,0.5,-2), byrow=TRUE, ncol=3)

    Bblock1 = makeblock3D(block1)

    R3 = ROTX(-40)
    R2 = ROTY(0)
    R1 = ROTZ(20)
    T =  TRANmat(.1, 0, 0 )
    M =     R1  %*% R2  %*%  R3  %*% T

    T2 =  TRANmat(1, 0.5, 0 )
    MT =       T2 %*%   R1  %*% R2  %*%   R3 %*% T
```

```
Z1 =  PROJ3D(Bblock1$aglyph, M=MT,  anorms=Bblock1$anorm , zee=c(0,0,1))
```

PTaxes *Plot P-T axis on CLVD*

Description

Plot P-T axis on CLVD

Usage

```
PTaxes(strike, dip, rake)
```

Arguments

strike	strike
dip	dip
rake	rake

Details

Lower Hemisphere. Add PT axes on a moment tensor plot

Value

Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

doNonDouble, MapNonDouble

Examples

```
mo = list(n=1, m1=1.035675e+017, m2=-1.985852e+016,
m3=-6.198052e+014, m4=1.177936e+017, m5=-7.600627e+016, m6=-3.461405e+017)
moments = cbind(mo$n, mo$m1, mo$m2, mo$m3, mo$m4, mo$m5, mo$m6)
doNonDouble(moments)
```

PTXY2 *Plot P-T Axes*

Description

given a focal mechanism, add P-T lines to a plot

Usage

```
PTXY2(x = x, y = y, MEC, focsiz, pt = 0, ...)
```

Arguments

`x`	x-location on plot
`y`	y-location on plot
`MEC`	Focal Mechanism list from SDRFOC
`focsiz`	size of mechanism, inches
`pt`	pt = 0(plot both), 1=only P axes, 2=only T axes, default=0
`...`	graphical parameters

Details

This is a summary plot to be used instead of Beach Balls.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Lees, J. M., Geotouch: Software for Three and Four Dimensional GIS in the Earth Sciences, Computers & Geosciences, 26, 7, 751-761, 2000.

See Also

nipXY, justfocXY

Examples

```
### HAiti Earthquake Jan, 2010
MEC <-  SDRfoc(71, 64, 25 , u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
plot(c(0, 1), c(0,1), type='n', asp=1)
u <- par("usr")

justfocXY(MEC, x=.5,  y= .5,  focsiz=0.5,
fcol ='brown' , fcolback = "white", xpd = TRUE)

 PTXY2(1.0, .5 , MEC  ,0.5, col="purple", lwd=3 )

nipXY(MEC, x = 0.25, y = .5, focsiz=0.5,
fcol ='purple', nipcol = "black", cex = 0.4)
#####  or
set.seed(2015)
N = 20
lon=runif(20, 268.1563 , 305)
lat=runif(20, 7.593004,  25.926045)
str1=runif(20,50,100)
dip1=runif(20,10, 80)
rake1=runif(20,5, 180)

dep=runif(20,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)

 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm

XY = GEOmap::GLOB.XY(lat, lon, PROJ)

plot(range(XY$x), range(XY$y), type='n', asp=1)

for(i in 1:length(XY$x))
{
  Msdr = CONVERTSDR(MEKS$str1[i], MEKS$dip1[i],MEKS$rake1[i])
     MEC = MRake(Msdr$M)
       MEC$UP = FALSE

         jcol =  foc.color(foc.icolor(MEC$rake1), pal=1)

PTXY2(XY$x[i], XY$y[i] , MEC  ,focsiz=0.5, col=jcol, lwd=3)

}
```

qpoint *Point on Stereonet*

Description

Plot a set of (azimuths, takeoff) angles on a stereonet.

Usage

```
qpoint(az, iang, col = 2, pch = 5, lab = "", POS = 4, UP = FALSE, PLOT = FALSE, cex = 1)
```

Arguments

az	vector of azimuths, degrees
iang	vector of incident angles, degrees
col	color
pch	plotting character
lab	text labels
POS	position for labels
UP	logical, TRUE=upper
PLOT	logical, add to existing plot
cex	character expansion of labels

Details

The iang argument represents the takeoff angle, and is measured from the nadir (z-axis pointing down).

Value

List

x	coordinate on plot
y	coordinate on plot

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

FixDip, focpoint

Examples

```
d = runif(10, 0, 90)
a = runif(10, 0,360)
net()
qpoint(a, d)
```

---

radiateP *Plot radiation pattern for P-waves*

Description

Plots focal mechanism and makes radiation plot with mark up

Usage

```
radiateP(MEC, SCALE = FALSE, col = col, TIT = FALSE)
```

Arguments

MEC	focal mechanism structure
SCALE	logical, TRUE=add scale
col	color palette
TIT	title for plot

Value

Used for side graphical effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

radP, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
radiateP(MEC, SCALE = FALSE, col = rainbow(100) , TIT = FALSE)
```

radiateSH *Plot radiation pattern for SH-waves*

Description

Plots focal mechanism and makes radiation plot with mark up

Usage

```
radiateSH(MEC, SCALE = FALSE, col = col, TIT = FALSE)
```

Arguments

MEC	focal mechanism structure
SCALE	logical, TRUE=add scale
col	color palette
TIT	title for plot

Value

Used for side graphical effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

radSH, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
radiateSH(MEC, SCALE = FALSE, col = rainbow(100) , TIT = FALSE)
```

radiateSV *Plot radiation pattern for SV-waves*

Description

Plots focal mechanism and makes radiation plot with mark up

Usage

```
radiateSV(MEC, SCALE = FALSE, col = col, TIT = FALSE)
```

Arguments

MEC	focal mechanism structure
SCALE	logical, TRUE=add scale
col	color palette
TIT	title for plot

Value

Used for side graphical effect

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

radSV, SDRfoc

Examples

```
MEC =SDRfoc(65,25,13, u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
radiateSV(MEC, SCALE = FALSE, col = rainbow(100) , TIT = FALSE)
```

radP *Radiation pattern for P waves*

Description

calculate the radiation patterns for P waves

Usage

```
radP(del, phiS, lam, ichi, phi)
```

Arguments

`del`	degrees, angle
`phiS`	degrees,angle
`lam`	degrees, angle
`ichi`	degrees, take off angle
`phi`	degrees, take off azimuth

Details

Given a focal mechanism strike-dip-rake and a given incident angle (take-off angle) and azimuth, return the P amplitude

Value

Amplitude of the P wave

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radP, radSV, imageP

Examples

```
phiS=65
del=25
lam=13
x = seq(-1, 1, 0.01)
y = x

X = matrix(rep(x, length(y)), nrow= length(x))
Y = t(X)
RAD2DEG = 180/pi
p = RAD2DEG*(pi/2 -atan2(Y, X))
p[p<0] = p[p<0] + 360

R = sqrt(X^2+Y^2)
R[R>1] = NaN
dip =RAD2DEG*2*asin(R/sqrt(2))

###  Calculate the radiation pattern
G = radP(del, phiS, lam, dip, p)

###  plot values
image(x,y,G, asp=1)
```

---

radSH *Radiation pattern for SH waves*

Description

calculate the radiation patterns for SH waves

Usage

```
radSH(del, phiS, lam, ichi, phi)
```

Arguments

del	degrees, angle
phiS	degrees,angle
lam	degrees, angle
ichi	degrees, take off angle
phi	degrees, take off azimuth

Details

Given a focal mechanism strike-dip-rake and a given incident angle (take-off angle) and azimuth, return the SH amplitude

Value

Amplitude of the SH wave

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radP, radSV, imageSH

Examples

```
phiS=65
del=25
lam=13
x = seq(-1, 1, 0.01)
y = x

X = matrix(rep(x, length(y)), nrow= length(x))
Y = t(X)
RAD2DEG = 180/pi
p = RAD2DEG*(pi/2 -atan2(Y, X))
p[p<0] = p[p<0] + 360

R = sqrt(X^2+Y^2)
R[R>1] = NaN
dip =RAD2DEG*2*asin(R/sqrt(2))

###  Calculate the radiation pattern
G = radSH(del, phiS, lam, dip, p)

###  plot values
image(x,y,G, asp=1)
```

---

radSV *Radiation pattern for SV waves*

Description

calculate the radiation patterns for SV waves

Usage

```
radSV(del, phiS, lam, ichi, phi)
```

Arguments

`del`	degrees, angle
`phiS`	degrees,angle
`lam`	degrees, angle
`ichi`	degrees, take off angle
`phi`	degrees, take off azimuth

Details

Given a focal mechanism strike-dip-rake and a given incident angle (take-off angle) and azimuth, return the SV amplitude

Value

Amplitude of the SV wave

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

K.~Aki and P.~G. Richards.*Quantitative seismology*. University Science Books, Sausalito, Calif., 2nd edition, 2002.

See Also

radP, radSH, imageSV

Examples

```
phiS=65
del=25
lam=13
x = seq(-1, 1, 0.01)
y = x

X = matrix(rep(x, length(y)), nrow= length(x))
Y = t(X)
RAD2DEG = 180/pi
p = RAD2DEG*(pi/2 -atan2(Y, X))
p[p<0] = p[p<0] + 360

R = sqrt(X^2+Y^2)
R[R>1] = NaN
```

```
dip =RAD2DEG*2*asin(R/sqrt(2))

###  Calculate the radiation pattern
G = radSV(del, phiS, lam, dip, p)

###  plot values
image(x,y,G, asp=1)
```

`rakelegend` *Focal Legend based on rake*

Description

Focal Legend based on rake

Usage

```
rakelegend(corn="topright", pal=1)
```

Arguments

`corn`	position of legend, default="topright"
`pal`	palette number, default=1

Details

Colors are based on earlier publication of Geotouch program.

For pal = 1, colors are , DarkSeaGreen, cyan1, SkyBlue1, RoyalBlue, GreenYellow, orange, red.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Lees, J. M., (1999) Geotouch: Software for Three and Four-Dimensional GIS in the Earth Sciences, Computers and Geosciences, 26(7) 751-761.

See Also

foc.color,focleg

Examples

```
plot(c(0,1), c(0,1), type='n')

rakelegend(corn="topleft", pal=1)
```

---

readCMT *Read Harvard CMT moment*

Description

Read and plot a CMT solution copied from the Harvard CMT website.

Usage

```
readCMT(filename, PLOT=TRUE)
```

Arguments

`filename`	character, file name
`PLOT`	Logical, TRUE=plot mechanisms sequentially

Details

Uses the standard output format.

Value

List of mechanisms and graphical Side effects. Each element in the list consists of a list including: FIRST,yr,mo,dom,hr,mi,sec,name,tshift,half,lat,lon,z,Mrr,Mtt,Mpp,Mrt,Mrp,Mtp. The FIRST element is simply a duplicate of the PDE solution card.

Note

Other formats are available.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Ekstrom, G.; Nettles, M. and DziewoDski, A. The Global CMT Project 2004-2010: centroid-moment tensors for 13,017 earthquakes Physics of the Earth and Planetary Interiors, 2012.

See Also

doNonDouble, MapNonDouble

Examples

```
Z = c('MLI 1981  1 30  8 52 44.10  51.7400  176.2700  33.0 6.3 7.0 RAT ISLANDS, ALEUTIANS',
'event name:     013081B',
'time shift:      6.0000',
'half duration:   7.0000',
'latitude:       51.5200',
'longitude:     176.1000',
'vdepth:          20.0000',
'Mrr:       2.375000e+26',
'Mtt:      -2.777000e+26',
'Mpp:       4.030000e+25',
'Mrt:        2.8e+26',
'Mrp:       1.19e+26',
'Mtp:      -5.39e+25'
)

fn =  tempfile("temp", fileext = ".cmt")
cat(file=fn, Z, sep="\n")

Hcmt = readCMT(fn, PLOT=FALSE)
```

`RectDense` *Divide a region into rectangles based on density*

Description

Given a set of (x,y) points, partition the field into rectangles each containing a minimum number of points

Usage

```
RectDense(INx, INy, icut = 1, u = par("usr"), ndivs = 10)
```

Arguments

`INx`	x-coordinates
`INy`	y-coordinates
`icut`	cut off for number of points
`u`	user coordinates
`ndivs`	number of divisions in x-coordinate

Details

Based on the user coordinates as returned from par('usr'). Each rectangular region is tested for the number of points that fall within icut or greater.

Value

List:

icorns	matrix of corners that passed test
ilens	vector,number of points in each icorns box
ipass	vector, index of the corners that passed icut
corners	matrix of all corners
lens	vector,number of points for each box

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

Examples

```
x = rnorm(100)
y = rnorm(100)

plot(x,y)
u = par('usr')
RI = RectDense(x, y, icut=3, u=u, ndivs=10)

 rect(RI$icorns[,1],RI$icorns[,2],RI$icorns[,3],RI$icorns[,4], col=NA, border='blue')
```

REFLECT *reflect pole*

Description

Reflect pole to lower hemisphere

Usage

```
REFLECT(A)
```

Arguments

A	structure of azimuth and Dips in degrees

Value

list of:cartesian coordinates of reflected pole

x	x-coordinate
y	y-coordinate
z	z-coordinate
az	azimuth, degrees
dip	dip, degrees

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

Preflect

Examples

```
A = list(az=231, dip = -65)
REFLECT(A)
```

---

rotateFoc *Rotate Focal Mechanism*

Description

Rotate mechanism to vertical plan at specified angle

Usage

```
rotateFoc(MEX, phi)
```

Arguments

MEX	Focal Mechanism list
phi	angle in degrees

Details

Assumed vertical plane, outer hemisphere

Value

Focal Mechanism

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

plotfoc, SDRfoc,Beachfoc, TEACHFOC, plotmanyfoc, getUWfocs

Examples

```
a1 = SDRfoc(90, 90, 90, u = TRUE , PLOT = TRUE)


par(mfrow=c(2,2))

SDRfoc(a1$az1, a1$dip1, a1$rake1, u = TRUE, PLOT = TRUE)
ra1 = rotateFoc(a1, -90)

SDRfoc(ra1$az1, ra1$dip1, ra1$rake1, u = TRUE , PLOT = TRUE)

ra1 = rotateFoc(a1, 0)


SDRfoc(a1$az1, a1$dip1, a1$rake1, u = TRUE, PLOT = TRUE)

SDRfoc(ra1$az1, ra1$dip1, ra1$rake1, u = TRUE , PLOT = TRUE)
```

Rotfocphi *Rotate Focal Mechanism*

Description

Rotate Focal Mechanism into the vertical plane by a certain number of degrees

Usage

```
Rotfocphi(phi, urot, udip, vrot, vdip, az1, d1, az2, d2, prot, pdip, trot, tdip)
```

Arguments

phi	degrees in plane to rotate
urot	U-vector azimuth
udip	U-vector dip

vrot	V-vector azimuth
vdip	V-vector dip
az1	First plane - azimuth
d1	First plane - dip
az2	Second plane - azimuth
d2	Second plane - dip
prot	P-axis azimuth
pdip	P-axis dip
trot	T-axis azimuth
tdip	T-axis dip

Details

Rotate the focal mech by phi degrees

Value

list:

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

xsecmanyfoc, rotateFoc

RotTP *Rotate T-P axes*

Description

Rotate T-P axes

Usage

```
RotTP(rotmat, strk1, dip1)
```

Arguments

rotmat	rotation matrix, 3 by 3
strk1	strike angle
dip1	dip angle

Details

These are used as functions auxiallry to rotateFoc.

Value

list:

`strk`	strike angle
`dip`	dip angle

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

Rotfocphi, TP2XYZ

Examples

```
phi = 18

MAT = JMAT(phi)

RotTP(MAT, 30, 40)
```

`ROTX` *X-axis Rotation Matrix*

Description

Matrix rotation about the X-axis

Usage

```
ROTX(deg)
```

Arguments

`deg`	Angle in degrees

Value

A 4 by 4 matrix for rotation and translation for 3-D transformation

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Rogers and Adams, 1990, Mathematical Elements for Computer Graphics, McGraw-Hill, 611p.

See Also

ROTY, ROTZ

Examples

```
v = c(1,4,5)
A = ROTX(23)
vp = c(v, 1)
```

---

rotx3 — *Rotate about the x axis*

Description

3x3 Rotation about the x axis

Usage

```
rotx3(deg)
```

Arguments

deg	angle, degrees

Details

returns a 3 by 3 rotation matrix

Value

matrix, 3 by 3

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

roty3, rotz3, ROTX, ROTZ, ROTY

Examples

```
a = 45
rotx3(a)
```

`ROTY` *Y-axis Rotation Matrix*

Description

Matrix rotation about the Y-axis

Usage

```
ROTY(deg)
```

Arguments

`deg`	Angle in degrees

Value

A 4 by 4 matrix for rotation and translation for 3-D transformation

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Rogers and Adams, 1990, Mathematical Elements for Computer Graphics, McGraw-Hill, 611p.

See Also

ROTX, ROTZ

Examples

```
v = c(1,4,5)
A = ROTY(23)
vp = c(v, 1)
```

`roty3` *Rotate about the y axis*

Description

3x3 Rotation about the y axis

Usage

```
roty3(deg)
```

Arguments

`deg`	angle, degrees

Details

returns a 3 by 3 rotation matrix

Value

matrix, 3 by 3

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

rotz3, rotx3, ROTX, ROTZ, ROTY

Examples

```
a = 45
roty3(a)
```

ROTZ *Z-axis Rotation Matrix*

Description

Matrix rotation about the Z-axis

Usage

```
ROTZ(deg)
```

Arguments

deg	Angle in degrees

Value

A 4 by 4 matrix for rotation and translation for 3-D transformation

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Rogers and Adams, 1990, Mathematical Elements for Computer Graphics, McGraw-Hill, 611p.

See Also

ROTX, ROTY

Examples

```
v = c(1,4,5)
A = ROTZ(23)
vp = c(v, 1)
```

`rotz3` *Rotate about the z axis*

Description

3x3 Rotation about the z axis

Usage

```
rotz3(deg)
```

Arguments

deg	angle, degrees

Details

returns a 3 by 3 rotation matrix

Value

matrix, 3 by 3

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

roty3, rotx3, ROTX, ROTZ, ROTY

Examples

```
a = 45
rotz3(a)
```

SDRfoc	*Plot a Focal Mechanism from SDR*

Description

Given Strike-Dip-Rake plot a focal mechanism

Usage

```
SDRfoc(s, d, r, u = FALSE, ALIM = c(-1, -1, +1, +1), PLOT = TRUE)
```

Arguments

`s`	strike, degrees
`d`	dip, degrees
`r`	rake, degrees
`u`	logical, TRUE=upper hemisphere
`ALIM`	bounding box on plot
`PLOT`	logical, TRUE=add to plot

Details

The ALIM vector allows one to zoom into portions of the focal mechanism for details when points are tightly clustered.

Value

MEC structure

Note

Basic MEC List Structure

az1	azimuth angle plane 1, degrees
dip1	dip angle plane 1, degrees
az2	azimuth angle plane 2, degrees
dip2	dip angle plane 2, degrees
dir	0,1 to determine which section of focal sphere is shaded
rake1	rake angle plane 1, degrees
dipaz1	dip azimuth angle plane 1, degrees
rake2	rake angle plane 2, degrees
dipaz2	dip azimuth angle plane 2, degrees
P	pole list(az, dip) P-axis
T	pole list(az, dip) T-axis
U	pole list(az, dip) U-axis
V	pole list(az, dip) V-axis

F	pole list(az, dip) F-axis
G	pole list(az, dip) G-axis
sense	0,1 to determine which section of focal sphere is shaded
M	list of focal parameters used in some calculations
UP	logical, TRUE=upper hemisphere
icol	index to suite of colors for focal mechanism
ileg	Kind of fault
fcol	color of focal mechanism
CNVRG	Character, note on convergence of solution
LIM	vector plotting region (x1, y1, x2, y2)

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

CONVERTSDR

Examples

```
M = SDRfoc(-25, 34, 16,u = FALSE, ALIM = c(-1, -1, +1, +1), PLOT=TRUE)
```

ShadowCLVD *Plot CLVD focal mechanism*

Description

Plot non-double couple part of the focal mechanism provided in the moment tensor.

Usage

```
ShadowCLVD(m, PLOT = TRUE, col=rgb(1, .75, .75))
```

Arguments

`m`	moment tensor
`PLOT`	logical, TRUE means plot
`col`	color, either a single color, rgb, or a color palette

Details

This code is meant to be used with doNonDouble or MapNonDouble functions for plotting the non-double couple components of the moment tensor. A color palette can be provided for some details of the radiation patterns, e.g. col=rainbow(12).

Value

Side effects and image list

Note

Lower Hemisphere.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

doNonDouble, MapNonDouble

Examples

```
############  moment tensor from Harvard CMT catalog
sponent = 26
ef = 1*10^(sponent)
Mrr =  2.375*ef
Mtt = -2.777*ef
Mpp = 0.403*ef
Mrt = 2.800*ef
Mrp = 1.190*ef
Mtp = -0.539*ef

############  convert to cartesian coordinates
Mzz=Mrr
Mxx= Mtt
Myy= Mpp
Mxz= Mrt
Myz= -Mrp
Mxy= -Mtp


m=matrix( c(Mxx,Mxy,Mxz,
      Mxy,Myy,Myz,
       Mxz,Myz,Mzz), ncol=3, byrow=TRUE)

Fi=seq(from=0, by=0.1, to=361)
  ###  dev.new()
    plot(cos(Fi*pi/180.0),sin(Fi*pi/180.0),type='l', asp=1 , ann=FALSE, axes=FALSE)

  ShadowCLVD(m, col='red')
```

`SHradfoc` *Plot SH-wave radiation*

Description

Plot SH-wave radiation with information from the pickfile and waveform data

Usage

```
SHradfoc(A, MEC, GU, pscale, col)
```

Arguments

`A`	Pickfile structure
`MEC`	MEC structure
`GU`	Waveform Event Structure
`pscale`	logical (not used)
`col`	color palette

Details

Image plot of the SH radiation pattern

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

imageSH

Examples

```
MEC = SDRfoc(65, 32, -34, u=TRUE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)

SHradfoc(NULL, MEC , NULL, TRUE, rainbow(100) )
```

`SourceType` *Moment Tensor Source Type*

Description

Given a vector of EigenValues, extract the source type.

Usage

```
SourceType(v)
```

Arguments

`v`	vector of decreasing eigenvalues

Details

plotting for -30 to 30 degree quadrant.

Value

list:

`phi`	latitude angle in degrees
`lam`	longitude angle in degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Tape, W.,and C.Tape(2012), A geometric comparison of source-type plots for moment tensors, Geophys. J. Int., 190, 499-510.

See Also

HAMMERprojXY, TapeBase, TapePlot

Examples

```
SourceType(c(1,-1,1) )

T1 = TapeBase()

m1 = list(Mxx=1.543,  Mxy=0.786,  Myy=0.336, Mxz=-2.441,  Myz=0.353,  Mzz=0.961)

i = 1
M1=matrix( c(m1$Mxx[i],m1$Mxy[i],m1$Mxz[i],
```

```
      m1$Mxy[i],m1$Myy[i],m1$Myz[i],
       m1$Mxz[i],m1$Myz[i],m1$Mzz[i]), ncol=3, byrow=TRUE)

 E1 = eigen(M1)
           h = SourceType( sort(E1$values, decreasing=TRUE) )
           h$dip = 90-h$phi
           ##  cat(paste(h$dip, h$lam, sep=" "), sep="\n")
           h1 = HAMMERprojXY(h$dip*pi/180, h$lam*pi/180)



TapePlot(T1)
           points(h1$x, h1$y,  pch=21, bg="red" )
```

---

spherefocgeo *SphereFocGeo*

Description

Spherical Projections of PT axes distributed geographically.

Usage

```
spherefocgeo(CMTSOL, PROJ = NULL, icut = 5,
ndivs = 10,  bbox=c(0,1, 0, 1), PLOT = TRUE,
 add = FALSE, RECT = FALSE, pal = terrain.colors(100))
```

Arguments

CMTSOL	see output of getCMT for list input
PROJ	Map projection
icut	cut off for number of points in box, default=5
ndivs	divisions of map area, default=10
bbox	bounding box for dividing the area, given as minX, maxX, minY, maxY; default=usr coordinates from par()
PLOT	logical, default=TRUE
add	logical, add to existing plot
RECT	logical, TRUE=plot rectangles
pal	palette fo rimages in each box

Details

Program divides the area into blocks, tests each one for minimum number per block and projects the P and T axes onto an equal area stereonet.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

PlotPTsmooth, ternfocgeo, prepFOCS, RectDense

Examples

```
N = 100
LATS = c(7.593004,  25.926045)
LONS = c(268.1563 , 305)
lon=rnorm(N, mean=mean(LONS), sd=diff(LONS)/2 )
lat=rnorm(N, mean=mean(LATS), sd=diff(LATS)/2)

str1=runif(N,50,100)
dip1=runif(N,10, 80)
rake1=runif(N,5, 180)


dep=runif(N,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)


 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
 rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm
XY = GEOmap::GLOB.XY(lat, lon, PROJ)
plot(range(XY$x), range(XY$y), type='n', asp=1)

  points(XY$x, XY$y)
spherefocgeo(MEKS, PROJ, PLOT=TRUE, icut = 3, ndivs = 4,
 add=TRUE, pal=terrain.colors(100), RECT=TRUE )
```

spline.arrow *Spline Arrow*

Description

Given a set of points, draw a spline and affix an arrow at the end.

Usage

```
spline.arrow(x, y = 0, kdiv = 20, arrow = 1,
 length = 0.2, col = "black", thick = 0.01,
headlength = 0.2, headthick = 0.1, code = 2, ...)
```

Arguments

`x`	vector, x-coordinates
`y`	vector, y-coordinates
`kdiv`	Number of divisions
`arrow`	style of arrow, 1=simple arrow, 2=fancy arrow
`length`	length of head
`col`	color of arrow
`thick`	thickness of arrow stem
`headlength`	length of arrow head
`headthick`	thickness of arrow head
`code`	code, 1=arrow on end of spline, 3=arrow on beginning.
`...`	graphical parameters for the line

Details

Can use either simple arrows or fancy arrows.

Value

list of x,y coordinates of the spline and Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

fancyarrows

Examples

```
plot(c(0,1), c(0,1), type='n')


G=list()
G$x=c(0.1644,0.1227,0.0659,0.0893,0.2346,
0.3514,0.5518,0.7104,0.6887,0.6903,0.8422)
G$y=c(0.8816,0.8305,0.7209,0.6086,0.5372,
0.6061,0.6545,0.6367,0.4352,0.3025,0.0475)



spline.arrow(G$x, G$y)
```

StrikeDip *Plot Strike Dip Lines*

Description

Given a focal mechanism, add Strike Dip lines to a plot.

Usage

```
StrikeDip(x = x, y = y, MEC, focsiz, addDIP = TRUE, ...)
```

Arguments

x	x-location on plot
y	y-location on plot
MEC	Focal Mechanism list from SDRFOC
focsiz	size of mechanism, inches
addDIP	Logical, TRUE = add dip line perpendicular to strike
...	graphical parameters

Details

This is a summary plot to be used instead of Beach Balls.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Lees, J. M., Geotouch: Software for Three and Four Dimensional GIS in the Earth Sciences, Computers & Geosciences, 26, 7, 751-761, 2000.

See Also

nipXY, justfocXY, plotmanyfoc

Examples

```
###  HAiti Earthquake Jan, 2010
MEC <-  SDRfoc(71, 64, 25 , u=FALSE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)
plot(c(0, 1), c(0,1), type='n', asp=1)
u <- par("usr")
focsiz <-  0.5
justfocXY(MEC, x=.5,  y= .5,  focsiz=0.5,
fcol ='brown' , fcolback = "white", xpd = TRUE)
 StrikeDip(1.0, .5 , MEC  ,focsiz, col="purple", lwd=3 )
nipXY(MEC, x = 0.25, y = .5,  focsiz=0.5,
fcol ='purple', nipcol = "black", cex = 1)


#####  or
set.seed(2015)
N = 20
lon=runif(20, 268.1563 , 305)
lat=runif(20, 7.593004,  25.926045)
str1=runif(20,50,100)
dip1=runif(20,10, 80)
rake1=runif(20,5, 180)

dep=runif(20,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)

 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm

XY = GEOmap::GLOB.XY(lat, lon, PROJ)

plot(range(XY$x), range(XY$y), type='n', asp=1)

for(i in 1:length(XY$x))
{
  Msdr = CONVERTSDR(MEKS$str1[i], MEKS$dip1[i],MEKS$rake1[i])
     MEC = MRake(Msdr$M)
       MEC$UP = FALSE
```

```
          jcol =  foc.color(foc.icolor(MEC$rake1), pal=1)

   StrikeDip(XY$x[i], XY$y[i] , MEC  ,focsiz, col=jcol, lwd=3 )

   }
```

---

strikeslip.fault *Strikeslip Fault Cartoon*

Description

Illustrate a strikeslip fault using animation

Usage

```
strikeslip.fault(anim = seq(from = 0, to = 1, by = 0.1), KAPPA = 2,
                 Light = c(45, 45))
```

Arguments

`anim`	animation vector
`KAPPA`	Phong parameter for lighting
`Light`	lighting point

Details

Program will animate a strikeslip fault for educational purposes. Animation must be stopped by halting execution.

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

normal.fault, thrust.fault

Examples

```
strikeslip.fault(anim=0, Light=c(45,90) )

if(interactive()){
#### execute a stop command to stop this animation
anim= seq(from=0, to=1, by=.1)
 strikeslip.fault(anim=anim, Light=c(45,90) )
 }
```

SVradfoc *Plot SV-wave radiation*

Description

Plot SV-wave radiation with information from the pickfile and waveform data

Usage

```
SVradfoc(A, MEC, GU, pscale, col)
```

Arguments

A	Pickfile structure
MEC	MEC structure
GU	Waveform Event Structure
pscale	logical (not used)
col	color palette

Details

Image plot of the SV radiation pattern

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

imageSV

Examples

```
MEC = SDRfoc(65, 32, -34, u=TRUE, ALIM=c(-1,-1, +1, +1), PLOT=FALSE)

SVradfoc(NULL, MEC , NULL, TRUE, rainbow(100) )
```

TapeBase *Tape Base Lines*

Description

Create a structure of Tape Base lines

Usage

```
TapeBase()
```

Details

Program returns the lines and points for plotting a Tape plot. Based on the Hammer projection.

Value

List

Note

The list includes points and other information

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Tape, W., and C. Tape (2012), A geometric comparison of source-type plots for moment tensors, Geophys. J. Int., 190, 499-510.

See Also

TapePlot, HAMMERprojXY

Examples

```
T1 =TapeBase()
TapePlot(T1)
```

`TapePlot` *Tape style Lune Plot*

Description

Tape style Lune Plot using Hammer projection

Usage

```
TapePlot(TapeList = list(), add = FALSE, ann = TRUE,
pcol = c(grey(0), grey(0.85), grey(0.95)))
```

Arguments

`TapeList`	List of strokes from TapeBase
`add`	logical, TRUE=add to existing plot
`ann`	logical, TRUE=annotape
`pcol`	3-vector of colors: inner lines, upper polygon, lower polygon

Details

Plot an Tape net from the TapeBase function.

Value

Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Tape, W., and C. Tape (2012), A geometric comparison of source-type plots for moment tensors, Geophys. J. Int., 190, 499-510. https://doi.org/10.1111/j.1365-246X.2012.05490.x

See Also

TapeBase, HAMMERprojXY

Examples

```
T1 = TapeBase()
TapePlot(T1)

 data(widdenMoments)
WM = widdenMoments

         par(mfrow=c(1,1), mai=c(0,0,0,0))
         T1 = TapeBase()
         TapePlot(T1)

         for(i in 1:length(WM$Mxx))
         {
           M1=matrix( c(WM$Mxx[i],WM$Mxy[i],WM$Mxz[i],
      WM$Mxy[i],WM$Myy[i],WM$Myz[i],
       WM$Mxz[i],WM$Myz[i],WM$Mzz[i]), ncol=3, byrow=TRUE)

           E1 = eigen(M1)
           h = SourceType( sort(E1$values, decreasing=TRUE) )
           h$dip = 90-h$phi
           ##  cat(paste(h$dip, h$lam, sep=" "), sep="\n")
           h1 = HAMMERprojXY(h$dip*pi/180, h$lam*pi/180)

           points(h1$x, h1$y,  pch=21, bg="orange" )

         }
```

TEACHFOC *Graphical Plot of Focal Mechanism*

Description

Plots Beachball figure with numerous vectors and points added and labeled. Useful for teaching about focal mechanisms.

Usage

```
TEACHFOC(s, d, r, up = FALSE)
```

Arguments

s	strike
d	dip
r	rake
up	logical, TRUE = upper

Value

Graphical side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

CONVERTSDR, MRake,foc.icolor,focleg, foc.color, focpoint, PlotPlanes, nipXY , fancyarrows

Examples

```
TEACHFOC(65, 32, -34, up=TRUE)
```

---

ternfoc.point *Plot Ternary Point*

Description

Add a point to a ternary plot

Usage

```
ternfoc.point(deltaB, deltaP, deltaT)
```

Arguments

deltaB	angle, degrees
deltaP	angle, degrees
deltaT	angle, degrees

Details

Plot point on a Ternary diagram using Froelich's algorithm.

Value

List

h	vector of x coordinates
v	vector of y coordinates

Note

Use Bfocvec(az1, dip1, az2, dip2) to get the deltaB angle.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

C. Frohlich. Triangle diagrams: ternary graphs to display similarity and diversity of earthquake focal mechanisms. Physics of the Earth and Planetary Interiors, 75:193-198, 1992.

See Also

Bfocvec

Examples

```
Msdr = CONVERTSDR(55.01, 165.65,  29.2   )
 MEC = MRake(Msdr$M)
  MEC$UP = FALSE
   az1 = Msdr$M$az1
  dip1 = Msdr$M$d1
  az2 = Msdr$M$az2
  dip2 = Msdr$M$d2
  BBB = Bfocvec(az1, dip1,  az2,  dip2)
  V = ternfoc.point(BBB$Bdip, Msdr$M$pd, Msdr$M$td )
```

---

ternfocgeo *Ternary Focals*

Description

Ternary plots of rake categories (strike-slip, normal, thrust) distributed geographically.

Usage

```
ternfocgeo(CMTSOL, PROJ = NULL, icut = 5, ndivs = 10,
 bbox=c(0,1, 0, 1), PLOT = TRUE, add = FALSE, RECT = FALSE)
```

Arguments

CMTSOL	see output of getCMT for list input
PROJ	Map projection
icut	cut off for number of points in box, default=5
ndivs	divisions of map area, default=10
bbox	bounding box for dividing the area, given as minX, maxX, minY, maxY; default=usr coordinates from par()
PLOT	logical, default=TRUE
add	logical, add to existing plot
RECT	logical, TRUE=plot rectangles

Details

Program divides the area into blocks, tests each one for minimum number per block and plots a ternary plot for each block.

Value

Graphical Side Effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

PlotTernfoc, spherefocgeo, prepFOCS, RectDense

Examples

```
N = 100
LATS = c(7.593004,  25.926045)
LONS = c(268.1563 , 305)
lon=rnorm(N, mean=mean(LONS), sd=diff(LONS)/2 )
lat=rnorm(N, mean=mean(LATS), sd=diff(LATS)/2)

str1=runif(N,50,100)
dip1=runif(N,10, 80)
rake1=runif(N,5, 180)


dep=runif(N,1,15)
name=seq(from=1, to=length(lon), by=1)
Elat=NULL
Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)


 MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)
PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm
XY = GEOmap::GLOB.XY(lat, lon, PROJ)
plot(range(XY$x), range(XY$y), type='n', asp=1)

##  points(XY$x, XY$y)

ternfocgeo(MEKS , PROJ, PLOT=TRUE, icut = 3,
ndivs = 4, add=TRUE, RECT=TRUE)

points(XY$x, XY$y, pch=8, col="purple" )

#################  next restrict the boxes to a specific region
plot(range(XY$x), range(XY$y), type='n', asp=1)
```

```
points(XY$x, XY$y)

ternfocgeo(MEKS , PROJ, PLOT=TRUE, icut = 3, ndivs = 5,
 bbox=c(-2000,2000,-2000,2000) , add=TRUE, RECT=TRUE)
```

testrightHAND *Test Right Hand of tensor*

Description

Test Right Hand of tensor

Usage

```
testrightHAND(U)
```

Arguments

U	3 by 3 matrix

Details

The fuction eigen does not always produce a right-handed eigenvector matrix. The code tests each cross product to see if it creates a right-hand system.

Value

logical vector

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

forcerighthand

Examples

```
Mtens <- c(-0.412, 0.084, 0.328 ,0.398, -1.239, 1.058)

M1 <-  matrix(c(Mtens[1], Mtens[4], Mtens[5], Mtens[4],
Mtens[2], Mtens[6], Mtens[5],Mtens[6],
Mtens[3]), ncol=3, nrow=3, byrow=TRUE)

E1 <-  eigen(M1)
testrightHAND(E1$vectors)
```

`thrust.fault` *Thrust Fault Cartoon*

Description

Illustrate a thrust fault using animation

Usage

```
thrust.fault(anim = seq(from = 0, to = 1, by = 0.1), KAPPA = 2,
             Light = c(45, 45))
```

Arguments

`anim`	animation vector
`KAPPA`	Phong parameter for lighting
`Light`	lighting point

Details

Program will animate a thrust fault for educational purposes. Animation must be stopped by halting execution.

Value

Graphical Side effects

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

strikeslip.fault, thrust.fault

Examples

```
thrust.fault(anim=0, KAPPA=4, Light=c(-20, 80))

if(interactive()){
#### execute a stop command to stop this animation
anim= seq(from=0, to=1, by=.1)
thrust.fault(anim=anim, KAPPA=4, Light=c(-20, 80))
}
```

---

tk2uv *Tk2uv*

Description

Tk plot to u-v coordinate transformation

Usage

```
tk2uv(T, k)
```

Arguments

T	T-value
k	k-value

Details

T and k come from moment tensor analysis.

Value

List: u and v

Author(s)

Keehoon Kim<keehoon@live.unc.edu> Jonathan M. Lees<jonathan.lees@unc.edu>

References

Hudson

See Also

m2tk, hudson.net, hudson.plot

Examples

```
v = c(2,-1,-1)
m = m2tk(v)
tk2uv(m$T, m$k)
```

`to.spherical` *Convert Cartesian to Spherical*

Description

Convert cartesian coordinates to strike and dip

Usage

```
to.spherical(x, y, z)
```

Arguments

`x`	x-coordinate
`y`	y-coordinate
`z`	z-coordinate

Value

LIST

`az`	angle, degrees
`dip`	angle, degrees
`x`	x-coordinate
`y`	y-coordinate
`z`	z-coordinate

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

SDRfoc

Examples

```
to.spherical(3, 4, 5)
```

TOCART.DIP *Convert to Cartesian*

Description

Convert azimuth and dip to cartesian coordinates

Usage

```
TOCART.DIP(az, dip)
```

Arguments

az	azimuth, degrees
dip	dip, degrees

Value

LIST

x	x-coordinate
y	y-coordinate
z	z-coordinate
az	azimuth, degrees
dip	dip, degrees

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

to.spherical

Examples

```
TOCART.DIP(134, 32)
```

tocartL *Convert to cartesian coordinate*

Description

Convert azimuth-dip to cartesian coordinates with list as argument

Usage

```
tocartL(A)
```

Arguments

A	**az** degrees, azimuth **dip** degrees, dip

Value

List

x	x-coordinate
y	y-coordinate
z	z-coordinate

Note

x positive north, y positive east, z positive downward

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

TOCART.DIP, RSEIS::TOCART, tosphereL, to.spherical

Examples

```
A = list(az=23, dip=84)
tocartL(A)
```

`TOSPHERE` *Convert to Spherical Coordinates*

Description

Get Azimuth and Dip from Cartesian vector on a sphere.

Usage

```
TOSPHERE(x, y, z)
```

Arguments

`x`	x-coordinate
`y`	y-coordinate
`z`	z-coordinate

Value

`az`	azimuth angle, degrees
`dip`	dip, degrees

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

TOSPHERE.DIP, tosphereL, to.spherical

Examples

```
TOSPHERE(3, 4, 5)
```

TOSPHERE.DIP *convert to spherical coordinates*

Description

convert to spherical coordinates

Usage

```
TOSPHERE.DIP(x, y, z)
```

Arguments

x	x-coordinate
y	y-coordinate
z	z-coordinate

Details

takes three components and returns azimuth and dip

Value

List

az	azimuth, degrees
dip	Dip, degrees
x	x-coordinate
y	y-coordinate
z	z-coordinate

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

to.spherical

Examples

```
TOSPHERE.DIP(3, 4, 5)
```

tosphereL *convert to spherical coordinates*

Description

convert to spherical coordinates

Usage

```
tosphereL(A)
```

Arguments

A	list (x,y,z)

Details

takes list of three components and returns azimuth and dip

Value

List

az	azimuth, degrees
dip	Dip, degrees
x	x-coordinate
y	y-coordinate
z	z-coordinate

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

TOSPHERE

Examples

```
A = list(x=12 ,y=2, z=-3 )
tosphereL(A)
```

TP2XYZ *Trend - Dip to XYZ*

Description

Convert trend and dip to cartesian coordinates.

Usage

```
TP2XYZ(trend, dip)
```

Arguments

trend	trend angle, degrees
dip	dip angle, degrees

Details

These are used as functions auxiallry to rotateFoc.

Value

vector: x, y, z

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

See Also

RotTP

Examples

```
TP2XYZ(34, 40)
```

TRANmat *Translation Matrix*

Description

Create a 4 by 4 translation matrix

Usage

```
TRANmat(x, y, z)
```

Arguments

x	x-translation
y	y-translation
z	z-translation

Value

Matrix suitaqble for translating a 3D body.

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

References

Rogers and Adams, 1990, Mathematical Elements for Computer Graphics, McGraw-Hill, 611p.

See Also

ROTX, ROTZ, ROTY

Examples

```
zT = TRANmat(5, 4, 2)
```

Vmoments *Cartesian Moment Tensors*

Description

Cartesian Moment Tensors from Varvryuk

Usage

```
data(Vmoments)
```

Format

A list of 9 moment tensors from Vaclav Varvryuk

Source

http://www.ig.cas.cz/en/research-&-teaching/software-download/

References

http://www.ig.cas.cz/en/research-&-teaching/software-download/

widdenMoments *Cartesian Moment Tensors*

Description

Cartesian Moment Tensors from Widden Paper in Utah

Usage

```
data(widdenMoments)
```

Format

A list of 48 moment tensors from Utah

Source

SRL paper

References

Seismological Research Letters

Wnet *Wulff Stereonet*

Description

plot a Wulff Stereonet (Equal-Angle)

Usage

```
Wnet(add = FALSE, col = gray(0.7), border = "black", lwd = 1)
```

Arguments

add	Logical, TRUE=add to existing plot
col	color
border	border color
lwd	line width

Details

Plots equal-angle stereonet as opposed to equal-area.

Value

graphical side effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

net, pnet

Examples

```
Wnet()
```

Wpoint *Plot points on Wulff Stereonet*

Description

Adds points to Wulff Equal-Angle Stereonet

Usage

```
Wpoint(az1, dip1, col = 2, pch = 5, lab = "", UP = FALSE)
```

Arguments

az1	azimuth angle, degrees
dip1	dip angle, degrees
col	color
pch	plotting character
lab	label for point
UP	logical, TRUE=Upperhemisphere

Details

Wulff net point is added to existing plot.

Value

graphical side effects

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

Wnet

Examples

```
Wnet()
Wpoint(23, 34)
```

xsecmanyfoc	*Plot Focal Mechs at X-Y position on cross sections*

Description

Plot Focal Mechs at X-Y positions on cross sectionsor other plots that do not have geographic coordinates and projection.

Usage

```
xsecmanyfoc(MEK,  theta=NULL, focsiz = 0.5,
 foccol = NULL, UP=TRUE, focstyle=1, LEG = FALSE, DOBAR = FALSE)
```

Arguments

MEK	List of Focal Mechanisms, see details
focsiz	focal size, inches
theta	degrees, angle from north for projecting the focal mechs
foccol	focal color, default is to calculate based on rake
UP	logical, UP=TRUE means plot upper hemisphere (DEFAULT=TRUE)
focstyle	integer, 1=beach ball, 2=nipplot
LEG	logical, TRUE= add focal legend for color codes
DOBAR	add strike dip bar at epicenter

Details

Input MEK list contains

MEKS = list(lon=0, lat=0, str1=0, dip1=0, rake1=0, dep=0, name="", Elat=0, Elon=0, x=0, y=0)

The x, y coordinates of the input list are location where the focals will be plotted. For cross sections x=distance along the section and y would be depth. The focal mechs are added to the current plot.

Value

Graphical Side Effects

Note

If theta is NULL focals are plotted as if they were on a plan view. If theta is provided, however, the mechs are plotted with view from the vertical cross section. The cross section is taken at two points. Theta should be determined by viewing the cross section with the first point on the left and the second on the right. The view angle is through the section measured in degrees from north.

Author(s)

Jonathan M. Lees<jonathan.lees@unc.edu>

References

Lees, J. M., Geotouch: Software for Three and Four Dimensional GIS in the Earth Sciences, Computers & Geosciences, 26, 7, 751-761, 2000.

See Also

justfocXY, plotmanyfoc

Examples

```
############# create and  plot the mechs in plan view:
N = 20
lon=runif(20, 235, 243)
     lat=runif(20, 45.4, 49)
     str1=runif(20,50,100)
     dip1=runif(20,10, 80)
     rake1=runif(20,5, 180)

     dep=runif(20,1,15)
     name=seq(from=1, to=length(lon), by=1)
     Elat=NULL
     Elon=NULL
yr = rep(2017, times=N)
jd = runif(N, min=1, max=365)

      MEKS = list(lon=lon, lat=lat, str1=str1, dip1=dip1,
 rake1=rake1, dep=dep, name=name, yr=yr, jd = jd)

     PROJ = GEOmap::setPROJ(type=2, LAT0=mean(lat) , LON0=mean(lon) )   ##   utm

     XY = GEOmap::GLOB.XY(lat, lon, PROJ)

     plot(range(XY$x), range(XY$y), type='n', asp=1)

     plotmanyfoc(MEKS, PROJ, focsiz=0.5)

ex = range(XY$x)
why = range(XY$y)


JJ = list(x=ex, y=why)


SWA = GEOmap::eqswath(XY$x, XY$y, MEKS$dep, JJ, width = diff(why) , PROJ = PROJ)


MEKS$x = rep(NA, length(XY$x))
MEKS$y = rep(NA, length(XY$y))


MEKS$x[SWA$flag] = SWA$r
MEKS$y[SWA$flag] = -SWA$depth
```

```
bigR = sqrt(  (JJ$x[2]-JJ$x[1])^2 + (JJ$y[2]-JJ$y[1])^2)

plot(c(0,bigR)   , c(0, min(-SWA$depth)) , type='n',
 xlab="Distance, KM", ylab="Depth")
points(SWA$r, -SWA$depth)

xsecmanyfoc(MEKS, focsiz=0.5,  LEG = TRUE, DOBAR=FALSE)
title("cross section: focals are plotted as if in plan view")


ang1 = atan2( JJ$y[2]-JJ$y[1] , JJ$x[2]-JJ$x[1])

 degang =  ang1*180/pi


xsecmanyfoc(MEKS, focsiz=0.5, theta=degang, LEG = TRUE, DOBAR=FALSE)
title("cross section: focals are view from the side projection (outer hemisphere)")
```

Z3Darrow *Make a 3D arrow*

Description

Create the list structure for a 3D arrow.

Usage

```
Z3Darrow(len = 1, basethick = 0.1, headlen = 0.6, headlip = 0.1)
```

Arguments

`len`	Length in user coordinates
`basethick`	Thickness of the base
`headlen`	Length of the head
`headlip`	Width of the overhang lip

Details

Creates a strucutre suitable for plotting rotated and translated 3D arrows.

Value

List

`aglyph`	List of vertices of the faces
`anorm`	Outward facing normal vectors to faces

Author(s)

Jonathan M. Lees <jonathan.lees@unc.edu>

See Also

PROJ3D, pglyph3D, phong3D

Examples

```
ZA = Z3Darrow(len = 1, basethick = 0.1, headlen = 0.6, headlip = 0.1)
```

Index