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Description Provides functions for quantifying visible (VIS) and ultraviolet (UV) radiation in relation to the photoreceptors Phytochromes, Cryptochromes, and UVR8 which are present in plants. It also includes data sets on the optical properties of plants. Part of the 'r4photobiology' suite, Aphalo P. J. (2015) <doi:10.19232/uv4pb.2015.1.14>.

License GPL (>= 2)

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`photobiologyPlants-package`

photobiologyPlants: Plant Photobiology Related Functions and Data

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Description

Provides functions for quantifying visible (VIS) and ultraviolet (UV) radiation in relation to the photoreceptors Phytochromes, Cryptochromes, and UVR8 which are present in plants. It also includes data sets on the optical properties of plants. Part of the 'r4photobiology' suite, Aphalo P. J. (2015) doi:10.19232/uv4pb.2015.1.14.

Details

Package 'photobiologyPlants' is part of a suite of packages for analysis and plotting of data relevant to photobiology (described at https://www.r4photobiology.info/). The current component package provides functions and data related to plant photoreceptors, light dependent reponses and optical properties of plants.

Acknowledgements

This work was partly funded by the Academy of Finland (decision 252548). COST Action FA9604 'UV4Growth' facilitated discussions and exchanges of ideas that lead to the development of this package.

Author(s)

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References

Aphalo, Pedro J. (2015) The r4photobiology suite. UV4Plants Bulletin, 2015:1, 21-29. doi:10.19232/uv4pb.2015.1.14.

Aphalo, P. J., Albert, A., Bjoern, L. O., McLeod, A. R., Robson, T. M., Rosenqvist, E. (Eds.). (2012). Beyond the Visible: A handbook of best practice in plant UV photobiology (1st ed., p. xxx + 174). Helsinki: University of Helsinki, Department of Biosciences, Division of Plant Biology. ISBN 978-952-10-8363-1 (PDF), 978-952-10-8362-4 (paperback). Open access PDF download available at http://hdl.handle.net/10138/37558

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10.

Banerjee, R., Schleicher, E., Meier, S., Viana, R. M., Pokorny, R., Ahmad, M., ... Batschauer, A. (2007). The signaling state of Arabidopsis cryptochrome 2 contains flavin semiquinone. J Biol Chem, 282(20), 14916-14922. doi:10.1074/jbc.M700616200.

See Also

Package photobiology-package and photobiologyWavebands-package.

`Betula_ermanii.mspct` *Spectral data for 'Betula ermanii' leaves*

Description

A dataset containing for wavelengths at a 1 nm interval in the range 350 to 1000 nm, tabulated values for total reflectance and total transmittance, for the upper and lower epidermis of leaves of different ages from Erman's birch (*Betula ermanii*) trees growing in the forest in Japan.

The variables in each spectrum are as follows:

- w.length (nm)
- Rfr
- Tfr

Usage

```
Betula_ermanii.mspct
```

Format

`object_mspct` collection object with six `object_spct` member objects, each with 651 rows and 3 variables

Note

We thank H. M. Noda for allowing us to include these data in our package. We have included here only data for two leaves from one species (*Betula ermanii*) and for wavelengths shorter than 1000 nm, from the much larger original data set. The whole data set is publicly available and the data easy to read into R. The data included here where measured with a Li-Cor LI-1800 spectroradiometer equipped with a LI-1800-12 (Li-Cor) integrating sphere, and consequently are for total reflectance and total transmittance. Further details on methods are available through the JaLTER web site. If you use these data in a publication, please cite the original source as given under references and contact the original author. In addition cite this package.

References

Noda H. 'Reflectance and transmittance spectra of leaves and shoots of 22 vascular plant species and reflectance spectra of trunks and branches of 12 tree species in Japan' ERDP-2013-02.1.1 (http://db.cger.nies.go.jp/JaLTER/metacat/metacat/ERDP-2013-02.1.1/jalter-en)
JaLTER, Japan Long Term Ecological Research Network, http://www.jalter.org/

`carotenoids.mspct` *Absorbance spectra for carotenoids.*

Description

A dataset containing the wavelengths at an arbitrary nm interval. Tabulated values for the in vitro absorbance spectrum of beta-carotene, lutein, lycopene, 3-4,di-hydro-lycopene, phytoene, phytofluene, violaxanthin and zeaxanthin. Data were digitized from plots downloaded from Lipid-Base (https://lipidbank.jp/), The official database of Japanese Conference on the Biochemistry of Lipids (JCBL). Data contributed to LipinBank by Takaichi Sinichi.

Usage

```
carotenoids.mspct
```

Format

A `filter_mspct` with eight member `filter_spct` objects each with 300 rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

Watanabe K., Yasugi E. and Oshima M. "How to search the glycolipid data in LIPIDBANK for Web: the newly developed lipid database" Japan Trend Glycosci. and Glycotechnol. 12, 175-184, 2000.

Examples

```
names(carotenoids.mspct)
getWhatMeasured(carotenoids.mspct[[1]])
```

`chlorophylls.mspct` *Absorbance spectra for chlorophylls.*

Description

Optical absorption spectra of chlorophyll a in methanol and chlorophylls a and by in diethyl ether containing the wavelengths at 1 nm interval.

Usage

```
chlorophylls.mspct
```

Format

A `filter_mspct` with three member `filter_spct` objects each with variable number of rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Data from PhotochemCAD 2.1a has been munged on 2 June 2017 by Scott Prahl (https://omlc.org/) to make the information available to non-Windows users. Although he has tried to be as careful as possible, he may have introduced some error; the cautious user is advised to compare these results with the original sources (Du et al., 1998; Dixon et al., 2005).

The spectral absorption measurements of chlorophyll a in methanol, chlorophyll a and chlorophyll b in diethyl ether were made by J. Li on 12-11-1997 using a Cary 3 spectrophotometer. The absorption values were collected using a spectral bandwidth of 1.0 nm, a signal averaging time of 0.133 sec, a data interval of 0.25 nm, and a scan rate of 112.5 nm/min.

Chlorophyll a measurements were scaled to make the molar extinction coefficient match the value of 111700 cm-1/M at 417.8 nm. These values were then interpolated to report extinction coefficients at regular 1 nm intervals. The reported molar extinction coefficient is from Strain et al. (1963).

Chlorophyll b measurements were scaled to make the molar extinction coefficient match the value of 159100 cm-1/M at 453.0 nm. These values were then interpolated to report extinction coefficients at regular 1 nm intervals. The reported molar extinction coefficient is from Vernon and Seely (1966).

Note

If you use these data in a publication, please cite also the original sources as given under references. For more information please visit https://omlc.org/.

References

J. M. Dixon, M. Taniguchi and J. S. Lindsey "PhotochemCAD 2. A refined program with accompanying spectral databases for photochemical calculations", Photochem. Photobiol., 81, 212-213, 2005.

H. Du, R. A. Fuh, J. Li, A. Corkan, J. S. Lindsey, "PhotochemCAD: A computer-aided design and research tool in photochemistry," Photochem. Photobiol., 68, 141-142, 1998.

Strain, H. H., M. R. Thomas and J. J. Katz (1963) Spectral absorption properties of ordinary and fully deuteriated chlorophylls a and b. Biochim. Biophys. Acta 75, 306-311.

Vernon, L. P. and G. R. Seely (1966) The chlorophylls. Academic Press, NY.

See Also

Other photosynthesis-related functions and data: `McCree_photosynthesis.mspct`, `chlorophylls_fluorescence.mspct`, `photon irradiances`

Examples

```
names(chlorophylls.mspct)
getWhatMeasured(chlorophylls.mspct[[1]])
```

---

chlorophylls_fluorescence.mspct

Fluorescence emission spectra for chlorophylls.

Description

Optical absorption spectra of chlorophyll a in methanol and chlorophylls a and b in diethyl ether containing the wavelengths at 1 nm interval.

Usage

```
chlorophylls_fluorescence.mspct
```

Format

A `filter_mspct` with three member `filter_spct` objects each with variable number of rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Data from PhotochemCAD 2.1a has been munged on 2 June 2017 by Scott Prahl (https://omlc.org/) to make the information available to non-Windows users. Although he has tried to be as careful as possible, he may have introduced some error; the cautious user is advised to compare these results with the original sources at https://www.photochemcad.com/ (Du et al., 1998; Dixon et al., 2005).

Fluorescence emission was measured using a Spex FluoroMax. The excitation and emission monochromators were set at 1 mm, giving a spectral bandwidth of 4.25 nm. The data interval was 0.5 nm and the integration time was 2.0 sec. Samples were prepared in 1cm path length quartz cells with absorbance less than 0.1 at the excitation and all emission wavelengths to uniformly illuminate across the sample, and to avoid the inner-filter effect. The dark counts were subtracted and the spectra were corrected for wavelength-dependent instrument sensitivity.

Note

If you use these data in a publication, please cite also the original sources as given under references. For more information please visit https://omlc.org/.

References

J. M. Dixon, M. Taniguchi and J. S. Lindsey "PhotochemCAD 2. A refined program with accompanying spectral databases for photochemical calculations", Photochem. Photobiol., 81, 212-213, 2005.

H. Du, R. A. Fuh, J. Li, A. Corkan, J. S. Lindsey, "PhotochemCAD: A computer-aided design and research tool in photochemistry," Photochem. Photobiol., 68, 141-142, 1998.

See Also

Other photosynthesis-related functions and data: McCree_photosynthesis.mspct, chlorophylls.mspct, photon irradiances

Examples

```
names(chlorophylls_fluorescence.mspct)
getWhatMeasured(chlorophylls_fluorescence.mspct[[1]])
```

CRYs.mspct *CRY1, CRY2 and CRY3 absorbance spectra.*

Description

A dataset containing the wavelengths at an arbitrary nm interval and spectral absorbance for plant cryptochromes 1 (CRY1), 2 (CRY2), and 3 (CRY3 or CRY-DASH). Tabulated values for the in vitro absorbance spectrum for *Arabidopsis thaliana*. CRY1 data were digitized from figure 1, curve "dark" and curve "30 min illumination" in Zeugnwer et al. (2005). The CRY2 data were digitized from Figure 1.B, curve "dark adapted sample", and curve "irradiated with blue light (450 nm, 50 umol m-2 s-1) during 30 min" in Banerjee et al. (2007). CRY3 data were digitized from figure 2a, curve "cry3" in Song et al. (2006).

Format

A `filter_mspct` with five member `filter_spct` objects each with 300 rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

Banerjee, R., Schleicher, E., Meier, S., Viana, R. M., Pokorny, R., Ahmad, M., ... Batschauer, A. (2007) The signaling state of Arabidopsis cryptochrome 2 contains flavin semiquinone. J Biol Chem, 282(20), 14916-14922. doi:10.1074/jbc.M700616200

SONG, S.-H., B. DICK, , A. PENZKOFER, , R. POKORNY, , A. BATSCHAUER, L.-O. ESSEN (2006) Absorption and fluorescence spectroscopic characterization of cryptochrome 3 from Arabidopsis thaliana. Journal of Photochemistry and Photobiology B: Biology. 85(1):1-16.

ZEUGNER, A., MARTIN BYRDIN, JEAN-PIERRE BOULY, NADIA BAKRIM, BALDISSERA GIOVANI, KLAUS BRETTEL, MARGARET AHMAD (2005) Light-induced Electron Transfer in Arabidopsis Cryptochrome-1 Correlates with in Vivo Function. Journal of Biological Chemistry. 280(20):19437-19440.

`D_water` *Diffusion coefficients in air*

Description

Diffusion coefficients of water and carbon dioxide in excess air as a function of temperature.

Usage

```
D_water(temperature)

D_CO2(temperature)
```

Arguments

`temperature`	numeric Temperature [$^{\circ}C$], in the range -7 to 47 $^{\circ}C$.

Details

Implemented as interpolating splines from tabulated data.

Value

A numeric vector of the same length as `temperature` containing diffusion coefficients expressed in $m^2\ s^{-1}$. `NA` is returned silently for off-range arguments passed to `temperature`.

References

Monteith, J. L. and Unsworth M. H. (2008) Principles of Environmental Physics (3 ed.) Academic Press-Elsevier. ISBN: 978-0-12-505103-3. See Table A.3.

Examples

```
D_water(23)
D_water(c(10, 12, 15, 100))

D_CO2(11)
```

`ET_ref` *Evapotranspiration*

Description

Compute an estimate of reference (= potential) evapotranspiration from meteorologial data. Evapotranspiration from vegetation includes transpiraction by plants plus evaporation from the soil or other wet surfaces. ET_0 is the reference value assuming no limitation to transpiration due to soil water, similar to potential evapotranspiration (PET). An actual evapotranpiration value ET can be estimated only if additional information on the plants and soil is available.

Usage

```
ET_ref(
  temperature,
  water.vp,
  wind.speed,
  net.irradiance,
  nighttime = FALSE,
  atmospheric.pressure = 10.13,
  soil.heat.flux = 0,
  method = "FAO.PM",
  check.range = TRUE
)

ET_ref_day(
```

```
  temperature,
  water.vp,
  wind.speed,
  net.radiation,
  atmospheric.pressure = 10.13,
  soil.heat.flux = 0,
  method = "FAO.PM",
  check.range = TRUE
)
```

Arguments

temperature	numeric vector of air temperatures (C) at 2 m height.
water.vp	numeric vector of water vapour pressure in air (Pa).
wind.speed	numeric Wind speed (m/s) at 2 m height.
net.irradiance	numeric Long wave and short wave balance (W/m2).
nighttime	logical Used only for methods that distinguish between daytime- and nighttime canopy conductances.
atmospheric.pressure	numeric Atmospheric pressure (Pa).
soil.heat.flux	numeric Soil heat flux (W/m2), positive if soil temperature is increasing.
method	character The name of an estimation method.
check.range	logical Flag indicating whether to check or not that arguments for temperature are within range of method. Passed to function calls to water_vp_sat() and water_vp_sat_slope().
net.radiation	numeric Long wave and short wave balance (J/m2/day).

Details

Currently three methods, based on the Penmann-Monteith equation formulated as recommended by FAO56 (Allen et al., 1998) as well as modified in 2005 for tall and short vegetation according to ASCE-EWRI are implemented in function ET_ref(). The computations rely on data measured according WHO standards at 2 m above ground level to estimate reference evapotranspiration (ET_0). The formulations are those for ET expressed in mm/h, but modified to use as input flux rates in W/m2 and pressures expressed in Pa.

Value

A numeric vector of reference evapotranspiration estimates expressed in mm/h for ET_ref() and in mm/d for ET_ref_day().

References

Allen R G, Pereira L S, Raes D, Smith M. 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. Rome: FAO.

Allen R G, Pruitt W O, Wright J L, Howell T A, Ventura F, Snyder R, Itenfisu D, Steduto P, Berengena J, Yrisarry J, et al. 2006. A recommendation on standardized surface resistance for hourly

calculation of reference ETo by the FAO56 Penman-Monteith method. Agricultural Water Management 81.

See Also

Other Evapotranspiration and energy balance related functions.: net_irradiance(), water_vp_sat()

Examples

```
# instantaneous
ET_ref(temperature = 20,
       water.vp = water_RH2vp(relative.humidity = 70,
                              temperature = 20),
       wind.speed = 0,
       net.irradiance = 10)

ET_ref(temperature = c(5, 20, 35),
       water.vp = water_RH2vp(70, c(5, 20, 35)),
       wind.speed = 0,
       net.irradiance = 10)

# Hot and dry air
ET_ref(temperature = 35,
       water.vp = water_RH2vp(10, 35),
       wind.speed = 5,
       net.irradiance = 400)

ET_ref(temperature = 35,
       water.vp = water_RH2vp(10, 35),
       wind.speed = 5,
       net.irradiance = 400,
       method = "FAO.PM")

ET_ref(temperature = 35,
       water.vp = water_RH2vp(10, 35),
       wind.speed = 5,
       net.irradiance = 400,
       method = "ASCE.PM.short")

ET_ref(temperature = 35,
       water.vp = water_RH2vp(10, 35),
       wind.speed = 5,
       net.irradiance = 400,
       method = "ASCE.PM.tall")

# Low temperature and high humidity
ET_ref(temperature = 5,
       water.vp = water_RH2vp(95, 5),
       wind.speed = 0.5,
       net.irradiance = -10,
       nighttime = TRUE,
       method = "ASCE.PM.short")
```

```
ET_ref_day(temperature = 35,
           water.vp = water_RH2vp(10, 35),
           wind.speed = 5,
           net.radiation = 35e6) # 35 MJ / d / m2
```

---

gs_c_from_gs_w *Convert stomatal conductance*

Description

Convert between stomatal conductances to water vapour and carbon dioxide.

Usage

```
gs_c_from_gs_w(gs_w, temperature = 21)

gs_w_from_gs_c(gs_c, temperature = 21)

gs_vol2mol(gs, temperature = 21, pressure = 101300)

gs_mol2vol(gs_c, temperature = 21, pressure = 101300)
```

Arguments

gs_w, gs_c, gs	numeric Stomatal conductance to water vapour and carbon dioxide [$m^2\ s^{-1}$].
temperature	numeric Temperature [$^\circ C$], in the range -7 to 47 $^\circ C$.
pressure	numeric Pressure of the gas, e.g., atmospheric pressure [Pa].

Details

These conversions are based on the diffusion coefficients, both of which are looked up based on the temperature.

Value

A numeric vector of stomatal conductance values expressed as $m^2\ s^{-1}$.

Examples

```
# example code
gs_c_from_gs_w(1/120)
gs_vol2mol(1/120)
```

`leaf_fluorescence.mspct` *Fluorescence emission spectra of leaves.*

Description

Fluroescence spectra of whole leaves of wheat excited with low irradiance of UVA1 radiation at 355 nm. Fluorescence state of chlorophylls equivalent to F_0.

Format

A `source_mspct` with one member `source_spct` object. each with variable number of rows and 2 numeric variables, `w.length` and `s.e.irrad`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- s.e.irrad (QSEU)

Data for spectrum `wheat_Fo_ex355nm` from Meyer et al. (2003, Fig. 2A). The fluorescence emission is expressed in quinine sulphate equivalent units (QSEU). Data were obtained by digitizing the figure in the publication and extracting the data with DigitizeIt under Windows 11.

Note

If you use these data in a publication, please cite also the original sources as given under references.

References

Meyer et al. (2003) UV-induced blue-green and far-red fluorescence along wheat leaves: a potential signature of leaf ageing. Journal of Experimental Botany, 54: 757-769. doi:10.1093/jxb/erg063.

Examples

```
names(leaf_fluorescence.mspct)
what_measured(leaf_fluorescence.mspct)
```

`McCree_photosynthesis.mspct` *McCree's action spectra for whole-leaf photosynthesis.*

Description

The 'classical' action spectra for *Amaranthus edulis* Speg. var. UCD 1966, *Avena sativa* L. var. Coronado (McCree 1972) and Lettuce var. Great Lakes or Boston (McCree 1972a) are included in this data set. Response is net CO_2 uptake measured on leaf sections umder monochromatic light. The light source used was a xenon-arc lamp fitted with a monochromator. Irradiance was in the range 10 to 15 Wm^{-2}.

Format

A `response_mspct` object with two member `response_spct` objects each with 300 rows and 2 numeric variables, `w.length` and `s.e.response`.

Note

Digitised from bitmap of from the original publication.

If you use these data in a publication, please cite also the original source as given under references.

References

McCree, K. J. (1972) Significance of Enhancement for Calculations Based on the Action Spectrum for Photosynthesis. Plant Physiology, 49, 704-706. Fig. 1, AMARANTH. McCree, K. J. (1972a) The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. Agricultural Meteorology 9, 191–216. Table III, species 12.

See Also

Other photosynthesis-related functions and data: `chlorophylls.mspct`, `chlorophylls_fluorescence.mspct`, `photon irradiances`

Examples

```
summary(McCree_photosynthesis.mspct)
```

molar_vol *Molar volume of an ideal gas*

Description

Compute the molar volume of an ideal gas from temåerature and pressure.

Usage

```
molar_vol(temperature = 20, pressure = 101300)
```

Arguments

temperature	numeric Temperature of the gas [$^{\circ}C$].
pressure	numeric Pressure of the gas, e.g., atmospheric pressure [Pa].

Details

The ideal gas equation, $V = R * T/P$, is used to compute the returned value. In the equation R is the gas constant ($8.314\, m^3\, Pa\, mol^{-1}\, K^{-1}$), T temperature expressed in degrees kelvin and P the pressure expressed in pascals. The argument passed to `temperature`, expressed in $^{\circ}C$, is re-expressed in K for the computation.

Value

A numeric vector with the molar volume of a gas expressed in m^3 per mole.

Examples

```
molar_vol()
molar_vol(0)
molar_vol(0, 90e3)
```

net_irradiance *Net radiation flux*

Description

Estimate net radiation balance expressed as a flux in W/m2. If `lw.down.irradiance` is passed a value in W / m2 the difference is computed directly and if not an approximate value is estimated, using `R_rel = 0.75` which corresponds to clear sky, i.e., uncorrected for cloudiness. This is the approach to estimation that is recommended by FAO for hourly estimates while here we use it for instantaneous or mean flux rates.

Usage

```
net_irradiance(
  temperature,
  sw.down.irradiance,
  lw.down.irradiance = NULL,
  sw.albedo = 0.23,
  lw.emissivity = 0.98,
  water.vp = 0,
  R_rel = 1
)
```

Arguments

`temperature`	numeric vector of air temperatures (C) at 2 m height.
`sw.down.irradiance`, `lw.down.irradiance`	numeric Down-welling short wave and long wave radiation radiation (W/m2).
`sw.albedo`	numeric Albedo as a fraction of one (/1).
`lw.emissivity`	numeric Emissivity of the surface (ground or vegetation) for long wave radiation.
`water.vp`	numeric vector of water vapour pressure in air (Pa), ignored if `lw.down.irradiance` is available.
`R_rel`	numeric The ratio of actual and clear sky short wave irradiance (/1).

Value

A numeric vector of evapotranspiration estimates expressed as W / m-2.

See Also

Other Evapotranspiration and energy balance related functions.: `ET_ref()`, `water_vp_sat()`

`Pfr_Ptot` *Calculate phytochrome photoequilibrium*

Description

Calculate the phytochrome photoequilibrium for monochromatic light from its wavelength or from a spectrum expressed as spectral irradiance.

Usage

```
Pfr_Ptot(x, ...)

## Default S3 method:
Pfr_Ptot(x, ...)

## S3 method for class 'numeric'
Pfr_Ptot(x, spct.out = length(x) > 20, ...)

## S3 method for class 'source_spct'
Pfr_Ptot(x, return.tb = !is.null(attr2tb), attr2tb = NULL, ..., na.rm = FALSE)

## S3 method for class 'source_mspct'
Pfr_Ptot(
  x,
  return.tb = TRUE,
  attr2tb = NULL,
  ...,
  na.rm = FALSE,
  idx = "spct.idx",
  .parallel = FALSE,
  .paropts = NULL
)
```

Arguments

x	an R object. A numeric vector
...	currently ignored.
spct.out	logical Flag indicating if the returned object should be of class response_spct instead of numeric.
return.tb	logical If TRUE force return of a data frame for a single spectrum, to match the returned class for collections of spectra.
attr2tb	character vector, see add_attr2tb() the syntax for attr2tb passed as is to formal parameter col.names.
na.rm	logical. If TRUE link[stats]{na.omit} is first called on x.
idx	character Name of the column with the names of the members of the collection of spectra.
.parallel	if TRUE, apply function in parallel, using parallel backend provided by foreach
.paropts	a list of additional options passed into the foreach function when parallel computation is enabled. This is important if (for example) your code relies on external data or packages: use the .export and .packages arguments to supply them so that all cluster nodes have the correct environment set up for computing.

Details

The calculations are based on data describing the photochemical constants for the plant photoreceptor phytochrome measured *in vitro* and available for wavelengths in the range 380 nm to 770 nm

as published by Mancinelli (1994). For reliable estimates of P_{fr}/P_{tot} from spectral irradiance, the spectrum should cover all these wavelengths with reasonably high wavelength resolution.

Two approaches are possible, using wavelength for monochromatic radiation or spectral irradiance data. Spectral irradiance data are accepted either as individual spectra or collections of spectra.

Value

When input is spectral data, a numeric vector of values giving the P_{fr}/P_{tot} or a data frame are returned, possibly with attributes extracted from the spectral objects as additional columns. When input is a numeric vector of wavelengths, the returned object is either a numeric vector or a `generic_spct` object with giving the P_{fr}/P_{tot} for each wavelength in the input.

Note

If you use these data in a publication, please cite also the original source as given under references.

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

Other phytochrome-related functions and data: `PHYs.mspct`, `Pfr_Ptot_R_FR()`, `Phy_Sigma()`, `Phy_Sigma_FR()`, `Phy_Sigma_R()`, `Phy_reaction_rates()`

Examples

```
# monochromatic light
Pfr_Ptot(620) # one wavelength in nm
Pfr_Ptot(c(570, 600, 630, 660, 690, 735, 760)) # six wavelengths
# spectral irradiance
Pfr_Ptot(sun.spct) # one spectrum
Pfr_Ptot(sun.spct, attr2tb = "when.measured")
Pfr_Ptot(sun_evening.spct) # five spectra
Pfr_Ptot(sun_evening.mspct)
Pfr_Ptot(sun_evening.mspct, attr2tb = "when.measured")
```

`Pfr_Ptot_R_FR` *Pr:Ptot ratio (photoequilibrium) from R:FR photon ratio.*

Description

Calculation of Pfr:Ptot ratio for Type I Phytochrome from red:far-red photon ratio. "Exact" only for dichromatic irradiation, only approximate for R:FR ratio calculated from a broadband light source.

Usage

```
Pfr_Ptot_R_FR(R.FR)
```

Arguments

R.FR	R:FR a single value or a vector of photon ratio (dimentionless) values

Value

a single value or a vector of numeric values giving the Pr:Ptot dimensionless ratio

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

q_ratio

Other phytochrome-related functions and data: PHYs.mspct, Pfr_Ptot(), Phy_Sigma(), Phy_Sigma_FR(), Phy_Sigma_R(), Phy_reaction_rates()

Examples

```
Pfr_Ptot_R_FR(1.15)
Pfr_Ptot_R_FR(0.10)
Pfr_Ptot_R_FR(c(0.1,1.15,5.0,20.0))
```

---

photon irradiances *Constrained extended PAR from spectral irradiance*

Description

Compute the constrained extended photosynthetically active radiation (xPAR) photon irradiance and its components ePAR, PAR and FR.700.750.

Usage

```
xPAR_irrad(
  spct,
  w.band,
  time.unit,
  scale.factor,
  use.cached.mult,
```

```
  use.hinges,
  ...
)

## Default S3 method:
xPAR_irrad(
  spct,
  w.band,
  time.unit,
  scale.factor,
  use.cached.mult,
  use.hinges,
  ...
)

## S3 method for class 'source_spct'
xPAR_irrad(
  spct,
  w.band = list(),
  time.unit = NULL,
  scale.factor = 1,
  use.cached.mult = getOption("photobiology.use.cached.mult", default = FALSE),
  use.hinges = NULL,
  return.tb = !is.null(attr2tb),
  attr2tb = NULL,
  ...
)

## S3 method for class 'source_mspct'
xPAR_irrad(
  spct,
  w.band = list(),
  time.unit = NULL,
  scale.factor = 1,
  use.cached.mult = getOption("photobiology.use.cached.mult", default = FALSE),
  use.hinges = NULL,
  attr2tb = NULL,
  ...,
  idx = "spct.idx",
  .parallel = FALSE,
  .paropts = NULL
)
```

Arguments

spct	an object of class "source.spct".
w.band	a waveband object or a list of waveband objects with additional waveband definitions for which to compute photon irradiance.

time.unit	character or lubridate::duration object.
scale.factor	numeric Multiplier applied to returned value.
use.cached.mult	logical indicating whether multiplier values should be cached between calls.
use.hinges	logical indicating whether to use hinges to reduce interpolation errors.
...	ignored.
return.tb	logical If TRUE force return of a data frame for a single spectrum, to match the returned class for collections of spectra.
attr2tb	character vector, see add_attr2tb for the syntax for attr2tb passed as is to formal parameter col.names.
idx	character Name of the column with the names of the members of the collection of spectra.
.parallel	if TRUE, apply function in parallel, using parallel backend provided by foreach
.paropts	a list of additional options passed into the foreach function when parallel computation is enabled. This is important if (for example) your code relies on external data or packages: use the .export and .packages arguments to supply them so that all cluster nodes have the correct environment set up for computing.

Details

PAR is defined by a very simple biological spectral weighting function (BSWF) giving equal action per photon in the range 400 nm to 700 nm. Radiation in the range 700 to 750 nm has a synergistic effect on the photosynthesis rate as long as it is present in addition to PAR. This synergism is called Emerson's effect. An alternative definition, ePAR, was proposed by Bugbee and Zhen. It uses the same BSWF as PAR but over the range 400 to 750 nm. Apogee, sells nowadays a sensor able to directly measure this photon irradiance, type SQ-610-SS ePAR sensor. The limitation is, as these authors have demonstrated, that when the contribution of FR is more than 40 photosynthesis. This can be assessed by quantifying both components separately, either from spectral data or using a sensor with at least two channels, such as Apogee's S2-141-SS PAR-FAR sensor. This bounded extended PAR is labelled here xPAR.

Under natural illumination and commonly used plant grow lights, a difference between unconstrained (ePAR) and constrained (xPAR) extended PAR is very unlikely to be observed. As xPAR cannot be computed from spectral irradiance using a single waveband definition or measured with a single-channel broadband sensor, this function can be used to check under which conditions ePAR and xPAR irradiances differ.

Methods xPAR_irrad() return four photon irradiances: ePAR (400-750 nm, unconstrained), xPAR(400-750 nm, with FR contribution constrained to a maximum of 40

Value

a data.frame with four numeric variables photon irradiances for xPAR, ePAR, PAR, and the far-red with wavelength 700 to 750 nm. expressed in $mol\,m^{-2}\,s^{-1}$ if scale.factor = 1, and possibly additional ones with metadata copied from the spectra. The data frame has one row for each spectrum in the object passed as argument to formal parameter spct.

References

McCree KJ. 1972. Test of current definitions of photosynthetically active radiation against leaf photosynthesis data. Agricultural Meteorology 10, 443-453. doi:10.1016/00021571(72)900453.

McCree KJ. 1976. A Rational Approach to Light Measurements in Plant Ecology. In: Smith H, ed. Commentaries in Plant Science. Oxford: Pergamon Press.

Zhen S, van Iersel M, Bugbee B. 2021. Why Far-Red Photons Should Be Included in the Definition of Photosynthetic Photons and the Measurement of Horticultural Fixture Efficacy. Frontiers in Plant Science 12. doi:10.3389/fpls.2021.693445.

Zhen S, van Iersel MW, Bugbee B. 2022. Photosynthesis in sun and shade: the surprising importance of far-red photons. New Phytologist 236, 538–546. doi:10.1111/nph.18375.

See Also

q_irrad() and PAR().

Other photosynthesis-related functions and data: McCree_photosynthesis.mspct, chlorophylls.mspct, chlorophylls_fluorescence.mspct

Examples

```
# default with a single spectrum (spectral irradiance)
xPAR_irrad(sun.spct) # mol m-2 s-1
xPAR_irrad(sun.spct, scale.factor = 1e6) # umol m-2 s-1
xPAR_irrad(sun.spct, time.unit = "hour") # mol m-2 h-1

# add irradiances for other wavebands
xPAR_irrad(sun.spct, scale.factor = 1e6, w.band = UVA("CIE"))

# DLI from a daily spectrum (spectral daily integral)
summary(sun_daily.spct)
xPAR_irrad(sun_daily.spct) # mol m-2 d-1

# multiple spectra
xPAR_irrad(sun_evening.spct, scale.factor = 1e6)

# multiple spectra as a collection
xPAR_irrad(sun_evening.mspct, scale.factor = 1e6)

# copy metadata from the spectra, see help(q_irrad)
xPAR_irrad(sun_evening.mspct,
           scale.factor = 1e6,
           attr2tb = c("lon", "lat", "when.measured"))
```

---

photon ratios *Calculate photon ratios from spectral irradiance*

Description

Photon ratios used in plant photobiology to summarize difference in spectral composition of light. Both historical, current and recently proposed photon ratios are implemented. The denominator is always a photon (= quantum) irradiance for a single waveband. The denominator is the irradiance either in a single waveband or the sum of irradiances in two wavebands.

Usage

```
R_FR(
  spct,
  std = "Smith20",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

FR_ePAR(
  spct,
  std = "Smith20",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

FR_PAR(
  spct,
  std = "Smith20",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

FR_RpFR(
  spct,
  std = "Smith20",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)
```

```
R_RpFR(
  spct,
  std = "Smith20",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

B_G(
  spct,
  std = "Sellaro",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVB_UV(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVB_UVA(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVA_UV(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
```

```
)

UVAlw_UV(
  spct,
  std = "plants",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVAsw_UV(
  spct,
  std = "plants",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UV_PAR(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVB_PAR(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVA_PAR(
  spct,
  std = "ISO",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
```

```
  name.tag = "[q:q]",
  ...
)

UVA1_UV(
  spct,
  std = "CIE",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVA2_UV(
  spct,
  std = "CIE",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVA2_UVA(
  spct,
  std = "CIE",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)

UVA1_UVA(
  spct,
  std = "CIE",
  use.cached.mult = FALSE,
  use.hinges = TRUE,
  naming = "short",
  name.tag = "[q:q]",
  ...
)
```

Arguments

spct	an object of class "source.spct" or an object of class "source.mspct" containing one of more spectra.

std	character Name of the variants of the waveband definitions to use (see table below).
use.cached.mult	logical indicating whether multiplier values should be cached between calls.
use.hinges	logical indicating whether to use hinges to reduce interpolation errors.
naming	character one of "long", "default", "short" or "none". Used to select the type of names to assign to the returned value.
name.tag	character Used to tag the name of the returned values.
...	named arguments to be forwarded to q_ratio or q_irrad methods.

Details

These functions are convenience wrappers on calls to method q_ratio() with specific waveband definitions from package photobiologyWavebands. To compute other photon ratios call method q_ratio() with predefined or ad hoc waveband() definitions.

Many predefined waveband() definitions accept a character string as argument to std used to select among different standardised and ad hoc but frequently used variations in the wavelength ranges. These functions for computing photon ratios forward the arguments received through parameter std to the parameter of the same name of the different waveband constructors as listed in the table below.

The returned value is the ratio between two photon irradiances (identical two photon fluence values) each integrated over the range of wavelengths in a waveband definition, which can differ in wavelength extent. Some ratios are defined for non-overlapping ranges of wavelengths (e.g., R:FR photon ratio) while others are defined for overlapping ranges of wavelengths (e.g., UVB:UV, which will never exceed 1 in value) or for the sum of irradiance in two wavelength ranges (e.g., FR:R+FR).

Function	Numerator	Denominator	Default std	Ref.
R_FR()	Red(std)	Far_red(std)	"Smith20"	4,5,6
R_RpFR()	Red(std)	Red(std) + Far_red(std)	"Smith20"	2
FR_RpFR()	Far_red(std)	Red(std) + Far_red(std)	"Smith20"	2
FR_ePAR()	Far_red(std)	PAR("ePAR")	"Smith20"	3
FR_PAR()	Far_red(std)	PAR("McCree")	"Smith20"	3
B_G()	Blue(std)	Green(std)	"Sellaro"	4
UVB_UV()	UVB(std)	UV(std)	"ISO"	1,7
UVB_UVA()	UVB(std)	UVA(std)	"ISO"	1,7
UVA_UV()	UVA(std)	UV(std)	"ISO"	1,7
UVAlw_UV()	UVAlw(std)	UV(std)	"plants"	7,8
UVAsw_UV()	UVAsw(std)	UV(std)	"plants"	7,8
UV_PAR()	UV(std)	PAR("McCree")	"ISO"	1
UVB_PAR()	UVB(std)	PAR("McCree")	"ISO"	1
UVA_PAR()	UVA(std)	PAR("McCree")	"ISO"	1
UVA1_UV()	UVA1(std)	UV(std)	"CIE"	1,7
UVA2_UV()	UVA2(std)	UV(std)	"CIE"	1,7
UVA1_UVA()	UVA1(std)	UVA(std)	"CIE"	1,7
UVA2_UVA()	UVA2(std)	UVA(std)	"CIE"	1,7

Value

When `spct` contains a single spectrum, a single named numeric dimensionless value giving a photon ratio, with name constructed from the name of the wavebands, with "(q:q)" appended is returned. When `spct` contains multiple spectra, either in long form or as a collection of spectral objects, the returned object is a data frame with a factor identifying the spectra and a numeric variable with the numeric values of the ratio.

References

[1] Aphalo PJ, Albert A, Björn LO, McLeod AR, Robson TM, Rosenqvist E (Eds.). 2012. Beyond the Visible: A handbook of best practice in plant UV photobiology. Helsinki: University of Helsinki, Department of Biosciences, Division of Plant Biology. doi:10.31885/9789521083631.

[2] Kusuma P, Bugbee B. 2021. Improving the Predictive Value of Phytochrome Photoequilibrium: Consideration of Spectral Distortion Within a Leaf. Frontiers in Plant Science 12. doi:10.3389/fpls.2021.596943.

[3] Kusuma P, Bugbee B. 2021. Far-red Fraction: An Improved Metric for Characterizing Phytochrome Effects on Morphology. Journal of the American Society for Horticultural Science 146, 3–13. doi:10.21273/jashs0500220.

[4] Sellaro R, Crepy M, Trupkin SA, Karayekov E, Buchovsky AS, Rossi C, Casal JJ. 2010. Cryptochrome as a sensor of the blue / green ratio of natural radiation in Arabidopsis. Plant Physiology 154, 401–409. doi:10.1104/pp.110.160820.

[5] Smith H. 1981. Plants and the Daylight Spectrum. London: Academic Press.

[6] Smith H, Holmes MG. 1984. Techniques in Photomorphogenesis. London: Academic Press.

[7] Rai N, Morales LO, Aphalo PJ. 2021. Perception of solar UV radiation by plants: photoreceptors and mechanisms. Plant Physiology 186, 1382–1396. doi:10.1093/plphys/kiab162.

[8] Rai N, Farkas AOD, Safronov O, et al. 2020. The photoreceptor UVR8 mediates the perception of both UV-B and UV-A wavelengths up to 350 nm of sunlight with responsivity moderated by cryptochromes. Plant, Cell & Environment 43, 1513–1527. doi:10.1111/pce.13752.

See Also

Ratios are computed with `q_ratio()` with `waveband()` objects as input. Two "fractions": R fraction `R_RpFR()` and FR fraction `FR_RpFR()` are computed using directly `q_irrad()`, which is also called by `q_ratio()`. In the table above the wavebands and default argument for `std` used to compute the photon ratios in each of the functions are listed and linked to the respective help pages.

Examples

```
# default, one spectrum
R_FR(sun.spct)

# naming
R_FR(sun.spct, naming = "default")
R_FR(sun.spct, naming = "none")
R_FR(sun.spct, naming = "short")
R_FR(sun.spct, naming = "long")
R_FR(sun.spct, name.tag = "")
```

```
# default, multiple spectra
R_FR(sun_evening.spct)
R_FR(sun_evening.mspct)
R_FR(sun_evening.mspct, naming = "long")
R_FR(sun_evening.mspct, name.tag = "")

# different waveband definitions
R_FR(sun.spct, std = "Smith10")
R_FR(sun.spct, std = "Smith20")
R_FR(sun.spct, std = "Sellaro")
R_FR(sun.spct, std = "Apogee")
R_FR(sun.spct, std = "Apogee", naming = "long")

FR_ePAR(sun.spct)
FR_ePAR(sun.spct, "Smith10")
FR_ePAR(sun.spct, "Smith20")
FR_ePAR(sun.spct, "Sellaro")

FR_PAR(sun.spct)
FR_PAR(sun.spct, "Smith10")
FR_PAR(sun.spct, "Smith20")
FR_PAR(sun.spct, "Sellaro")

FR_RpFR(sun.spct)
FR_RpFR(sun.spct, "Smith10")
FR_RpFR(sun.spct, "Smith20")
FR_RpFR(sun.spct, "Sellaro")

R_RpFR(sun.spct)
R_RpFR(sun.spct, "Smith10")
R_RpFR(sun.spct, "Smith20")
R_RpFR(sun.spct, "Sellaro")

B_G(sun.spct)

UVB_UV(sun.spct)

UVB_UVA(sun.spct)

UVA_UV(sun.spct)

UVAlw_UV(sun.spct)

UVAsw_UV(sun.spct)

UV_PAR(sun.spct)

UVB_PAR(sun.spct)

UVA_PAR(sun.spct)

UVA1_UV(sun.spct)
```

```
UVA2_UV(sun.spct)

UVA2_UVA(sun.spct)

UVA1_UVA(sun.spct)
```

PHOTs.mspct *PHOT1 and PHOT2 absorbance spectra.*

Description

A dataset containing the wavelengths at an arbitrary nm interval for plant photoreceptors phototropin 1 and phototropin 2. Tabulated values for the in vitro absorbance spectrum of PHOT1 LOV2 domain for fluorescence yield of PHOT1 and PHOT2 from *Arabidopsis thaliana* measured in vitro. PHOT1 fluorescence yield data were digitized from figure 1a curve "LOV1 + LOV2 (WT) and PHOT2 fluorescence yield data were digitized from figure 7a curve "LOV1 + LOV2 (WT) in Christie et al. (2002). PHOT1 LOV2, dark adapted, spectral absorbance data were digitized from figure 3, black curve and PHOT1 LOV2, blue-light adapted spectral absorbance data were digitized from figure 3, blue curve in Christie et al. (2015).

Format

A `filter_mspct` with five member `filter_spct` objects each with 300 rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

CHRISTIE, John M., SWARTZ, Trevor E., BOGOMOLNI, Roberto A., BRIGGS, Winslow R. (2002) Phototropin LOV domains exhibit distinct roles in regulating photoreceptor function. The Plant Journal 32(2):205-219.

CHRISTIE, J. M., BLACKWOOD, L., PETERSEN, J., SULLIVAN, S. (2015) Plant Flavoprotein Photoreceptors. Plant and Cell Physiology. 56(3):401-413.

PHYs.mspct *Tabulated data for Phytochrome Sigma*

Description

A dataset containing the wavelengths at a 1 nm interval. Tabulated values for Sigma R and Sigma FR for Type I Phytochrome as compiled by Mancinelli (1994).

The variables are as follows:

- wavelength (nm)
- Sigma.R (quantum effectiveness)
- Sigma.FR (quantum effectiveness)

Usage

```
PHYs.mspct
```

Format

A `generic_mspct` with one member `generic_spct` object with 49 rows and 3 numeric variables, `w.length`, `Sigma.R` and `Sigma.FR`.

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

Other phytochrome-related functions and data: `Pfr_Ptot()`, `Pfr_Ptot_R_FR()`, `Phy_Sigma()`, `Phy_Sigma_FR()`, `Phy_Sigma_R()`, `Phy_reaction_rates()`

Phy_reaction_rates *Phytochrome reaction rates*

Description

Rate constants k_1 Pr -> Pfr; k_2 Pfr -> Pr; photoconversion rate $\nu = k_1 + k_2$ for Type I Phytochrome.

Usage

```
Phy_reaction_rates(
  w.length,
  s.irrad,
  unit.in = "energy",
  check.spectrum = TRUE,
  use.cached.mult = FALSE
)
```

Arguments

w.length	numeric array of wavelength (nm)
s.irrad	numeric array of spectral (energy) irradiances (W m-2 nm-1) or (mol s-1 m-2)
unit.in	character string with allowed values "energy", and "photon", or its alias "quantum"
check.spectrum	logical indicating whether to sanity check input data, default is TRUE
use.cached.mult	logical indicating whether multiplier values should be cached between calls

Value

a list of three numeric values giving the photoconversion rate (ν) and reaction rates (k_1, k_2).

References

Hayward, P. M. (1984) Determination of phytochrome parameters from radiation measurements. In Techniques in Photomorphogenesis, H. Smith and M. G. Holmes (eds). Academic Press, London, pp. 159-173. ISBN 0-12-652990-6.

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

q_ratio and e_ratio

Other phytochrome-related functions and data: PHYs.mspct, Pfr_Ptot(), Pfr_Ptot_R_FR(), Phy_Sigma(), Phy_Sigma_FR(), Phy_Sigma_R()

Examples

```
library(photobiology)
trimmed.sun.spct <- trim_wl(sun.spct, range = c(300, 770))
with(trimmed.sun.spct, Phy_reaction_rates(w.length, s.e.irrad))
```

Phy_Sigma *Phytochrome Sigma as a function of wavelength*

Description

Phytochrome Sigma as a function of wavelength, calculated by interpolation from data for Type I Phytochrome as compiled by Mancinelli (1994).

Usage

```
Phy_Sigma(w.length)
```

Arguments

w.length	numeric array of wavelength (nm)

Value

a numeric array with values for Sigma

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

Other phytochrome-related functions and data: PHYs.mspct, Pfr_Ptot(), Pfr_Ptot_R_FR(), Phy_Sigma_FR(), Phy_Sigma_R(), Phy_reaction_rates()

Examples

```
with(sun.data, Phy_Sigma(w.length))
```

`Phy_Sigma_FR` *Pfr Sigma as a function of wavelength*

Description

Pfr Sigma as a function of wavelength, calculated by interpolation from data for Type I Phytochrome as compiled by Mancinelli (1994).

Usage

```
Phy_Sigma_FR(w.length, use.cached.mult = FALSE)
```

Arguments

`w.length`	numeric array of wavelength (nm)
`use.cached.mult`	logical ignored

Value

a numeric array with values for Sigma

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

Other phytochrome-related functions and data: `PHYs.mspct`, `Pfr_Ptot()`, `Pfr_Ptot_R_FR()`, `Phy_Sigma()`, `Phy_Sigma_R()`, `Phy_reaction_rates()`

Examples

```
with(sun.spct, Phy_Sigma_FR(w.length))
with(sun.spct, Phy_Sigma_FR(w.length, TRUE))
```

Phy_Sigma_R *Pr Sigma as a function of wavelength*

Description

Pr Sigma as a function of wavelength, calculated by interpolation from data for Type I Phytochrome as compiled by Mancinelli (1994).

Usage

```
Phy_Sigma_R(w.length, use.cached.mult = FALSE)
```

Arguments

w.length	numeric array of wavelength (nm)
use.cached.mult	logical ignored

Value

a numeric array with values for Sigma

References

Mancinelli, A.L. (1994) The physiology of phytochrome action. In Photomorphogenesis in plants, 2nd edition. R.E. Kendrick and G.H.M. Kronenberg, eds. Kluwer Academic Publishers, Dordrecht, pp. 211-269. ISBN 978-0-7923-2551-2 (print), 978-94-011-1884-2 (on-line). doi:10.1007/97894-01118842_10

See Also

Other phytochrome-related functions and data: PHYs.mspct, Pfr_Ptot(), Pfr_Ptot_R_FR(), Phy_Sigma(), Phy_Sigma_FR(), Phy_reaction_rates()

Examples

```
with(sun.data, Phy_Sigma_R(w.length))
with(sun.data, Phy_Sigma_R(w.length, TRUE))
```

PQ_redox_state *Redox state of the plastoquinone pool*

Description

Estimate the redox state of the plastoquinone (PQ) pool from spectral irradiance.

Usage

```
PQ_redox_state(
  light.spct,
  coefs.spct = photobiologyPlants::PS1_PS2_k.spct,
  w.band = photobiologyWavebands::PAR(),
  force.to.range = TRUE,
  ...
)

## Default S3 method:
PQ_redox_state(
  light.spct,
  coefs.spct = photobiologyPlants::PS1_PS2_k.spct,
  w.band = photobiologyWavebands::PAR(),
  force.to.range = TRUE,
  ...
)

## S3 method for class 'source_spct'
PQ_redox_state(
  light.spct,
  coefs.spct = photobiologyPlants::PS1_PS2_k.spct,
  w.band = photobiologyWavebands::PAR(),
  force.to.range = TRUE,
  return.tb = !is.null(attr2tb),
  attr2tb = NULL,
  ...
)

## S3 method for class 'source_mspct'
PQ_redox_state(
  light.spct,
  coefs.spct = photobiologyPlants::PS1_PS2_k.spct,
  w.band = photobiologyWavebands::PAR(),
  force.to.range = TRUE,
  return.tb = TRUE,
  attr2tb = NULL,
  idx = "spct.idx",
  ...,
```

```
  .parallel = FALSE,
  .paropts = NULL
)
```

Arguments

light.spct	A source_spct object or a source_mspct object.
coefs.spct	A generic_spct object containing the coefficients of the fitted model. Defaults to those in Mattila et al. (2020).
w.band	A waveband object setting the waveband used for scaling each the spectral irradiance(s) in light.spct. Defaults to PAR as used in Mattila et al. (2020).
force.to.range	logical If TRUE, convert negative values into zero.
...	currently ignored.
return.tb	logical If TRUE force return of a data frame for a single spectrum, to match the returned class for collections of spectra.
attr2tb	character vector, see add_attr2tb the syntax for attr2tb passed as is to formal parameter col.names.
idx	character Name of the column with the names of the members of the collection of spectra.
.parallel	if TRUE, apply function in parallel, using parallel backend provided by foreach
.paropts	a list of additional options passed into the foreach function when parallel computation is enabled. This is important if (for example) your code relies on external data or packages: use the .export and .packages arguments to supply them so that all cluster nodes have the correct environment set up for computing.

Details

The computations follow the procedure in Mattila et al. (2020). The spectrum in light.spct is re-expressed by interpolation to the wavelengths from coefs.spct. As in Mattila et al. (2020) the state is expressed as percent of the PQ pool that is reduced. If the result of the computation is used in a publication, please, cite both Mattila et al. (2020) and this R package.

Value

A numeric vector, with one value for each spectrum in the input, or a data frame.

References

Mattila H, Khorobrykh S, Hakala-Yatkin M, Havurinne V, Kuusisto I, Antal T, Tyystjärvi T, Tyystjärvi E. 2020. Action spectrum of the redox state of the plastoquinone pool defines its function in plant acclimation. The Plant Journal 104, 1088–1104. doi:10.1111/tpj.14983.

Examples

```
PQ_redox_state(sun.spct) # PAR is default for scaling
PQ_redox_state(sun.spct, w.band = c(370, 730)) # scaling with wavelength range
PQ_redox_state(sun.spct, attr2tb = "what.measured")
PQ_redox_state(white_led.source_spct)
PQ_redox_state(sun_evening.mspct)
PQ_redox_state(sun_evening.mspct, attr2tb = "when.measured")
PQ_redox_state(sun_evening.spct)
```

PS1_PS2_k.spct *Coefficients for redox state of the plastoquinone pool*

Description

The variables are as follows:

Usage

```
PS1_PS2_k.spct
```

Format

`generic_spct` object with 351 rows and 2 variables.

Details

- w.length (nm)
- k

where k contains fitted coefficients of a model for estimating the redox state of the plastoquinone pool (Mattila et al., 2020). Based on measurements in *Arabidopsis* plants. If used in a publication, please, cite both Mattila et al. (2020) and this R package.

See Also

`PQ_redox_state()`

`rs_from_size` *Stomatal conductance from sizes and density*

Description

Computations based on mass transfer through pores.

Usage

```
rs_from_size(length, width = length, depth, num = 1, D)

gs_from_size(length, width = length, depth, num = 1, D)

gs_w_from_size(length, width = length, depth, num = 1, temperature)

gs_c_from_size(length, width = length, depth, num = 1, temperature)
```

Arguments

`length`, `width`	numeric "Length" and "width" of the stomatal opening, i.e., the major and minor diameters of the ellipse describing the stomatal pore's mean cross section [m].
`depth`	numeric The depth (or diffusion path length) of the stomatal pore [m].
`num`	numeric Number of stomata per unit area [m^{-2}].
`D`	numeric Diffusion coefficient of the gas [$m^2\ s^{-1}$].
`temperature`	numeric Leaf temperature. Used to estimate the diffusion coefficient `D`.

Details

The equation for r_s from Monteith and Unsworth (2008):

$$r_s = \frac{4(l + \pi\, d/8)}{\pi\, n\, d^2\, D}$$

is used to compute diffusive resistance in function `rs_from_size()`, which can be used to obtain diffusive resistance from a known size of a pore with circular or elliptical cross section. The value of `D`, the diffusion should match that of water vapour or CO_2, and its unit of expression determines the whether the returned value is expressed as the inverse of a volume or molar flux rate.

Functions `gs_from_size()`, `gs_w_from_size()` and `gs_c_from_size()` are convenience wrappers.

Arguments are expected in SI units with no scale multiplier. Enter dimensions in micrometers using scientific notation, e.g., `length = 20e-6` for a pore length of $20\,\mu m$ and `n = 10e6` for a density of $10\,mm^{-2}$.

Value

A numeric vector of resistances expressed in $s\,m^{-1}$ or $s\,mol^{-1}$, or of conductances expressed in $m\,s^{-1}$ or in $mol\,m^{-2}\,s^{-1}$ when the density expressed in estomata per m^2 is passed as argument to n. With the default of n = 1 the diffusive conductance per individual pore is returned expressed, e.g., for molar conductance, in $mol\,s-1$.

Note

This is an approximate computation as plant stomata have a section that varies with depth. The equation incorporates a single end correction and assumes no interference among the flows from neighbouring stomata crossing the bounday layer.

References

Monteith, J. L. and Unsworth M. H. (2008) Principles of Environmental Physics (3ed) Academic Press-Elsevier. ISBN: 978-0-12-505103-3. See Section 11.4 Mass transfer through pores.

See Also

Functions D_water() and D_CO2() can be used to compute the diffusion coefficients as a function of temperature. In addition function molar_vol() computes the molar volume of an ideal gas as a function of temperature and pressure. Functions gs_mol2vol() and gs_vol2mol() interconvert conductances between molar and volume bases of expression. These functions are used internally in the functions described here.

Examples

```
# a single round stomatal pore
gs_from_size(length = 20e-6, depth = 5e-6, D = D_water(23))

# a single elliptical stomatal pore
gs_from_size(length = 30e-6, width = 10e-6, depth = 5e-6, D = D_water(23))

# 200 circular stomatal pores per mm^2
rs_from_size(length = 5e-6,
             width = 5e-6,
             depth = 10e-6,
             num = 200e6,
             D = D_water(25))

# 50 elliptical stomatal pores per mm^2
rs_from_size(length = 10e-6,
             width = 5-6,
             depth = 20e-6,
             num = 50e6,
             D = D_water(23))

# a single round stomatal pore with dimensions in micrometers
gs_from_size(length = 20, depth = 5, D = D_water(23))
```

`Solidago_altissima.mspct` *Spectral optical data for 'Solidago altissima' leaves*

Description

A dataset containing for wavelengths at a 1 nm interval in the range 350 to 1000 nm, tabulated values for total reflectance and total transmittance, for the upper and lower epidermis of one leaf from the upper part of a shoot and another one from the lower part of a shoot of tall goldenrod (*Solidago altissima*).

The variables in each spectrum are as follows:

- w.length (nm)
- Rfr
- Tfr

Usage

```
Solidago_altissima.mspct
```

Format

`object_mspct` collection object with four `object_spct` member objects, each with 651 rows and 3 variables

Note

We thank H. M. Noda for allowing us to include these data in our package. We have included here only data for two leaves from one species (*Solidago altissima*) and for wavelengths shorter than 1000 nm, from the much larger original data set. The whole data set is publicly available and the data easy to read into R. The data included here where measured with a Li-Cor LI-1800 spectroradiometer equipped with a LI-1800-12 (Li-Cor) integrating sphere, and consequently are for total reflectance and total transmittance. Further details on methods are available through the JaLTER web site. If you use these data in a publication, please cite the original source as given under references and contact the original author. In addition cite this package.

References

Noda H. 'Reflectance and transmittance spectra of leaves and shoots of 22 vascular plant species and reflectance spectra of trunks and branches of 12 tree species in Japan' ERDP-2013-02.1.1 (http://db.cger.nies.go.jp/JaLTER/metacat/metacat/ERDP-2013-02.1.1/jalter-en)
JaLTER, Japan Long Term Ecological Research Network, http://www.jalter.org/

`UVR8s.mspct` *UVR8 absorbance spectrum*

Description

A dataset containing the wavelengths at an arbitrary nm interval. Tabulated values for the in vitro absorbance spectrum of UVR8.

Format

A `filter_spct` object with two member `filter_spct` objects.

Details

The variables are as follows:

- w.length (nm)
- A (spectral absorbance)

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

Christie, J. M., A. S. Arvai, K. J. Baxter, M. Heilmann, A. J. Pratt, A. O'Hara, S. M. Kelly, M. Hothorn, B. O. Smith, K. Hitomi, et al. (2012). Plant UVR8 photoreceptor senses UV-B by tryptophan-mediated disruption of cross-dimer salt bridges. In: Science (New York, N.Y.) 335.6075, pp. 1492-1496. doi:10.1126/science.1218091. (Figure S3)

Neha Rai Andrew O'Hara Daniel Farkas Omid Safronov Khuanpiroon Ratanasopa Fang Wang Anders V. Lindfors Gareth I. Jenkins Tarja Lehto Jarkko Salojärvi Mikael Brosché Åke Strid Pedro J. Aphalo Luis O. Morales (2020) The photoreceptor UVR8 mediates the perception of both UV-B and UV-A wavelengths up to 350 nm of sunlight with responsivity moderated by cryptochromes. Plant Cell and Environment, early on-line. doi:10.1111/pce.13752. (Figure S7)

Examples

```
names(UVR8s.mspct)
getWhatMeasured(UVR8s.mspct[[1]])
```

water_vp_sat *Water vapour pressure*

Description

Approximate water pressure in air as a function of temperature, and its inverse the calculation of dewpoint.

Usage

```
water_vp_sat(
  temperature,
  over.ice = FALSE,
  method = "tetens",
  check.range = TRUE
)

water_dp(water.vp, over.ice = FALSE, method = "tetens", check.range = TRUE)

water_fp(water.vp, over.ice = TRUE, method = "tetens", check.range = TRUE)

water_vp2mvc(water.vp, temperature)

water_mvc2vp(water.mvc, temperature)

water_vp2RH(
  water.vp,
  temperature,
  over.ice = FALSE,
  method = "tetens",
  pc = TRUE,
  check.range = TRUE
)

water_RH2vp(
  relative.humidity,
  temperature,
  over.ice = FALSE,
  method = "tetens",
  pc = TRUE,
  check.range = TRUE
)

water_vp_sat_slope(
  temperature,
  over.ice = FALSE,
  method = "tetens",
```

```
  check.range = TRUE,
  temperature.step = 0.1
)

psychrometric_constant(atmospheric.pressure = 101325)
```

Arguments

temperature	numeric vector of air temperatures (C).
over.ice	logical vector Is the estimate for equilibrium with liquid water or with ice.
method	character Currently "tetens", modified "magnus", "wexler" and "goff.gratch" equations are supported.
check.range	logical Flag indicating whether to check or not that arguments for temperature are within the range of validity of the method used.
water.vp	numeric vector of water vapour pressure in air (Pa).
water.mvc	numeric vector of water vapour concnetration as mass per volume (gm^{-3}).
pc	logical flag for result returned as percent or not.
relative.humidity	numeric Relative humidity as fraction of 1.
temperature.step	numeric Delta or step used to estimate the slope as a finite difference (C).
atmospheric.pressure	numeric Atmospheric pressure (Pa).

Details

Function water_vp_sat() provides implementations of several well known equations for the estimation of saturation vapor pressure in air. Functions water_dp() and water_fp() use the inverse of these equations to compute the dew point or frost point from water vapour pressure in air. The inverse functions are either analytical solutions or fitted approximations. None of these functions are solved numerically by iteration.

Method "tetens" implements Tetens' (1930) equation for the cases of equilibrium with a water and an ice surface. Method "magnus" implements the modified Magnus equations of Alduchov and Eskridge (1996, eqs. 21 and 23). Method "wexler" implements the equations proposed by Wexler (1976, 1977), and their inverse according to Hardy (1998). Method "goff.gratch" implements the equations of Groff and Gratch (1946) with the minor updates of Groff (1956).

The equations are approximations, and in spite of their different names, Tetens' and Magnus' equations have the same form with the only difference in the values of the parameters. However, the modified Magnus equation is more accurate as Tetens equation suffers from some bias errors at extreme low temperatures (< -40 C). In contrast Magnus equations with recently fitted values for the parameters are usable for temperatures from -80 C to +50 C over water and -80 C to 0 C over ice. The Groff Gratch equation is more complex and is frequently used as a reference in comparison as it is considered reliable over a broad range of temperatures. Wexler's equations are computationally simpler and fitted to relatively recent data. There is little difference at temperatures in the range -20 C to +50 C, and differences become large at extreme temperatures. Temperatures outside the range

where estimations are highly reliable for each equation return NA, unless extrapolation is enabled by passing FALSE as argument to parameter check.range.

The switch between equations for ice or water cannot be based on air temperature, as it depends on the presence or not of a surface of liquid water. It must be set by passing an argument to parameter over.ice which defaults to FALSE.

Tetens equation is still very frequently used, and is for example the one recommended by FAO for computing potential evapotranspiration. For this reason it is used as default here.

Value

A numeric vector of partial pressures in pascal (Pa) for water_vp_sat() and water_mvc2vp(), a numeric vector of dew point temperatures (C) for water_dp() and numeric vector of mass per volume concentrations (gm^{-3}) for water_vp2mvc(). water_vp_sat() and psychrometric_constant() both return numeric vectors of pressure per degree of temperature (PaC^{-1})

Note

The inverse of the Groff Gratch equation has yet to be implemented.

References

Tetens, O., 1930. Uber einige meteorologische Begriffe. Zeitschrift fur Geophysik, Vol. 6:297.

Goff, J. A., and S. Gratch (1946) Low-pressure properties of water from -160 to 212 F, in Transactions of the American Society of Heating and Ventilating Engineers, pp 95-122, presented at the 52nd annual meeting of the American Society of Heating and Ventilating Engineers, New York, 1946.

Wexler, A. (1976) Vapor Pressure Formulation for Water in Range 0 to 100°C. A Revision, Journal of Research ofthe National Bureau of Standards: A. Physics and Chemistry, September-December 1976, Vol. 80A, Nos.5 and 6, 775-785

Wexler, A., (1977) Vapor Pressure Formulation for Ice, Journal of Research of the National Bureau of Standards - A. Physics and Chemistry, Vol. 81A, No. 1, 5-19

Alduchov, O. A., Eskridge, R. E., 1996. Improved Magnus Form Approximation of Saturation Vapor Pressure. Journal of Applied Meteorology, 35: 601-609 .

Hardy, Bob (1998) ITS-90 formulations for vapor pressure, frostpoint temperature, dewpoint temperature, andenhancement factors in the range -100 TO +100 C. The Proceedings of the Third International Symposium on Humidity & Moisture, Teddington, London, England, April 1998. https://www.decatur.de/javascript/dew/resources/its90formulas.pdf

Monteith, J., Unsworth, M. (2008) Principles of Environmental Physics. Academic Press, Amsterdam.

Allen R G, Pereira L S, Raes D, Smith M. (1998) Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Rome: FAO.

[Equations describing the physical properties of moist air](http://www.conservationphysics.org/atmcalc/atmoclc2.pdf)

See Also

Other Evapotranspiration and energy balance related functions.: ET_ref(), net_irradiance()

Examples

```
water_vp_sat(20) # C -> Pa
water_vp_sat(temperature = c(0, 10, 20, 30, 40)) # C -> Pa
water_vp_sat(temperature = -10) # over water!!
water_vp_sat(temperature = -10, over.ice = TRUE)
water_vp_sat(temperature = 20) / 100 # C -> mbar

water_vp_sat(temperature = 20, method = "magnus") # C -> Pa
water_vp_sat(temperature = 20, method = "tetens") # C -> Pa
water_vp_sat(temperature = 20, method = "wexler") # C -> Pa
water_vp_sat(temperature = 20, method = "goff.gratch") # C -> Pa

water_vp_sat(temperature = -20, over.ice = TRUE, method = "magnus") # C -> Pa
water_vp_sat(temperature = -20, over.ice = TRUE, method = "tetens") # C -> Pa
water_vp_sat(temperature = -20, over.ice = TRUE, method = "wexler") # C -> Pa
water_vp_sat(temperature = -20, over.ice = TRUE, method = "goff.gratch") # C -> Pa

water_dp(water.vp = 1000) # Pa -> C
water_dp(water.vp = 1000, method = "magnus") # Pa -> C
water_dp(water.vp = 1000, method = "wexler") # Pa -> C
water_dp(water.vp = 500, over.ice = TRUE) # Pa -> C
water_dp(water.vp = 500, method = "wexler", over.ice = TRUE) # Pa -> C

water_fp(water.vp = 300) # Pa -> C
water_dp(water.vp = 300, over.ice = TRUE) # Pa -> C

water_vp2RH(water.vp = 1500, temperature = 20) # Pa, C -> RH %
water_vp2RH(water.vp = 1500, temperature = c(20, 30)) # Pa, C -> RH %
water_vp2RH(water.vp = c(600, 1500), temperature = 20) # Pa, C -> RH %

water_vp2mvc(water.vp = 1000, temperature = 20) # Pa -> g m-3

water_mvc2vp(water.mvc = 30, temperature = 40) # g m-3 -> Pa

water_dp(water.vp = water_mvc2vp(water.mvc = 10, temperature = 30)) # g m-3 -> C


water_vp_sat_slope(temperature = 20) # C -> Pa / C


psychrometric_constant(atmospheric.pressure = 81.8e3) # Pa -> Pa / C
```

`ZTLs.mspct` *ZTL absorbance spectra.*

Description

A dataset containing the wavelengths at an arbitrary nm interval. Tabulated values for the in vitro absorbance spectrum of ZTL LOV2 domain from Arabidopsis measured in vitro. Data were digitized from figure 2B in Zoltowski and Imaizumi (2014).

Format

A `filter_mspct` with five member `filter_spct` objects each with 300 rows and 2 numeric variables, `w.length` and `A`

Details

The variables of the member spectra are as follows:

- w.length (nm)
- A (spectral absorbance)

Note

If you use these data in a publication, please cite also the original source as given under references in addition to this package.

References

Zoltowski, B. D., Imaizumi, T. (2014). Structure and Function of the ZTL/FKF1/LKP2 Group Proteins in Arabidopsis. Enzymes, 35, 213-39.

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