Package: meteoEVT (via r-universe)

September 1, 2024

Type Package

Title Computation and Visualization of Energetic and Vortical Atmospheric Quantities

Version 0.1.0.999

Date 2022-09-02

Maintainer Laura Mack <laum52@zedat.fu-berlin.de>

Description Energy-Vorticity theory (EVT) is the fundamental theory to describe processes in the atmosphere by combining conserved quantities from hydrodynamics and thermodynamics. The package 'meteoEVT' provides functions to calculate many energetic and vortical quantities, like potential vorticity, Bernoulli function and dynamic state index (DSI) [e.g. Weber and Nevir, 2008, <doi:10.1111/j.1600-0870.2007.00272.x>], for given gridded data, like ERA5 reanalyses. These quantities can be studied directly or can be used for many applications in meteorology, e.g., the objective identification of atmospheric fronts. For this purpose, separate function are provided that allow the detection of fronts based on the thermic front parameter [Hewson, 1998, <doi:10.1017/S1350482798000553>], the F diagnostic [Parfitt et al., 2017, <doi:10.1002/2017GL073662>] and the DSI [Mack et al., 2022, <arXiv:2208.11438>].

Author Laura Mack [aut, cre]

Imports grDevices, graphics, purrr, ncdf4

License GPL (>= 2)

URL https://github.com/noctiluc3nt/meteoEVT

Encoding UTF-8

RoxygenNote 7.2.0

Suggests knitr, rmarkdown

VignetteBuilder knitr

Repository https://noctiluc3nt.r-universe.dev

RemoteUrl https://github.com/noctiluc3nt/meteoevt

RemoteRef HEAD

RemoteSha 05a7b45d347cdae09fcbb30d980b3c514e8151c8

Contents

`meteoEVT-package` *Introduction*

Description

Energy-Vorticity theory (EVT) is the fundamental theory to describe processes in the atmosphere by combining conserved quantities from hydrodynamics and thermodynamics. The package 'meteoEVT' provides functions to calculate many energetic and vortical quantities, like potential vorticity, Bernoulli function and dynamic state index (DSI) (Weber and Nevir, 2008), for given gridded data, like ERA5 reanalyses. These quantities can be studied directly or can be used for many applications in meteorology, e.g., the objective identification of atmospheric fronts. For this purpose, separate function are provided that allow the detection of fronts based on the thermic front parameter (Hewson, 1998), the F diagnostic (Parfitt et al., 2017) and the DSI (Mack et al., 2022).

Details

Phenomenons in the Earth's atmosphere, like tropical hurricanes or extratropical cyclones, can adequately be chararcterized by a combination of energetic and vortical quantities. These quantities can also be used for a consistent theoretical description of these phenomenons. This package provides functions to calculate Bernoulli function, vorticity, enstrophy, helicity, Lamb vector and potential vorticity based on given gridded data sets. Addiotionally, by using energy-vortex theory an adiabatic, stationary and invisicid basic state of the Earth's atmosphere can be derived, which is itself a solution of the primitive equations. The derivation from this basic state is given by the dynamic state index (DSI), which can be used for the study of, e.g., cyclones and fronts. Recently, the DSI was used to identify atmospheric fronts objectively from reanalysis data and thereby provides an alternative way for front detection. For this purpose, this package provides funtions to calculate the DSI and use it to identify atmospheric fronts. This method can be compared with state-of-the-art front identification methods based on the thermic front parameter or the F diagnostic.

References

- Weber, T. and Névir, P. (2008). Storm tracks and cyclone development using the theoretical concept of the Dynamic State Index (DSI). Tellus A, 60(1):1–10, doi:10.1111/j.1600-0870.2007.00272.x.
- Parfitt, R., Czaja, A., and Seo, H. (2017). A simple diagnostic for the detection of atmospheric fronts. Geophys. Res. Lett., 44:4351–4358, doi:10.1002/2017GL073662.
- Hewson, T. D. (1998). Objective fronts. Meteorol. Appl., 5:37–65, doi:10.1017/S1350482798000553.
- Mack, L., Rudolph, A. and Névir, P. (2022). Identifying atmospheric fronts based on diabatic processes using the dynamic state index (DSI), arXiv:2208.11438.

calc_bernoulli *Bernoulli function*

Description

Calculates the Bernoulli function, i.e. total energy density, as sum of potential, kinetic and thermal energy density

Usage

```
calc_bernoulli(t_fld, u_fld, v_fld, w_fld, phi_fld)
```

Arguments

t_fld	temperature field [K]
u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
phi_fld	geopotential height [gpm]

Value

Bernoulli function field [m^2/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
bernoulli=calc_bernoulli(data$temp,data$u,data$v,data$w,data$z)
```

calc_density *Density*

Description

Calculates the density of an ideal fluid

Usage

```
calc_density(t_fld, lev_p)
```

Arguments

t_fld	temperature field [K]
lev_p	vector containing pressure levels [Pa]

Value

density [kg/m^3]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
density=calc_density(data$temp,data$lev)
```

`calc_dsi` *Dynamic State Index (DSI)*

Description

Calculates the dynamic state index DSI

Usage

```
calc_dsi(
  t_fld,
  u_fld,
  v_fld,
  w_fld,
  phi_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  zvort_only = FALSE,
  relative = FALSE,
  pv_fld = NULL,
  mode = "lonlat"
)
```

Arguments

`t_fld`	temperature field [K]
`u_fld`	zonal velocity field [m/s]
`v_fld`	meridional velocity field [m/s]
`w_fld`	vertical velocity field [m/s]
`phi_fld`	geopotential height [gpm]
`lev_p`	vector containing pressure levels [Pa]
`lat`	vector containing latitude
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)

dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
zvort_only	logical, TRUE: if only the vertical vorticity (zvort) should be calculated, FALSE: for the whole vorticity vector, default: FALSE
relative	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity, default: FALSE
pv_fld	optional pv field (if e.g., PV is directly taken from ERA5 and not calculated separately)
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

dynamic state index [K^2*m^4/(kg^2*s^3)]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
dsi=calc_dsi(data$temp,data$u,data$v,data$w,data$z,lev_p=data$lev,lat=data$lat)
```

---

calc_enstrophy *Enstrophy density*

Description

Calculates the enstrophy density (vorticity squared) either in 2d or 3d

Usage

```
calc_enstrophy(
  u_fld,
  v_fld,
  w_fld = NULL,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  zvort_only = TRUE,
  relative = TRUE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
zvort_only	logical, TRUE: if only 2d enstrophy (based on z-vorticity) should be calculated, FALSE: for 3d enstrophy (based on 3d vorticity), default: TRUE
relative	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity should be used for calculation of enstrophy, default: TRUE
zvort_fld	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

enstrophy density field [1/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
#3d enstropy
ens3d=calc_enstrophy(data$u,data$v,data$w,data$lev,lat=data$lat)
#2d enstropy as scalar
ens2d=calc_enstrophy(data$u,data$v,lev_p=data$lev,lat=data$lat,zvort_only=TRUE)
```

---

calc_fdiag *F diagnostic*

Description

Calculates the F diagnostic

Usage

```
calc_fdiag(
  t_fld,
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  mode = "lonlat"
)
```

Arguments

t_fld	temperature field [K]
u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	only for lonlat mode: vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	the horizontal coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

F diagnostic (dimensionless)

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
fdiag=calc_fdiag(data$temp,data$u,data$v,data$w,data$lev,data$lat)
```

`calc_frontogenesis` *Petterssen Frontogenesis Function*

Description

Calculates the Petterssen frontogenesis function based on the potential temperature

Usage

```
calc_frontogenesis(
  t_fld,
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  mode = "lonlat",
  lat = NULL,
  dx = 0.25,
  dy = 0.25
)
```

Arguments

`t_fld`	temperature field [K]
`u_fld`	zonal velocity field [m/s]
`v_fld`	meridional velocity field [m/s]
`w_fld`	vertical velocity field [m/s]
`lev_p`	vector containing pressure levels [Pa]
`mode`	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid
`lat`	only for lonlat mode: vector containing latitude
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)

Value

Petterssen Frontogenesis Function

`calc_helicity` *Helicity density*

Description

Calculates the helicity density (scalar product of wind vector and vorticity vector) either for the whole vector (3d) or only for the vertical component (updraft helicity)

Usage

```
calc_helicity(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  vert_only = FALSE,
  relative = TRUE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

`u_fld`	zonal velocity field [m/s]
`v_fld`	meridional velocity field [m/s]
`w_fld`	vertical velocity field [m/s]
`lev_p`	vector containing pressure levels [Pa]
`lat`	vector containing latitude
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`vert_only`	logical, TRUE: if only the updraft helicity w*zeta (based on z-vorticity) should be calculated, FALSE: for 3d helicity (based on 3d vorticity), default: FALSE
`relative`	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity should be used for calculation of enstrophy, default: TRUE
`zvort_fld`	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
`mode`	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

helicity density field [m/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
#3d helicity
hel=calc_helicity(data$u,data$v,data$w,data$lev,lat=data$lat)
#updraft helicity
up_hel=calc_helicity(data$u,data$v,data$w,data$lev,lat=data$lat,vert_only=TRUE)
```

---

calc_hydrodynamic_charge

Hydrodynamic charge

Description

Calculates the hydrodynamic charge (density), i.e. the divergence of the Lamb vector

Usage

```
calc_hydrodynamic_charge(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  relative = TRUE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')

relative	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity should be used for calculation of enstrophy, default: TRUE
zvort_fld	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

hydrodynamic charge [1/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
qh=calc_hydrodynamic_charge(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

calc_kinematic_vorticity_number

Kinematic vorticity number

Description

Calculates kinematic vorticity number = frobenius_norm(Omega)/frobenius_norm(S)

Usage

```
calc_kinematic_vorticity_number(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude

dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

kinematic vorticity number [-]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
eta=calc_kinematic_vorticity_number(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

calc_lamb *Lamb vector (sometimes called vortex energy)*

Description

Calculates the Lamb vector (cross product of wind vector and vorticity vector)

Usage

```
calc_lamb(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  relative = TRUE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]

lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
relative	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity should be used for calculation of enstrophy, default: TRUE
zvort_fld	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

lamb vector [m/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
lamb=calc_lamb(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

calc_pv *Potential Vorticity (PV)*

Description

Calculates the potential vorticity

Usage

```
calc_pv(
  t_fld,
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  zvort_only = FALSE,
  relative = FALSE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

t_fld	temperature field [K]
u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
zvort_only	logical, TRUE: if only the vertical vorticity (zvort) should be calculated, FALSE: for the whole vorticity vector, default: FALSE
relative	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity, default: FALSE
zvort_fld	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

potential vorticity field [K*m^2/(kg*s)]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
#PV based on all three components
pv=calc_pv(data$temp,data$u,data$v,data$w,data$lev,lat=data$lat)
#PV only based on vertical component
pv_vert=calc_pv(data$temp,data$u,data$v,data$w,lev_p=data$lev,lat=data$lat,zvort_only=TRUE)
```

---

calc_Qinvariant *Q-invariant*

Description

Calculates the Q-invariant := 1/2 * (frobenius_norm(Omega)^2 - frobenius_norm(S)^2)

Usage

```
calc_Qinvariant(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

Q-invariant [1/s^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
S=calc_Qinvariant(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

calc_strain_rate_tensor

Strain-rate tensor

Description

Calculates the strain-rate tensor (S matrix)

Usage

```
calc_strain_rate_tensor(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

Strain-rate tensor (3x3 tensor) [1/s]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
S=calc_strain_rate_tensor(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

calc_tfp *Thermic Front Parameter (TFP)*

Description

Calculates the thermic front parameter based on the potential temperature

Usage

```
calc_tfp(t_fld, lev_p, lat = NULL, dx = 0.25, dy = 0.25, mode = "lonlat")
```

Arguments

t_fld	temperature field [K]
lev_p	vector containing pressure levels [Pa]
lat	only for lonlat mode: vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	the horizontal coordinate system, options are 'lonlat' for a longitude-latitude-grid (default), or 'cartesian' for an equidistant cartesian grid

Value

thermic front parameter [K/m^2]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
tfp=calc_tfp(data$temp,data$lev,data$lat)
```

---

calc_theta *Potential temperature*

Description

Calculates the potential temperature

Usage

```
calc_theta(t_fld, lev_p)
```

Arguments

t_fld	temperature field [K]
lev_p	vector containing pressure levels [Pa]

Value

density [kg/m^3]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
theta=calc_theta(data$temp,data$lev)
```

`calc_vorticity` *Vorticity*

Description

Calculates the vorticity

Usage

```
calc_vorticity(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  zvort_only = FALSE,
  relative = FALSE,
  zvort_fld = NULL,
  mode = "lonlat"
)
```

Arguments

`u_fld`	zonal velocity field [m/s]
`v_fld`	meridional velocity field [m/s]
`w_fld`	vertical velocity field [m/s]
`lev_p`	vector containing pressure levels [Pa]
`lat`	vector containing latitude
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`zvort_only`	logical, TRUE: if only the vertical vorticity (zvort) should be calculated, FALSE: for the whole vorticity vector, default: FALSE
`relative`	logical, TRUE: only relative vorticity, FALSE: whole (absolute) vorticity, default: FALSE
`zvort_fld`	optional zvort field (if e.g., zvort is directly taken from ERA5 and not calculated separately)
`mode`	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

vorticity field [1/s]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
#3d vorticity
xi=calc_vorticity(data$u,data$v,data$w,data$lev,lat=data$lat)
#z-vorticity as scalar
zeta=calc_vorticity(data$u,data$v,data$w,data$lev,lat=data$lat,zvort_only=TRUE)
```

---

calc_vorticity_tensor *Vorticity tensor*

Description

Calculates the vorticity tensor (Omega matrix)

Usage

```
calc_vorticity_tensor(
  u_fld,
  v_fld,
  w_fld,
  lev_p,
  lat = NULL,
  dx = 0.25,
  dy = 0.25,
  mode = "lonlat"
)
```

Arguments

u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
lev_p	vector containing pressure levels [Pa]
lat	vector containing latitude
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	use 'lonlat' if the data is given on a lon-lat-grid or 'cartesian' if the data is given on an equidistant cartesian grid

Value

vorticity tensor (3x3 tensor) [1/s]

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
lamb=calc_vorticity_tensor(data$u,data$v,data$w,data$lev,lat=data$lat)
```

---

crossprod *cross product*

Description

Calculates the cross product of two given 3d vector fields

Usage

```
crossprod(fld1, fld2)
```

Arguments

fld1	field 1 with dimensions (lon,lat,p,3)
fld2	field 2 with dimensions (lon,lat,p,3)

Value

field containing the cross product

---

df_dp *df_dp*

Description

Calculates the p derivative (pressure system) using central differences

Usage

```
df_dp(fld, plev = 5000)
```

Arguments

fld	field with dimensions (lon,lat,p)
plev	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)

Value

field containing the partial derivative w.r.t. p

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
theta=calc_theta(data$temp,data$lev)
dtheta_dp=df_dp(theta)
```

`df_dx` *df_dx*

Description

Calculates the x derivative using central differences (for lonlat-grid or cartesian grid)

Usage

```
df_dx(fld, lat = NULL, dx = 0.25, mode = "lonlat")
```

Arguments

`fld`	field with dimensions (lon,lat,p)
`lat`	only for lonlat mode: vector containing latitude
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`mode`	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

field containing the partial derivative w.r.t. x

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
theta=calc_theta(data$temp,data$lev)
dtheta_dx=df_dx(theta,data$lat)
```

df_dy *df_dy*

Description

Calculates the y derivative using central differences

Usage

```
df_dy(fld, dy = 0.25, mode = "lonlat")
```

Arguments

fld	with dimensions (lon,lat,p)
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
mode	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

field containing the partial derivative w.r.t. y

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
theta=calc_theta(data$temp,data$lev)
dtheta_dy=df_dy(theta,dy=0.25)
```

df_dz *df_dz*

Description

Calculates the z derivative

Usage

```
df_dz(fld, rho, plev = 5000)
```

Arguments

fld	field with dimensions (lon,lat,p)
rho	field with dimensions (lon,lat,p) for density or a scalar rho (for constant density)
plev	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)

Value

field containing the partial derivative w.r.t. z

`div` *divergence*

Description

Calculates the divergence of a vector field

Usage

```
div(
  fld,
  lat = NULL,
  d = 3,
  system = "p",
  rho = NULL,
  dx = 0.25,
  dy = 0.25,
  plev = 5000,
  mode = "lonlat"
)
```

Arguments

`fld`	field with dimensions (lon,lat,p,d)
`lat`	vector containing latitude (only for `mode='lonlat'`)
`d`	scalar for dimension (use d=2 for horizontal gradient and d=3 for 3d-gradient)
`system`	for type of coordinate system (use 'p' for pressure system and 'z' for height system)
`rho`	field with dimensions (lon,lat,p) for density or a scalar rho (for constant density)
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`plev`	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)
`mode`	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

field containing the divergence of fld

fill_horiz *Plotting a xy domain with custom boundaries, colour paletts and optional world map*

Description

Plotting a xy domain with custom boundaries, colour paletts and optional world map

Usage

```
fill_horiz(
  x,
  y,
  fld,
  levels = 1:100,
  main = "",
  worldmap = TRUE,
  legend_loc = "topright",
  legend_title = "",
  legend_only = FALSE,
  Lab = NULL,
  ...
)
```

Arguments

x	array containing x-axis values (e.g. longitude)
y	array containing y-axis values (e.g. latitude)
fld	field (which should be plotted) with dimensions (x,y)
levels	levels for colour bar
main	character containing main title of the plot
worldmap	should the world map contours be plotted (default TRUE)
legend_loc	location of legend
legend_title	character containing legend title
legend_only	logical TRUE only legend should be pltted, or FALSE everything should be plotted (default)
Lab	lab palette from type colorRampPalette
...	additional graphic parameters

Value

no return

frobenius_norm *Frobenius norm*

Description

Calculates the Frobenius norm of a given matrix or array

Usage

```
frobenius_norm(mat)
```

Arguments

```
mat
```

Value

Frobenius norm

frontid *Front Identification und Statistics*

Description

Calculates frontal zones based on a chosen method (TFP, F diagnostic, DSI) and provides statistics of the distribution of meteorological quantities inside the determined frontak zones.

Usage

```
frontid(
  t_fld,
  u_fld = NULL,
  v_fld = NULL,
  w_fld = NULL,
  phi_fld = NULL,
  lev_p,
  lat = NULL,
  method = "tfp",
  threshold = 2 * 10^-10,
  dx = 0.25,
  dy = 0.25,
  fronts_only = FALSE,
  mode = "lonlat"
)
```

Arguments

t_fld	temperature field [K]
u_fld	zonal velocity field [m/s]
v_fld	meridional velocity field [m/s]
w_fld	vertical velocity field [m/s]
phi_fld	geopotential height [gpm]
lev_p	vector containing pressure levels [Pa]
lat	only for lonlat mode: vector containing latitude
method	character containing the method, use 'tfp' for TFP method, 'f' for F diagnostic and 'dsi' for DSI method
threshold	scalar containing a suitable threshold (e.g., 2*10^-10 for TFP method, 1 or for F diagnostic, 10^-16 for DSI method)
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
fronts_only	if you only want to calculate the frontal regions and not their properties (default FALSE)
mode	the horizontal coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

list containing the used method and used threshold, field with logicals containing the detected frontal zones and numerics of temperature, u-wind, v-wind, w-wind, geopotential, vorticity, PV and DSI inside the determined frontal zones

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)

#front identification using the thermic front parameter (example without front statistic)
tfp_fronts=frontid(data$temp,lev_p=data$lev,lat=data$lat,fronts_only=TRUE)

#front identification using F diagnostic (example with front statistic)
f_fronts=frontid(data$temp,data$u,data$v,data$w,data$z,lev_p=data$lev,lat=data$lat,
method='f',threshold=2,fronts_only=FALSE)

#front identification using the dynamic state index (example with statistic)
dsi_fronts=frontid(data$temp,data$u,data$v,data$w,data$z,lev_p=data$lev,lat=data$lat,
method='dsi',threshold=4*10^-16,fronts_only=FALSE)
```

grad *gradient of a scalar field*

Description

Calculates the gradient

Usage

```
grad(
  fld,
  lat = NULL,
  d = 3,
  system = "p",
  rho = NULL,
  dx = 0.25,
  dy = 0.25,
  plev = 5000,
  mode = "lonlat"
)
```

Arguments

fld	field with dimensions (lon,lat,p)
lat	vector containing latitude
d	scalar for dimension (use d=2 for horizontal gradient and d=3 for 3d-gradient)
system	for type of coordinate system (use 'p' for pressure system and 'z' for height system)
rho	field with dimensions (lon,lat,p) for density or a scalar rho (for constant density)
dx	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
dy	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with mode='lonlat' or e.g. 1000 m in cartesian coordinates with mode='cartesian')
plev	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)
mode	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

field containing the gradient with dimension (lon,lat,p,d)

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
theta=calc_theta(data$temp,data$lev)
theta_grad=grad(theta,data$lat)
```

`jacobian` *Jacobian matrix and determinant*

Description

Calculates the Jacobian matrix and Jacobian determinant for 2 or 3 given scalar fields

Usage

```
jacobian(
  fld1,
  fld2,
  fld3 = NULL,
  lat = NULL,
  d = 3,
  system = "p",
  rho = NULL,
  dx = 0.25,
  dy = 0.25,
  plev = 5000,
  mode = "lonlat"
)
```

Arguments

`fld1`	field 1 with dimensions (lon,lat,p)
`fld2`	field 2 with dimensions (lon,lat,p)
`fld3`	field 3 with dimensions (lon,lat,p)
`lat`	vector containing latitude
`d`	scalar for dimension (use d=2 for 2 input fields and d=3 for 3 inpt fields)
`system`	for type of coordinate system (use 'p' for pressure system and 'z' for height system)
`rho`	field with dimensions (lon,lat,p) for density or a scalar rho (for constant density)
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`plev`	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)
`mode`	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

list containing Jacobian matrix and determinant

`readin_dim` *read in dimensions*

Description

: reads dimensions of ERA5 data

Usage

```
readin_dim(filename)
```

Arguments

`filename`	name of file to read in

Value

no return

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data_dims = readin_dim(myfile)
```

`readin_era5` *read in ERA5 data*

Description

: reads ERA5 data

Usage

```
readin_era5(filename)
```

Arguments

`filename`	name of file to read in

Value

no return

Examples

```
myfile=system.file("extdata", "era5_storm-zeynep.nc", package = "meteoEVT")
data = readin_era5(myfile)
```

`rot` *rotation*

Description

Calculates the rotation of a vector field

Usage

```
rot(
  fld,
  lat = NULL,
  d = 3,
  system = "p",
  rho = NULL,
  dx = 0.25,
  dy = 0.25,
  plev = 5000,
  mode = "lonlat"
)
```

Arguments

`fld`	with dimensions (lon,lat,p,d)
`lat`	vector containing latitude
`d`	scalar for dimension (use d=2 for horizontal gradient and d=3 for 3d-gradient)
`system`	for type of coordinate system (use 'p' for pressure system and 'z' for height system)
`rho`	field with dimensions (lon,lat,p) for density or a scalar rho (for constant density)
`dx`	x resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`dy`	y resolution in the corresponding unit (e.g. 0.25 degree for ERA5 with `mode='lonlat'` or e.g. 1000 m in cartesian coordinates with `mode='cartesian'`)
`plev`	a scalar containing the p resolution (if equidistant) or a vector containing pressure levels in Pa (for non-equidistant)
`mode`	the coordinate system, options are lonlat for a longitude-latitude-grid (default), or cartesian for an equidistant cartesian grid

Value

field containing the divergence of fld

`scalarprod` *scalar product*

Description

Calculates the scalar product of two given fields

Usage

```
scalarprod(fld1, fld2)
```

Arguments

`fld1`	field 1 with dimensions (lon,lat,p,d)
`fld2`	field 2 with dimensions (lon,lat,p,d)

Value

field of the scalar product with dimensions (lon,lat,p)

Index