Package ‘geosphere’

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Type Package

Title Spherical Trigonometry

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Suggests methods, raster

Description Spherical trigonometry for geographic applications. That is, compute distances and related measures for angular (longitude/latitude) locations.

License GPL (>= 3)

LazyLoad yes

NeedsCompilation yes

Author Robert J. Hijmans [cre, aut],
Ed Williams [ctb],
Chris Vennes [ctb]

Maintainer Robert J. Hijmans <r.hijmans@gmail.com>

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R topics documented:

`geosphere-package` *Geosphere*

Description

This package implements functions that compute various aspects of distance, direction, area, etc. for geographic (geodetic) coordinates. Some of the functions are based on an ellipsoid (spheroid) model of the world, other functions use a (simpler, but less accuarate) spherical model. Functions using an ellipsoid can be recognized by having arguments to specify the ellipsoid's radius and flattening (`a` and `f`). By setting the value for `f` to zero, the ellipsoid becomes a sphere.

There are also functions to compute intersections of of rhumb lines. There are also functions to compute the distance between points and polylines, and to characterize spherical polygons; for random sampling on a sphere, and to compute daylength. See the vignette `vignette('geosphere')` for examples.

Geographic locations must be specified in latitude and longitude in degrees (NOT radians). Degrees are (obviously) in decimal notation. Thus 12 degrees, 30 minutes, 10 seconds = 12 + 30/60 + 10/3600 = 12.50278 degrees. The Southern and Western hemispheres have a negative sign.

The default unit of distance is meter; but this can be adjusted by supplying a different radius `r` to functions.

Directions are expressed in degrees (North = 0 and 360, East = 90, Sout = 180, and West = 270 degrees).

Acknowledgements

David Purdy, Bill Monahan and others for suggestions to improve the package.

Author(s)

Robert Hijmans, using code by C.F.F. Karney and Chris Veness; formulas by Ed Williams; and with contributions from George Wang, Elias Pipping and others. Maintainer: Robert J. Hijmans <r.hijmans@gmail.com>

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

http://williams.best.vwh.net/avform.htm

http://www.movable-type.co.uk/scripts/latlong.html

http://en.wikipedia.org/wiki/Great_circle_distance

http://mathworld.wolfram.com/SphericalTrigonometry.html

`alongTrackDistance` *Along Track Distance*

Description

The "along track distance" is the distance from the start point (p1) to the closest point on the path to a third point (p3), following a great circle path defined by points p1 and p2. See `dist2gc` for the "cross track distance"

Usage

```
alongTrackDistance(p1, p2, p3, r=6378137)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`p3`	as above
`r`	radius of the earth; default = 6378137m

Value

A distance in units of r (default is meters)

Author(s)

Ed Williams and Robert Hijmans

See Also

`dist2gc`

Examples

```
alongTrackDistance(c(0,0),c(60,60),c(50,40))
```

`antipode` *Antipodes*

Description

Compute an antipode, or check whether two points are antipodes. Antipodes are places on Earth that are diametrically opposite to one another; and could be connected by a straight line through the centre of the Earth.

Antipodal points are connected by an infinite number of great circles (e.g. the meridians connecting the poles), and can therefore not be used in some great circle based computations.

Usage

```
antipode(p)
antipodal(p1, p2, tol=1e-9)
```

Arguments

`p`	Longitude/latitude of a single point, in degrees; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p1`	as above
`p2`	as above
`tol`	tolerance for equality

Value

antipodal points or a logical value (TRUE if antipodal)

Author(s)

Robert Hijmans

References

http://en.wikipedia.org/wiki/Antipodes

Examples

```
antipode(rbind(c(5,52), c(-120,37), c(-60,0), c(0,70)))
antipodal(c(0,0), c(180,0))
```

---

areaPolygon — *Area of a longitude/latitude polygon*

Description

Compute the area of a polygon in angular coordinates (longitude/latitude) on an ellipsoid.

Usage

```
## S4 method for signature 'matrix'
areaPolygon(x, a=6378137, f=1/298.257223563, ...)

## S4 method for signature 'SpatialPolygons'
areaPolygon(x, a=6378137, f=1/298.257223563, ...)
```

Arguments

x	longitude/latitude of the points forming a polygon; Must be a matrix or data.frame of 2 columns (first one is longitude, second is latitude) or a SpatialPolygons* object
a	major (equatorial) radius of the ellipsoid
f	ellipsoid flattening. The default value is for WGS84
...	Additional arguments. None implemented

Value

area in square meters

Note

Use raster::area for polygons that have a planar (projected) coordinate reference system.

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

See Also

centroid, perimeter

Examples

```
p <- rbind(c(-180,-20), c(-140,55), c(10, 0), c(-140,-60), c(-180,-20))
areaPolygon(p)

# Be careful with very large polygons, as they may not be what they seem!
# For example, if you wanted a polygon to compute the area equal to about 1/4 of the ellipsoid
# this won't work:
b <- matrix(c(-180, 0, 90, 90, 0, 0, -180, 0), ncol=2, byrow=TRUE)
areaPolygon(b)
# Becausee the shortest path between (-180,0) and (0,0) is
# over one of the poles, not along the equator!
# Inserting a point along the equator fixes that
b <- matrix(c(-180, 0, 0, 0, -90,0, -180, 0), ncol=2, byrow=TRUE)
areaPolygon(b)
```

---

bearing *Direction of travel*

Description

Get the initial bearing (direction; azimuth) to go from point p1 to point p2 (in longitude/latitude) following the shortest path on an ellipsoid (geodetic). Note that the bearing of travel changes continuously while going along the path. A route with constant bearing is a rhumb line (see bearingRhumb).

Usage

```
bearing(p1, p2, a=6378137, f=1/298.257223563)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`a`	major (equatorial) radius of the ellipsoid. The default value is for WGS84
`f`	ellipsoid flattening. The default value is for WGS84

Value

Bearing in degrees

Note

use `f=0` to get a bearing on a sphere (great circle)

Author(s)

Robert Hijmans

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. `https://dx.doi.org/10.1007/s00190-012-0578-z`. Addenda: `http://geographiclib.sf.net/geod-addenda.html`. Also see `http://geographiclib.sourceforge.net/`

See Also

`bearingRhumb`

Examples

```
bearing(c(10,10),c(20,20))
```

`bearingRhumb` *Rhumbline direction*

Description

Bearing (direction of travel; true course) along a rhumb line (loxodrome) between two points.

Usage

```
bearingRhumb(p1, p2)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above

Value

A direction (bearing) in degrees

Note

Unlike most great circles, a rhumb line is a line of constant bearing (direction), i.e. tracks of constant true course. The meridians and the equator are both rhumb lines and great circles. Rhumb lines approaching a pole become a tightly wound spiral.

Author(s)

Chris Veness and Robert Hijmans, based on formulae by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Rhumb

http://en.wikipedia.org/wiki/Rhumb_line

See Also

bearing, distRhumb

Examples

```
bearingRhumb(c(10,10),c(20,20))
```

---

centroid *Centroid of spherical polygons*

Description

Compute the centroid of longitude/latitude polygons. Unlike other functions in this package, there is no spherical trigonomery involved in the implementation of this function. Instead, the function projects the polygon to the (conformal) Mercator coordinate reference system, computes the centroid, and then inversely projects it to longitude and latitude. This approach fails for polygons that include one of the poles (and is rather biased for anything close to the poles). The function should work for polygons that cross the -180/180 meridian (date line).

Usage

```
centroid(x, ...)
```

Arguments

`x`	a 2-column matrix (longitude/latitude)
`...`	Additional arguments. None implemented

Value

A matrix (longitude/latitude)

Note

For multi-part polygons, the centroid of the largest part is returned.

Author(s)

Robert J. Hijmans

See Also

`area`, `perimeter`

Examples

```
pol <- rbind(c(-180,-20), c(-160,5), c(-60, 0), c(-160,-60), c(-180,-20))
centroid(pol)
```

`daylength` *Daylength*

Description

Compute daylength (photoperiod) for a latitude and date.

Usage

```
daylength(lat, doy)
```

Arguments

`lat`	latitude, in degrees. I.e. between -90.0 and 90.0
`doy`	Interger, day of the year (1..365) for leap years; or an object of class Date; or a character that can be coerced into a date, using 'yyyy-mm-dd' format, e.g. '1982-11-23'

Value

Daylength in hours

Author(s)

Robert J. Hijmans

References

Forsythe, William C., Edward J. Rykiel Jr., Randal S. Stahl, Hsin-i Wu and Robert M. Schoolfield, 1995. A model comparison for daylength as a function of latitude and day of the year. Ecological Modeling 80:87-95.

Examples

```
daylength(-25, '2010-10-10')
daylength(45, 1:365)

# average monthly daylength
dl <- daylength(45, 1:365)
tapply(dl, rep(1:12, c(31,28,31,30,31,30,31,31,30,31,30,31)), mean)
```

---

destPoint *Destination given bearing (direction) and distance*

Description

Given a start point, initial bearing (direction), and distance, this function computes the destination point travelling along a the shortest path on an ellipsoid (the geodesic).

Usage

```
destPoint(p, b, d, a=6378137, f=1/298.257223563, ...)
```

Arguments

`p`	Longitude and Latitude of point(s), in degrees. Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`b`	numeric. Bearing (direction) in degrees
`d`	numeric. Distance in meters
`a`	major (equatorial) radius of the ellipsoid. The default value is for WGS84
`f`	ellipsoid flattening. The default value is for WGS84
`...`	additional arguments. If an argument 'r' is supplied, this is taken as the radius of the earth (e.g. 6378137 m) and computations are for a sphere (great circle) instead of an ellipsoid (geodetic). This is for backwards compatibility only

Value

A pair of coordinates (longitude/latitude)

Note

Direction changes continuously when travelling along a geodesic. Therefore, the final direction is not the same as the initial direction. You can compute the final direction with `finalBearing` (see examples, below)

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

Examples

```
p <- cbind(5,52)
d <- destPoint(p,30,10000)
d

#final direction, when arriving at endpoint:
finalBearing(d, p)
```

`destPointRhumb` *Destination along a rhumb line*

Description

Calculate the destination point when travelling along a 'rhumb line' (loxodrome), given a start point, direction, and distance.

Usage

```
destPointRhumb(p, b, d, r = 6378137)
```

Arguments

`p`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`b`	bearing (direction) in degrees
`d`	distance; in the same unit as `r` (default is meters)
`r`	radius of the earth; default = 6378137 m

Value

Coordinates (longitude/latitude) of a point

Author(s)

Chris Veness; ported to R by Robert Hijmans

References

http://williams.best.vwh.net/avform.htm#Rhumb

http://www.movable-type.co.uk/scripts/latlong.html

http://en.wikipedia.org/wiki/Rhumb_line

See Also

destPoint

Examples

```
destPointRhumb(c(0,0), 30, 100000, r = 6378137)
```

---

dist2gc *Cross Track Distance*

Description

Compute the distance of a point to a great-circle path (also referred to as the cross track distance or cross track error). The great circle is defined by `p1` and `p2`, while `p3` is the point away from the path.

Usage

```
dist2gc(p1, p2, p3, r=6378137)
```

Arguments

`p1`	Start of great circle path. longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	End of great circle path. As above
`p3`	Point away from the great cricle path. As for p2
`r`	radius of the earth; default = 6378137

Value

A distance in units of `r` (default is meters)

The sign indicates which side of the path p3 is on. Positive means right of the course from p1 to p2, negative means left.

Author(s)

Ed Williams and Robert Hijmans

References

http://www.movable-type.co.uk/scripts/latlong.html

http://williams.best.vwh.net/ftp/avsig/avform.txt

See Also

`dist2Line`, `alongTrackDistance`

Examples

```
dist2gc(c(0,0),c(90,90),c(80,80))
```

---

dist2Line *Distance between points and lines or the border of polygons.*

Description

The shortest distance between points and polylines or polygons.

Usage

```
dist2Line(p, line, distfun=distHaversine)
```

Arguments

`p`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`line`	longitude/latitude of line as a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialLines* or SpatialPolygons* object
`distfun`	A distance function, such as distHaversine

Value

matrix with distance and lon/lat of the nearest point on the line. Distance is in the same unit as `r` in the `distfun`(default is meters). If `line` is a `Spatial*` object, the ID (index) of (one of) the nearest objects is also returned. Thus if the objects are polygons and the point is inside a polygon the function may return the ID of a neighboring polygon that shares the nearest border. You can use the `over` functions in packages `sp` or `rgeos` for point-in-polygon queries.

Author(s)

George Wang and Robert Hijmans

See Also

dist2gc, alongTrackDistance

Examples

```
line <- rbind(c(-180,-20), c(-150,-10), c(-140,55), c(10, 0), c(-140,-60))
pnts <- rbind(c(-170,0), c(-75,0), c(-70,-10), c(-80,20), c(-100,-50),
         c(-100,-60), c(-100,-40), c(-100,-20), c(-100,-10), c(-100,0))
d = dist2Line(pnts, line)
plot( makeLine(line), type='l')
points(line)
points(pnts, col='blue', pch=20)
points(d[,2], d[,3], col='red', pch='x')
for (i in 1:nrow(d)) lines(gcIntermediate(pnts[i,], d[i,2:3], 10), lwd=2)
```

---

distCosine *'Law of cosines' great circle distance*

Description

The shortest distance between two points (i.e., the 'great-circle-distance' or 'as the crow flies'), according to the 'law of the cosines'. This method assumes a spherical earth, ignoring ellipsoidal effects.

Usage

```
distCosine(p1, p2, r=6378137)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above
r	radius of the earth; default = 6378137 m

Value

Vector of distances in the same unit as r (default is meters)

Author(s)

Robert Hijmans

References

http://en.wikipedia.org/wiki/Great_circle_distance

See Also

distHaversine, distVincentySphere, distVincentyEllipsoid, distMeeus

Examples

```
distCosine(c(0,0),c(90,90))
```

---

distGeo *Distance on an ellipsoid (the geodesic)*

Description

Highly accurate estimate of the shortest distance between two points on an ellipsoid (default is WGS84 ellipsoid). The shortest path between two points on an ellipsoid is called the geodesic.

Usage

```
distGeo(p1, p2, a=6378137, f=1/298.257223563)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first column is longitude, second column is latitude) or a SpatialPoints* object
p2	as above
a	numeric. Major (equatorial) radius of the ellipsoid. The default value is for WGS84
f	numeric. Ellipsoid flattening. The default value is for WGS84

Details

Parameters from the WGS84 ellipsoid are used by default. It is the best available global ellipsoid, but for some areas other ellipsoids could be preferable, or even necessary if you work with a printed map that refers to that ellipsoid. Here are parameters for some commonly used ellipsoids. Also see the refEllipsoids function.

```
ellipsoid            a              f
WGS84                6378137        1/298.257223563
GRS80                6378137        1/298.257222101
GRS67                6378160        1/298.25
Airy 1830            6377563.396    1/299.3249646
Bessel 1841          6377397.155    1/299.1528434
Clarke 1880          6378249.145    1/293.465
Clarke 1866          6378206.4      1/294.9786982
International 1924   6378388        1/297
Krasovsky 1940       6378245        1/298.2997381
```

more info: http://en.wikipedia.org/wiki/Reference_ellipsoid

Value

Vector of distances in meters

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

See Also

`distCosine`, `distHaversine`, `distVincentySphere`, `distVincentyEllipsoid`, `distMeeus`

Examples

```
distGeo(c(0,0),c(90,90))
```

`distHaversine` *'Haversine' great circle distance*

Description

The shortest distance between two points (i.e., the 'great-circle-distance' or 'as the crow flies'), according to the 'haversine method'. This method assumes a spherical earth, ignoring ellipsoidal effects.

Usage

```
distHaversine(p1, p2, r=6378137)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`r`	radius of the earth; default = 6378137 m

Details

The Haversine ('half-versed-sine') formula was published by R.W. Sinnott in 1984, although it has been known for much longer. At that time computational precision was lower than today (15 digits precision). With current precision, the spherical law of cosines formula appears to give equally good results down to very small distances. If you want greater accuracy, you could use the `distVincentyEllipsoid` method.

Value

Vector of distances in the same unit as `r` (default is meters)

Author(s)

Chris Veness and Robert Hijmans

References

Sinnott, R.W, 1984. Virtues of the Haversine. Sky and Telescope 68(2): 159

http://www.movable-type.co.uk/scripts/latlong.html

http://en.wikipedia.org/wiki/Great_circle_distance

See Also

`distCosine`, `distVincentySphere`, `distVincentyEllipsoid`, `distMeeus`

Examples

```
distHaversine(c(0,0),c(90,90))
```

---

distm *Distance matrix*

Description

Distance matrix of a set of points, or between two sets of points

Usage

```
distm(x, y, fun=distHaversine)
```

Arguments

`x`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`y`	Same as `x`. If missing, y is the same as x
`fun`	A function to compute distances (e.g., distCosine, distHaversine, distVincenty*)

Value

Matrix of distances

Author(s)

Robert Hijmans

References

http://en.wikipedia.org/wiki/Great_circle_distance

See Also

distCosine, distHaversine, distVincentySphere, distVincentyEllipsoid

Examples

```
xy <- rbind(c(0,0),c(90,90),c(10,10),c(-120,-45))
distm(xy)
xy2 <- rbind(c(0,0),c(10,-10))
distm(xy, xy2)
```

---

distMeeus *'Meeus' great circle distance*

Description

The shortest distance between two points on an ellipsoid (the 'geodetic'), according to the 'Meeus' method. distGeo should be more accurate.

Usage

```
distMeeus(p1, p2, a=6378137, f=1/298.257223563)
```

Arguments

p1	longitude/latitude of point(s), in degrees 1; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above
a	numeric. Major (equatorial) radius of the ellipsoid. The default value is for WGS84
f	numeric. Ellipsoid flattening. The default value is for WGS84

Details

Parameters from the WGS84 ellipsoid are used by default. It is the best available global ellipsoid, but for some areas other ellipsoids could be preferable, or even necessary if you work with a printed map that refers to that ellipsoid. Here are parameters for some commonly used ellipsoids:

ellipsoid	a	f
WGS84	6378137	1/298.257223563
GRS80	6378137	1/298.257222101
GRS67	6378160	1/298.25
Airy 1830	6377563.396	1/299.3249646
Bessel 1841	6377397.155	1/299.1528434
Clarke 1880	6378249.145	1/293.465
Clarke 1866	6378206.4	1/294.9786982
International 1924	6378388	1/297
Krasovsky 1940	6378245	1/298.2997381

more info: http://en.wikipedia.org/wiki/Reference_ellipsoid

Value

Distance value in the same units as parameter a of the ellipsoid (default is meters)

Note

This algorithm is also used in the `spDists` function in the sp package

Author(s)

Robert Hijmans, based on a script by Stephen R. Schmitt

References

Meeus, J., 1999 (2nd edition). Astronomical algoritms. Willman-Bell, 477p.

See Also

`distVincentyEllipsoid`, `distVincentySphere`, `distHaversine`, `distCosine`

Examples

```
distMeeus(c(0,0),c(90,90))
# on a 'Clarke 1880' ellipsoid
distMeeus(c(0,0),c(90,90), a=6378249.145, f=1/293.465)
```

`distRhumb` *Distance along a rhumb line*

Description

A rhumb line (loxodrome) is a path of constant bearing (direction), which crosses all meridians at the same angle.

Usage

```
distRhumb(p1, p2, r=6378137)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`r`	radius of the earth; default = 6378137 m

Details

Rhumb (from the Spanish word for course, 'rumbo') lines are straight lines on a Mercator projection map. They were used in navigation because it is easier to follow a constant compass bearing than to continually adjust the bearing as is needed to follow a great circle, even though rhumb lines are normally longer than great-circle (orthodrome) routes. Most rhumb lines will gradually spiral towards one of the poles.

Value

distance in units of r (default=meters)

Author(s)

Robert Hijmans and Chris Veness

References

http://www.movable-type.co.uk/scripts/latlong.html

See Also

`distCosine`, `distHaversine`, `distVincentySphere`, `distVincentyEllipsoid`

Examples

```
distRhumb(c(10,10),c(20,20))
```

distVincentyEllipsoid *'Vincenty' (ellipsoid) great circle distance*

Description

The shortest distance between two points (i.e., the 'great-circle-distance' or 'as the crow flies'), according to the 'Vincenty (ellipsoid)' method. This method uses an ellipsoid and the results are very accurate. The method is computationally more intensive than the other great-circled methods in this package.

Usage

```
distVincentyEllipsoid(p1, p2, a=6378137, b=6356752.3142, f=1/298.257223563)
```

Arguments

`p1`	longitude/latitude of point(s), in degrees 1; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`a`	Equatorial axis of ellipsoid
`b`	Polar axis of ellipsoid
`f`	Inverse flattening of ellipsoid

Details

The WGS84 ellipsoid is used by default. It is the best available global ellipsoid, but for some areas other ellipsoids could be preferable, or even necessary if you work with a printed map that refers to that ellipsoid. Here are parameters for some commonly used ellipsoids:

ellipsoid	a	b	f
WGS84	6378137	6356752.3142	1/298.257223563
GRS80	6378137	6356752.3141	1/298.257222101
GRS67	6378160	6356774.719	1/298.25
Airy 1830	6377563.396	6356256.909	1/299.3249646
Bessel 1841	6377397.155	6356078.965	1/299.1528434
Clarke 1880	6378249.145	6356514.86955	1/293.465
Clarke 1866	6378206.4	6356583.8	1/294.9786982
International 1924	6378388	6356911.946	1/297
Krasovsky 1940	6378245	6356863	1/298.2997381

`a` is the 'semi-major axis', and `b` is the 'semi-minor axis' of the ellipsoid. `f` is the flattening. Note that `f = (a-b)/a`

more info: http://en.wikipedia.org/wiki/Reference_ellipsoid

Value

Distance value in the same units as the ellipsoid (default is meters)

Author(s)

Chris Veness and Robert Hijmans

References

Vincenty, T. 1975. Direct and inverse solutions of geodesics on the ellipsoid with application of nested equations. Survey Review Vol. 23, No. 176, pp88-93. Available here:

http://www.movable-type.co.uk/scripts/latlong-vincenty.html

http://en.wikipedia.org/wiki/Great_circle_distance

See Also

distVincentySphere, distHaversine, distCosine, distMeeus

Examples

```
distVincentyEllipsoid(c(0,0),c(90,90))
# on a 'Clarke 1880' ellipsoid
distVincentyEllipsoid(c(0,0),c(90,90), a=6378249.145, b=6356514.86955, f=1/293.465)
```

---

distVincentySphere *'Vincenty' (sphere) great circle distance*

Description

The shortest distance between two points (i.e., the 'great-circle-distance' or 'as the crow flies'), according to the 'Vincenty (sphere)' method. This method assumes a spherical earth, ignoring ellipsoidal effects and it is less accurate then the `distVicentyEllipsoid` method.

Usage

```
distVincentySphere(p1, p2, r=6378137)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above
r	radius of the earth; default = 6378137 m

Value

Distance value in the same unit as `r` (default is meters)

Author(s)

Robert Hijmans

References

http://en.wikipedia.org/wiki/Great_circle_distance

See Also

distVincentyEllipsoid, distHaversine, distCosine, distMeeus

Examples

```
distVincentySphere(c(0,0),c(90,90))
```

---

finalBearing *Final direction*

Description

Get the final direction (bearing) when arriving at p2 after starting from p1 and following the shortest path on an ellipsoid (following a geodetic) or on a sphere (following a great circle).

Usage

```
finalBearing(p1, p2, a=6378137, f=1/298.257223563, sphere=FALSE)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first column is longitude, second column is latitude) or a SpatialPoints* object
p2	as above
a	major (equatorial) radius of the ellipsoid. The default value is for WGS84
f	ellipsoid flattening. The default value is for WGS84
sphere	logical. If TRUE, the bearing is computed for a sphere, instead of for an ellipsoid

Value

A vector of directions (bearings) in degrees

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. `https://dx.doi.org/10.1007/s00190-012-0578-z`. Addenda: `http://geographiclib.sf.net/geod-addenda.html`. Also see `http://geographiclib.sourceforge.net/`

See Also

`bearing`

Examples

```
bearing(c(10,10),c(20,20))
finalBearing(c(10,10),c(20,20))
```

`gcIntersect` *Intersections of two great circles*

Description

Get the two points where two great cricles cross each other. Great circles are defined by two points on it.

Usage

```
gcIntersect(p1, p2, p3, p4)
```

Arguments

p1	Longitude/latitude of a single point, in degrees; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	As above
p3	As above
p4	As above

Value

two points for each pair of great circles

Author(s)

Robert Hijmans, based on equations by Ed Williams (see reference)

References

`http://williams.best.vwh.net/intersect.htm`

See Also

gcIntersectBearing

Examples

```
p1 <- c(5,52); p2 <- c(-120,37); p3 <- c(-60,0); p4 <- c(0,70)
gcIntersect(p1,p2,p3,p4)
```

---

gcIntersectBearing *Intersections of two great circles*

Description

Get the two points where two great cricles cross each other. In this function, great circles are defined by a points and an initial bearing. In function gcIntersect they are defined by two sets of points.

Usage

```
gcIntersectBearing(p1, brng1, p2, brng2)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
brng1	Bearing from p1
p2	As above. Should have same length as p1, or a single point (or vice versa when p1 is a single point
brng2	Bearing from p2

Value

a matrix with four columns (two points)

Author(s)

Chris Veness and Robert Hijmans based on code by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Intersection

http://www.movable-type.co.uk/scripts/latlong.html

See Also

gcIntersect

Examples

```
gcIntersectBearing(c(10,0), 10, c(-10,0), 10)
```

`gcLat` *Latitude on a Great Circle*

Description

Latitude at which a great circle crosses a longitude

Usage

```
gcLat(p1, p2, lon)
```

Arguments

`p1`	Longitude/latitude of a single point, in degrees; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	As above
`lon`	Longitude

Value

A numeric (latitude)

Author(s)

Robert Hijmans based on a formula by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Int

See Also

`gcLon`, `gcMaxLat`

Examples

```
gcLat(c(5,52), c(-120,37), lon=-120)
```

`gcLon` *Longitude on a Great Circle*

Description

Longitudes at which a great circle crosses a latitude (parallel)

Usage

```
gcLon(p1, p2, lat)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above
`lat`	a latitude

Value

vector of two numbers (longitudes)

Author(s)

Robert Hijmans based on code by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Intersection

See Also

`gcLat`, `gcMaxLat`

Examples

```
gcLon(c(5,52), c(-120,37), 40)
```

`gcMaxLat` *Highest latitude on a great circle*

Description

What is northern most point that will be reached when following a great circle? Computed with Clairaut's formula. The southern most point is the `antipode` of the northern-most point. This does not seem to be very precise; and you could use optimization instead to find this point (see examples)

Usage

```
gcMaxLat(p1, p2)
```

Arguments

`p1`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
`p2`	as above

Value

A matrix with coordinates (longitude/latitude)

Author(s)

Ed Williams, Chris Veness, Robert Hijmans

References

http://williams.best.vwh.net/ftp/avsig/avform.txt

http://www.movable-type.co.uk/scripts/latlong.html

See Also

`gcLat`, `gcLon`

Examples

```
gcMaxLat(c(5,52), c(-120,37))

# Another way to get there:
f <- function(lon){gcLat(c(5,52), c(-120,37), lon)}
optimize(f, interval=c(-180, 180), maximum=TRUE)
```

`geodesic` *geodesic and inverse geodesic problem*

Description

Highly accurate estimate of the 'geodesic problem' (find location and azimuth at arrival when departing from a location, given an direction (azimuth) at departure and distance) and the 'inverse geodesic problem' (find the distance between two points and the azimuth of departure and arrival for the shortest path. Computations are for an ellipsoid (default is WGS84 ellipsoid).

This is a direct implementation of the the GeographicLib code by C.F.F. Karney that is also used in several other functions in this package (for example, in `distGeo` and `areaPolygon`).

Usage

```
geodesic(p, azi, d, a=6378137, f=1/298.257223563, ...)

geodesic_inverse(p1, p2, a=6378137, f=1/298.257223563, ...)
```

Arguments

`p`	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first column is longitude, second column is latitude) or a SpatialPoints* object
`p1`	as above
`p2`	as above
`azi`	numeric. Azimuth of departure in degrees
`d`	numeric. Distance in meters
`a`	numeric. Major (equatorial) radius of the ellipsoid. The default value is for WGS84
`f`	numeric. Ellipsoid flattening. The default value is for WGS84
`...`	additional arguments (none implemented)

Details

Parameters from the WGS84 ellipsoid are used by default. It is the best available global ellipsoid, but for some areas other ellipsoids could be preferable, or even necessary if you work with a printed map that refers to that ellipsoid. Here are parameters for some commonly used ellipsoids.

```
ellipsoid          a              f
WGS84              6378137        1/298.257223563
GRS80              6378137        1/298.257222101
GRS67              6378160        1/298.25
Airy 1830          6377563.396    1/299.3249646
Bessel 1841        6377397.155    1/299.1528434
Clarke 1880        6378249.145    1/293.465
```

```
Clarke 1866            6378206.4      1/294.9786982
International 1924     6378388        1/297
Krasovsky 1940         6378245        1/298.2997381
```

more info: http://en.wikipedia.org/wiki/Reference_ellipsoid

Value

Three column matrix with columns 'longitude', 'latitude', 'azimuth' (geodesic); or 'distance' (in meters), 'azimuth1' (of departure), 'azimuth2' (of arrival) (geodesic_inverse)

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

See Also

distGeo

Examples

```
geodesic(cbind(0,0), 30, 1000000)
geodesic_inverse(cbind(0,0), cbind(90,90))
```

---

geomean *Mean location of sperhical coordinates*

Description

mean location for spherical (longitude/latitude) coordinates that deals with the angularity. I.e., the mean of longitudes -179 and 178 is 179.5

Usage

```
geomean(xy, w)
```

Arguments

xy	matrix with two columns (longitude/latitude), or a SpatialPoints or SpatialPolygons object with a longitude/latitude CRS
w	weights (vector of numeric values, with a length that is equal to the number of spatial features in x

Value

Ccoordinate pair (numeric)

Author(s)

Robert J. Hijmans

Examples

```
xy <- cbind(x=c(-179,179, 177), y=c(12,14,16))
xy
geomean(xy)
```

---

greatCircle *Great circle*

Description

Get points on a great circle as defined by the shortest distance between two specified points

Usage

```
greatCircle(p1, p2, n=360, sp=FALSE)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above
n	The requested number of points on the Great Circle
sp	Logical. Return a SpatialLines object?

Value

A matrix of points, or a list of such matrices (e.g., if multiple bearings are supplied)

Author(s)

Robert Hijmans, based on a formula provided by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Int

Examples

```
greatCircle(c(5,52), c(-120,37), n=36)
```

greatCircleBearing *Great circle*

Description

Get points on a great circle as defined by a point and an initial bearing

Usage

```
greatCircleBearing(p, brng, n=360)
```

Arguments

p	longitude/latitude of a single point. Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
brng	bearing
n	The requested number of points on the great circle

Value

A matrix of points, or a list of matrices (e.g., if multiple bearings are supplied)

Author(s)

Robert Hijmans based on formulae by Ed Williams

References

http://williams.best.vwh.net/avform.htm#Int

Examples

```
greatCircleBearing(c(5,52), 45, n=12)
```

horizon *Distance to the horizon*

Description

Empirical function to compute the distance to the horizon from a given altitude. The earth is assumed to be smooth, i.e. mountains and other obstacles are ignored.

Usage

```
horizon(h, r=6378137)
```

Arguments

h	altitude, numeric >= 0. Should have the same unit as r
r	radius of the earth; default value is 6378137 m

Value

Distance in units of h (default is meters)

Author(s)

Robert J. Hijmans

References

http://williams.best.vwh.net/avform.htm#Horizon

Bowditch, 1995. American Practical Navigator. Table 12.

Examples

```
horizon(1.80) # me
horizon(324)  # Eiffel tower
```

---

intermediate *Intermediate points on a great circle (sphere)*

Description

Get intermediate points (way points) between the two locations with longitude/latitude coordinates. gcIntermediate is based on a spherical model of the earth and internally uses distCosine.

Usage

```
gcIntermediate(p1, p2, n=50, breakAtDateLine=FALSE, addStartEnd=FALSE, sp=FALSE, sepNA)
```

Arguments

p1	longitude/latitude of a single point, in degrees. This can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as for p1
n	integer. The desired number of intermediate points
breakAtDateLine	logical. Return two matrices if the dateline is crossed?
addStartEnd	logical. Add p1 and p2 to the result?
sp	logical. Return a SpatialLines object?
sepNA	logical. Rather than as a list, return the values as a two column matrix with lines seperated by a row of NA values? (for use in 'plot')

Value

matrix or list with intermediate points

Author(s)

Robert Hijmans based on code by Ed Williams (great circle)

References

http://williams.best.vwh.net/avform.htm#Intermediate

Examples

```
gcIntermediate(c(5,52), c(-120,37), n=6, addStartEnd=TRUE)
```

---

makePoly — *Add vertices to a polygon or line*

Description

Make a polygon or line by adding intermedate points (vertices) on the great circles inbetween the points supplied. This can be relevant when vertices are relatively far apart. It can make the shape of the object to be accurate, when plotted on a plane. `makePoly` will also close the polygon if needed.

Usage

```
makePoly(p, interval=10000, r=6378137, sp=FALSE)
makeLine(p, interval=10000, r=6378137, sp=FALSE)
```

Arguments

`p`	a 2-column matrix (longitude/latitude) or a SpatialPolygons or SpatialLines object
`interval`	maximum interval of points, in units of r
`r`	radius of the earth; default = 6378137
`sp`	Logical. If `TRUE`, a SpatialPolygons object is retunred (depends on the 'sp' package)

Value

A matrix

Author(s)

Robert J. Hijmans

Examples

```
pol <- rbind(c(-180,-20), c(-160,5), c(-60, 0), c(-160,-60), c(-180,-20))
plot(pol)
lines(pol, col='red', lwd=3)
pol2 = makePoly(pol, interval=100000)
lines(pol2, col='blue', lwd=2)
```

---

mercator *Mercator projection*

Description

Transform longitude/latiude points to the Mercator projection. The main purpose of this function is to compute centroids, and to illustrate rhumb lines in the vignette.

Usage

```
mercator(p, inverse=FALSE, r=6378137)
```

Arguments

p	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
inverse	Logical. If TRUE, do the inverse projection (from Mercator to longitude/latitude
r	Numeric. Radius of the earth; default = 6378137 m

Value

matrix

Author(s)

Robert Hijmans

Examples

```
a = mercator(c(5,52))
a
mercator(a, inverse=TRUE)
```

midPoint *Mid-point*

Description

Find the point half-way between two points along an ellipsoid

Usage

```
midPoint(p1, p2, a=6378137, f = 1/298.257223563)
```

Arguments

p1	longitude/latitude of point(s). Can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	As above
a	major (equatorial) radius of the ellipsoid
f	ellipsoid flattening. The default value is for WGS84

Value

matrix with coordinate pairs

Author(s)

Elias Pipping and Robert Hijmans

Examples

```
midPoint(c(0,0),c(90,90))
midPoint(c(0,0),c(90,90), f=0)
```

onGreatCircle *Is a point on a given great circle?*

Description

Test if a point is on a great circle defined by two other points.

Usage

```
onGreatCircle(p1, p2, p3, tol=0.0001)
```

Arguments

p1	Longitude/latitude of the first point defining a great circle, in degrees; can be a vector of two numbers, a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPoints* object
p2	as above for the second point
p3	the point(s) to be tested if they are on the great circle or not
tol	numeric. maximum distance from the great circle (in degrees) that is tolerated to be considered on the circle

Value

logical

Author(s)

Robert Hijmans

Examples

```
onGreatCircle(c(0,0), c(30,30), rbind(c(-10 -11.33812), c(10,20)))
```

---

perimeter — *Compute the perimeter of a longitude/latitude polygon*

Description

Compute the perimeter of a polygon (or the length of a line) with longitude/latitude coordinates, on an ellipsoid (WGS84 by default)

Usage

```
## S4 method for signature 'matrix'
perimeter(x, a=6378137, f=1/298.257223563, ...)

## S4 method for signature 'SpatialPolygons'
perimeter(x, a=6378137, f=1/298.257223563, ...)

## S4 method for signature 'SpatialLines'
perimeter(x, a=6378137, f=1/298.257223563, ...)
```

Arguments

x	Longitude/latitude of the points forming a polygon or line; Must be a matrix of 2 columns (first one is longitude, second is latitude) or a SpatialPolygons* or SpatialLines* object
a	major (equatorial) radius of the ellipsoid. The default value is for WGS84
f	ellipsoid flattening. The default value is for WGS84
...	Additional arguments. None implemented

Value

Numeric. The perimeter or length in m.

Author(s)

This function calls GeographicLib code by C.F.F. Karney

References

C.F.F. Karney, 2013. Algorithms for geodesics, J. Geodesy 87: 43-55. https://dx.doi.org/10.1007/s00190-012-0578-z. Addenda: http://geographiclib.sf.net/geod-addenda.html. Also see http://geographiclib.sourceforge.net/

See Also

areaPolygon, centroid

Examples

```
xy <- rbind(c(-180,-20), c(-140,55), c(10, 0), c(-140,-60), c(-180,-20))
perimeter(xy)
```

---

plotArrows *Plot*

Description

Plot polygons with arrow heads on each line segment, pointing towards the next vertex. This shows the direction of each line segment.

Usage

```
plotArrows(p, fraction=0.9, length=0.15, first='', add=FALSE, ...)
```

Arguments

p	Polygons (either a 2 column matrix or data.frame; or a SpatialPolygons* object
fraction	numeric between 0 and 1. When smaller then 1, interrupted lines are drawn
length	length of the edges of the arrow head (in inches)
first	Character to plot on first (and last) vertex
add	Logical. If TRUE, the plot is added to an existing plot
...	Additional arguments, see Details

Note

Based on an example in Software for Data Analysis by John Chambers (pp 250-251) but adjusted such that the line segments follow great circles between vertices.

Author(s)

Robert J. Hijmans

Examples

```
pol <- rbind(c(-180,-20), c(-160,5), c(-60, 0), c(-160,-60), c(-180,-20))
plotArrows(pol)
```

---

randomCoordinates *Random or regularly distributed coordinates on the globe*

Description

randomCoordinates returns a 'uniform random sample' in the sense that the probability that a point is drawn from any region is equal to the area of that region divided by the area of the entire sphere. This would not happen if you took a random uniform sample of longitude and latitude, as the sample would be biased towards the poles.

regularCoordiaates returns a set of coordinates that are regularly distributed on the globe.

Usage

```
randomCoordinates(n)
regularCoordinates(N)
```

Arguments

n	Sample size (number of points (coordinate pairs))
N	Number of 'parts' in which the earth is subdived)

Value

Matrix of lon/lat coordiantes

Author(s)

Robert Hijmans, based on code by Nils Haeck (regularCoordinates), http://mathforum.org/kb/message.jspa?messageID=3985660&tstart=0

and suggstions by Michael Orion (randomCoordinates), http://sci.tech-archive.net/Archive/sci.math/2005-09/msg04691.html

Examples

```
randomCoordinates(3)
regularCoordinates(1)
```

`refEllipsoids` *Reference ellipsoids*

Description

This function returns a data.frame with parameters `a` (semi-major axis) and `1/f` (inverse flattening) for a set of reference ellipsoids.

Usage

```
refEllipsoids()
```

Value

data.frame

Note

To compute parameter `b` you can do

Author(s)

Robert J. Hijmans

See Also

`area`, `perimeter`

Examples

```
e <- refEllipsoids()
e[e$code=='WE', ]

#to compute semi-minor axis b:
e$b <- e$a - e$a / e$invf
```

`span` *Span of polygons*

Description

Compute the approximate surface span of polygons in longitude and latitude direction. Span is computed by rasterizing the polygons; and precision increases with the number of 'scan lines'. You can either use a fixed number of scan lines for each polygon, or a fixed band-width.

Usage

```
span(x, ...)
```

Arguments

`x`	a SpatialPolygons* object or a 2-column matrix (longitude/latitude)
`...`	Additional arguments, see Details

Details

The following additional arguments can be passed, to replace default values for this function

`nbands`	Character. Method to determine the number of bands to 'scan' the polygon. Either 'fixed' or 'variable'
`n`	Integer >= 1. If `nbands='fixed'`, how many bands should be used
`res`	Numeric. If `nbands='variable'`, what should the bandwidth be (in degrees)?
`fun`	Logical. A function such as mean or min. Mean computes the average span
`r`	Numeric. Radius of the earth; default=6378137m

Value

A list, or a matrix if a function `fun` is specified. Values are in the units of `r` (default is meter)

Author(s)

Robert J. Hijmans

Examples

```
pol <- rbind(c(-180,-20), c(-160,5), c(-60, 0), c(-160,-60), c(-180,-20))
plot(pol)
lines(pol)
# lon and lat span in m
span(pol, fun=max)
x <- span(pol)
max(x$latspan)
mean(x$latspan)
plot(x$longitude, x$lonspan)
```

`wrld` *World countries*

Description

world coastline and country outlines in longitude/latitude (wrld) and in Mercator projection (merc).

Usage

```
data(wrld)
data(merc)
```

Source

Derived from the wrld_simpl data set in package maptools

Index