Package 'TCHazaRds'

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Type Package

Title Tropical Cyclone (Hurricane, Typhoon) Spatial Hazard Modelling

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Maintainer Julian O'Grady <julian.ogrady@csiro.au>

Description Methods for generating modelled parametric Tropical Cyclone (TC) spatial hazard fields and time series output at point locations from TC tracks. R's compatibility to simply use fast 'cpp' code via the 'Rcpp' package and the wide range spatial analysis tools via the 'terra' package makes it an attractive open source environment to study 'TCs'. This package estimates TC vortex wind and pressure fields using parametric equations originally coded up in 'python' by 'TCRM' <https://github.com/GeoscienceAustralia/tcrm> and then coded up in 'Cuda' 'cpp' by 'TCwindgen' <https://github.com/CyprienBosserelle/TCwindgen>.

URL https://github.com/AusClimateService/TCHazaRds

License GPL (>= 3)

Imports Rcpp (>= 1.0.7), terra, utils, stats, geosphere, ncdf4, methods, sp, rasterVis, raster, latticeExtra

LinkingTo Rcpp

RoxygenNote 7.2.3

Encoding UTF-8

Suggests testthat (>= 3.0.0), knitr, rmarkdown

VignetteBuilder knitr

Config/testthat/edition 3

NeedsCompilation yes

Author Julian O'Grady [aut, cre] (<https://orcid.org/0000-0003-3552-9193>)

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R topics documented:

`beta_modelsR` *Compute the Exponential TC beta Profile-Curvature Parameter*

Description

Compute the Exponential TC beta Profile-Curvature Parameter

Usage

```
beta_modelsR(betaModel, vMax, rMax, cPs, eP, vFms, TClats, dPdt, rho = 1.15)
```

Arguments

`betaModel`	0=Holland (2008),1=Powell (2005),2=Willoughby & Rahn (2004),3=Vickery & Wadhera (2008),4=Hubbert (1991)
`vMax`	maximum wind speed m/s. see `vMax_modelsR`
`rMax`	radius of maximum winds (km). see `rMax_modelsR`
`cPs`	Tropical cyclone central pressure (hPa)
`eP`	Background environmental pressure (hPa)
`vFms`	Forward speed of the storm m/s
`TClats`	Tropical cyclone central latitude
`dPdt`	rate of change in central pressure over time, hPa per hour from Holland 2008
`rho`	density of air

Value

exponential beta parameter

Examples

```
beta_modelsR(0,10,10,960,1013,3,-15,1)
```

`inlandWindDecay` *Reduce Winds Overland*

Description

Reduce Winds Overland

Usage

```
inlandWindDecay(d, a = c(0.66, 1, 0.4))
```

Arguments

`d`	inland distance in km
`a`	three parameter of decay model a1,a2,a3

Value

a reduction factor Km

Examples

```
inlandWindDecay(10)
```

`land_geometry` *Calculate the Geometric Parameters for Terrestrial Wind*

Description

Returns geometric data to compute wind fields.

Usage

```
land_geometry(dem, inland_proximity, returnpoints = FALSE)
```

Arguments

`dem`	SpatRaster object, digital elevation model
`inland_proximity`	SpatRaster object, distance from the coast inland
`returnpoints`	Return SpatVector of points or SpatRaster

Value

SpatVector with attributes or SpatRaster

Abbreviated attribute	description	units
dem	Digital Elevation Model	m
lat	Latitude	degs
lon	Longitude	degs
slope	slope of terrain	-
aspect	DEM aspect	-
inlandD	distance inland from coast	m
f	Coriolis parameter	hz

Examples

```
require(terra)
dem <- rast(system.file("extdata/DEMs/YASI_dem.tif", package="TCHazaRds"))
land <- dem; land[land > 0] = 0
inland_proximity = distance(land,target = 0)
GEO_land = land_geometry(dem,inland_proximity)
plot(GEO_land)
```

`returnBearing` *Return the Bearing for Line Segments*

Description

Return the Bearing for Line Segments

Usage

```
returnBearing(x)
```

Arguments

x	spatial vector with line segments (two connected points)

Value

array of bearings see geosphere::bearing, i.e the Forward direction of the storm geographic bearing, positive clockwise from true north

Examples

```
### IBTRACS HAS the WRONG BEARING!!
require(terra)
northwardTC <- vect(cbind(c(154,154),c(-26.1,-26)),"lines",crs="epsg:4283") #track line segment
easthwardTC <- vect(cbind(c(154,154.1),c(-26,-26)),"lines",crs="epsg:4283") #track line segment
southhwardTC <- vect(cbind(c(154,154),c(-26,-26.1)),"lines",crs="epsg:4283") #track line segment
westwardTC <- vect(cbind(c(154.1,154),c(-26,-26)),"lines",crs="epsg:4283") #track line segment
returnBearing(northwardTC)
returnBearing(easthwardTC)
```

```
returnBearing(southhwardTC)
returnBearing(westwardTC)
```

`rMax_modelsR` *Compute the Tropical Cyclone Radius of Maximum Winds*

Description

Compute the Tropical Cyclone Radius of Maximum Winds

Usage

```
rMax_modelsR(
  rMaxModel,
  TClats,
  cPs,
  eP,
  R175ms = 150,
  dPdt = NULL,
  vFms = NULL,
  rho = 1.15
)
```

Arguments

`rMaxModel`	0=Powell et.al.(2005),1=McInnes et.al.(2014),2=Willoughby & Rahn (2004), 3=Vickery & Wadhera (2008), 4=Takagi & Wu (2016), 5 = Chavas & Knaff (2022)
`TClats`	Tropical cyclone central latitude (nautical degrees)
`cPs`	Tropical cyclone central pressure (hPa)
`eP`	Background environmental pressure (hPa)
`R175ms`	radius of 17.5m/s wind speeds (km)
`dPdt`	rate of change in central pressure over time, hPa per hour from Holland 2008
`vFms`	Forward speed of the storm m/s
`rho`	density of air

Value

radius of maximum winds (km)

Examples

```
rMax_modelsR(0,-14,950,1013,200,0,0,1.15)
```

`TCHazaRdsWindField` *Compute the Wind and Pressure Spatial Hazards Field Associated with TCs Single Time Step.*

Description

Compute the Wind and Pressure Spatial Hazards Field Associated with TCs Single Time Step.

Usage

```
TCHazaRdsWindField(GEO_land, TC, paramsTable)
```

Arguments

`GEO_land`	SpatVector or dataframe hazard geometry generated with land_geometry
`TC`	SpatVector or data.frame of Tropical cyclone track parameters for a single time step.
`paramsTable`	Global parameters to compute TC Hazards.

Value

SpatRaster with the following attributes

abbreviated attribute	description	units
P	Atmospheric pressure	hPa
Uw	Meridional wind speed	m/s
Vw	Zonal wind speed	m/s
Sw	Wind speed	m/s
Dw	The direction from which wind originates	deg clockwise from true north.

Examples

```
require(terra)
dem <- rast(system.file("extdata/DEMs/YASI_dem.tif", package="TCHazaRds"))
land <- dem; land[land > 0] = 0
inland_proximity = distance(land,target = 0)
GEO_land = land_geometry(dem,inland_proximity)

TCi = vect(cbind(c(154,154),c(-26.1,-26)),"lines",crs="epsg:4283") #track line segment
TCi$PRES = 950
TCi$RMW = 40
TCi$ISO_TIME = "2022-10-04 20:00:00"
TCi$LON = geom(TCi)[1,3]
TCi$LAT = geom(TCi)[1,4]
TCi$STORM_SPD = perim(TCi)/(3*3600) #m/s
TCi$thetaFm = 90-returnBearing(TCi)
#OR
```

```
TC <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TC$PRES <- TC$BOM_PRES
TCi = TC[47]
plot(dem);lines(TCi,lwd = 4,col=2)

paramsTable = read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
#calculate the wind hazard
HAZ = TCHazaRdsWindField(GEO_land,TCi,paramsTable)
plot(HAZ)

#require(rasterVis) #pretty spatial vector plot
#ats = seq(0, 80, length=9)
#UV = as(c(HAZ["Uw"],HAZ["Vw"]),"Raster") #need to convert back to raster
#vectorplot(UV, isField='dXY', col.arrows='white', aspX=0.002,aspY=0.002,at=ats ,
#colorkey=list( at=ats), par.settings=viridisTheme)
```

`TCHazaRdsWindFields` *Compute the Wind and Pressure Spatial Hazards Field Associated with TC track.*

Description

Compute the Wind and Pressure Spatial Hazards Field Associated with TC track.

Usage

```
TCHazaRdsWindFields(
  outdate = NULL,
  GEO_land,
  TC,
  paramsTable,
  outfile = NULL,
  overwrite = FALSE
)
```

Arguments

`outdate`	array of POSITx date times to linearly interpolate TC track
`GEO_land`	SpatVector or dataframe hazard geometry generated with land_geometry
`TC`	SpatVector of Tropical cyclone track parameters for a single time step
`paramsTable`	Global parameters to compute TC Hazards
`outfile`	character. Output netcdf filename
`overwrite`	TRUE/FALSE, option to overwrite outfile

Value

SpatRasterDataset with the following attributes.

abbreviated attribute	description	units
P	Atmospheric pressure	hPa
Uw	Meridional wind speed	m/s
Vw	Zonal wind speed	m/s
Sw	Wind speed	m/s
Dw	The direction from which wind originates	deg clockwise from true north

Examples

```
require(terra)
dem <- rast(system.file("extdata/DEMs/YASI_dem.tif", package="TCHazaRds"))
land <- dem; land[land > 0] = 0
inland_proximity = distance(land,target = 0)
GEO_land = land_geometry(dem,inland_proximity)

TCi = vect(cbind(c(154,154),c(-26.1,-26)),"lines",crs="epsg:4283") #track line segment
TCi$PRES = 950
TCi$RMW = 40
TCi$ISO_TIME = "2022-10-04 20:00:00"
TCi$LON = geom(TCi)[1,3]
TCi$LAT = geom(TCi)[1,4]
TCi$STORM_SPD = perim(TCi)/(3*3600) #m/s
TCi$thetaFm = 90-returnBearing(TCi)
#OR
TC <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TC$PRES <- TC$BOM_PRES
plot(dem);lines(TC,lwd = 4,col=2)

paramsTable = read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
#calculate the wind hazard

outdate = seq(strptime(TC$ISO_TIME[44],"%Y-%m-%d %H:%M:%S",tz="UTC"),
              strptime(TC$ISO_TIME[46],"%Y-%m-%d %H:%M:%S",tz="UTC"),
              3600*3)
HAZi = TCHazaRdsWindFields(outdate=outdate,GEO_land=GEO_land,TC=TC,paramsTable=paramsTable)
plot(min(HAZi$Pr))
```

`TCHazaRdsWindProfile` *Compute the Wind and Pressure Spatial Hazards Profile Associated with TCs Single Time Step.*

Description

Compute the Wind and Pressure Spatial Hazards Profile Associated with TCs Single Time Step.

Usage

```
TCHazaRdsWindProfile(GEO_land, TC, paramsTable)
```

Arguments

GEO_land	SpatVector or dataframe hazard geometry generated with land_geometry
TC	SpatVector or data.frame of Tropical cyclone track parameters for a single time step.
paramsTable	Global parameters to compute TC Hazards.

Value

SpatRaster with the following attributes

abbreviated attribute	description	units
P	Atmospheric pressure	hPa
Uw	Meridional wind speed	m/s
Vw	Zonal wind speed	m/s
Sw	Wind speed	m/s
Dw	Wind direction	deg clockwise from true north

Examples

```
require(terra)
dem <- rast(system.file("extdata/DEMs/YASI_dem.tif", package="TCHazaRds"))
land <- dem; land[land > 0] = 0
inland_proximity = distance(land,target = 0)
GEO_land = land_geometry(dem,inland_proximity)

TCi = vect(cbind(c(154,154),c(-26.1,-26)),"lines",crs="epsg:4283") #track line segment
TCi$PRES = 950
TCi$RMW = 40
TCi$ISO_TIME = "2022-10-04 20:00:00"
TCi$LON = geom(TCi)[1,3]
TCi$LAT = geom(TCi)[1,4]
TCi$STORM_SPD = perim(TCi)/(3*3600) #m/s
TCi$thetaFm = 90-returnBearing(TCi)
#OR
TC <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TC$PRES <- TC$BOM_PRES
TCi = TC[47]
TCi$thetaFm = 90-returnBearing(TCi)

#extract a profile/transect at right angles (90 degrees) from the TC heading/bearing direction
pp <- TCProfilePts(TC_line = TCi,bear=TCi$thetaFm+90,length =100,step=1)
#plot(dem);lines(TCi,lwd = 4,col=2)
#points(pp)
GEO_land_v = extract(GEO_land,pp,bind=TRUE,method = "bilinear")

paramsTable = read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
#calculate the wind hazard
HAZ = TCHazaRdsWindProfile(GEO_land_v,TCi,paramsTable)
#plot(HAZ$radialdist,HAZ$Sw,type="l",xlab = "Radial distance [km]",ylab = "Wind speed [m/s]");grid()
```

```
#plot(HAZ,"Sw",type="continuous")
```

`TCHazaRdsWindTimeSereies` *Compute the Wind Hazards Associated Over the Period of a TCs Event at one Given Location*

Description

Compute the Wind Hazards Associated Over the Period of a TCs Event at one Given Location

Usage

```
TCHazaRdsWindTimeSereies(outdate = NULL, GEO_land = NULL, TC, paramsTable)
```

Arguments

`outdate`	array of POSITx date times to linearly interpolate TC track,optional.
`GEO_land`	dataframe hazard geometry generated with land_geometry
`TC`	SpatVector of Tropical cyclone track parameters
`paramsTable`	Global parameters to compute TC Hazards.

Details

The function calculates wind speed and direction time series from a tropical cyclone track using various wind profile models.

Value

list() containing a timeseries

abbreviated attribute	description	units
date	POSIX data time object of TC or outdate if provided	as.POSIX
P	Atmospheric pressure	hPa
Uw	Meridional wind speed	m/s
Vw	Zonal wind speed	m/s
Sw	Wind speed	m/s
R	distance to TC centre	m
rMax	radius of maximum wind	km
vMax	TC maximum velocity	m/s
b	TC wind profile exponent	-
CP	TC central Pressure	hPa
dPdt	change in TC CP per hour	hPa/hr
vFm	velocity of TC forward motion	m/s

Examples

```
GEO_land = data.frame(dem=0,lons = 147,lats=-18,f=-4e-4,inlandD = 0)

require(terra)
TCi <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TCi$PRES <- TCi$BOM_PRES

paramsTable = read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
HAZts = TCHazaRdsWindTimeSereies(GEO_land=GEO_land,TC=TCi,paramsTable = paramsTable)
main =  paste(TCi$NAME[1],TCi$SEASON[1],"at",GEO_land$lons,GEO_land$lats)
#with(HAZts,plot(date,Sw,format = "%b-%d %H",type="l",main = main,ylab = "Wind speed [m/s]"))
```

TCProfilePts *Transect points from a origin through a point or with a bearing and to the opposite side.*

Description

Transect points from a origin through a point or with a bearing and to the opposite side.

Usage

```
TCProfilePts(
  TC_line,
  Through_point = NULL,
  bear = NULL,
  length = 200,
  step = 2
)
```

Arguments

TC_line	origin of the transect
Through_point	a point to pass through
bear	the bearing
length	the length of the transect in Km
step	the spacing of the transect in Km

Value

spatial vector of transect profile points with distances in Km (negative for left hand side)

Examples

```
require(terra)
TCi <- vect(cbind(c(154.1,154),c(-26.1,-26)),"lines",crs="epsg:4283") #track line segment
TCi$PRES <- 950
TCi$RMW <- 40
TCi$ISO_TIME <- "2022-10-04 20:00:00"
TCi$LON <- geom(TCi)[1,3]
TCi$LAT <- geom(TCi)[1,4]
TCi$STORM_SPD <- perim(TCi)/(3*3600) #m/s
TCi$thetaFm <- 90-returnBearing(TCi)
#Through_point <- isd[isd$OID==isdsi]
pp <- TCProfilePts(TC_line = TCi,Through_point=NULL,bear=TCi$thetaFm+90,length =100,step=10)
plot(pp,"radialdist",type="continuous")
lines(TCi,col=2)
```

TCvectInterp *Temporally Interpolate Along a Tropical Cyclone Track And Compute Along-Track Parameters*

Description

Temporally Interpolate Along a Tropical Cyclone Track And Compute Along-Track Parameters

Usage

```
TCvectInterp(outdate = NULL, TC, paramsTable)
```

Arguments

outdate	POSIX times to be interpolated to. The output date in "YYYY-MM-DD" format. Default is NULL.
TC	SpatVector of Tropical cyclone track parameters
paramsTable	Global parameters to compute TC Hazards.

Value

SpatVector of Tropical cyclone track parameters

Examples

```
require(terra)
TCi <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TCi$PRES <- TCi$BOM_PRES
TCi$PRES[is.na(TCi$PRES)] = 1010
outdate = seq(strptime(TCi$ISO_TIME[1],"%Y-%m-%d %H:%M:%S",tz="UTC"),
strptime(rev(TCi$ISO_TIME)[1],"%Y-%m-%d %H:%M:%S",tz="UTC"),3600)
paramsTable = read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
TCii = TCvectInterp(outdate = outdate,TC=TCi,paramsTable = paramsTable)
```

tunedParams *Update Parameter List to Calibrated Values*

Description

Update Parameter List to Calibrated Values

Usage

```
tunedParams(
  paramsTable,
 infile = system.file("extdata/tuningParams/QLD_modelSummaryTable.csv", package =
    "TCHazaRds")
)
```

Arguments

paramsTable	Global parameters to compute TC Hazards.
infile	File containing tuning parameters in a .csv. Default for QLD calibration.

Value

list of params with updated tuning wind parameters.

Examples

```
paramsTable <- read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))

tunedParams(paramsTable)
```

update_Track *Calculate Additional TC Parameters, and temporally Interpolate Along a Tropical Cyclone Track*

Description

Calculate Additional TC Parameters, and temporally Interpolate Along a Tropical Cyclone Track

Usage

```
update_Track(
  outdate = NULL,
  indate,
  TClons,
  TClats,
  vFms,
  thetaFms,
  cPs,
  rMaxModel,
  vMaxModel,
  betaModel,
  eP,
  rho = NULL
)
```

Arguments

outdate	POSIX times to be interpolated to
indate	POSIX input times
TClons	input central TC longitude
TClats	input central TC latitude
vFms	input forward velocity of TC
thetaFms	input forward direction
cPs	central pressure
rMaxModel	empirical model for radius of maximum wind calculation (rMax in km)
vMaxModel	empirical model for maximum wind velocity calculation (vMax in m/s)
betaModel	empirical model for TC shape parameter beta (dimensionless Beta)
eP	background environmental pressure (hPa)
rho	air density

Value

list of track data inclining the rMax vMax and Beta.

Examples

```
paramsTable <- read.csv(system.file("extdata/tuningParams/defult_params.csv",package = "TCHazaRds"))
params <- array(paramsTable$value,dim = c(1,length(paramsTable$value)))
colnames(params) <- paramsTable$param
params <- data.frame(params)
require(terra)
TCi <- vect(system.file("extdata/YASI/YASI.shp", package="TCHazaRds"))
TCi$PRES <- TCi$BOM_PRES
t1 <- strptime("2011-02-01 09:00:00","%Y-%m-%d %H:%M:%S", tz = "UTC") #first date in POSIX format
t2 <- strptime(rev(TCi$ISO_TIME)[1],"%Y-%m-%d %H:%M:%S", tz = "UTC") #last date in POSIX format
```

```
outdate <- seq(t1,t2,"hour") #array sequence from t1 to t2 stepping by “hour”
TCil = update_Track(outdate = outdate,
                    indate = strptime(TCi$ISO_TIME,"%Y-%m-%d %H:%M:%S", tz = "UTC"),
                    TClons = TCi$LON,
                    TClats = TCi$LAT,
                    vFms=TCi$STORM_SPD,
                   thetaFms=TCi$thetaFm,
                    cPs=TCi$PRES,
                   rMaxModel=params$rMaxModel,
                    vMaxModel=params$vMaxModel,
                    betaModel=params$betaModel,
                    eP = params$eP,
                    rho = params$rhoa)
```

---

vMax_modelsR *Compute the Tropical Cyclone Maximum Wind Speeds*

Description

Compute the Tropical Cyclone Maximum Wind Speeds

Usage

```
vMax_modelsR(
  vMaxModel,
  cPs,
  eP,
  vFms = NULL,
  TClats = NULL,
  dPdt = NULL,
  beta = 1.3,
  rho = 1.15
)
```

Arguments

vMaxModel	0=Arthur (1980),1=Holland (2008),2=Willoughby & Rahn (2004).3=Vickery & Wadhera (2008),4=Atkinson and Holliday (1977)
cPs	Tropical cyclone central pressure (hPa)
eP	Background environmental pressure (hPa)
vFms	Forward speed of the storm m/s
TClats	Tropical cyclone central latitude
dPdt	rate of change in central pressure over time, hPa per hour from Holland 2008
beta	exponential term for Holland vortex
rho	density of air

Value

maximum wind speed m/s.

Examples

```
vMax_modelsR(vMaxModel=1,cPs=950,eP=1010,vFms = 1,TClats = -14,dPdt = .1)
```

Index