Package ‘photobiologyPlants’

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Type Package

Title 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>.

VignetteBuilder knitr

Depends R (>= 4.1.0), photobiology (>= 0.14.0), photobiologyWavebands (>= 0.5.3)

Suggests knitr (>= 1.50), rmarkdown (>= 2.29), ggplot2 (>= 3.5.0), ggspectra (>= 0.3.17), testthat (>= 3.2.3)

LazyLoad yes

LazyData yes

ByteCompile true

Encoding UTF-8

URL https://docs.r4photobiology.info/photobiologyPlants/
https://github.com/aphalo/photobiologyplants

BugReports https://github.com/aphalo/photobiologyplants/issues

RoxygenNote 7.3.3

Config/testthat/edition 2

NeedsCompilation no

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photobiologyPlants: Plant Photobiology Related Functions and Data

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Description

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Details

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

Acknowledgements

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Author(s)

Maintainer: Pedro J. Aphalo <pedro.aphalo@helsinki.fi> (ORCID)

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.

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
```

`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 of K. J. McCree (1972) for *Amaranthus edulis* Speg. var. UCD 1966 and *Avena sativa* L. var. Coronado 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.

See Also

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

Examples

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

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, ..., na.rm = FALSE)
```

Arguments

x	an R object
...	not used
spct.out	logical Flag indicating if the returned object should be of class response_spct instead of numeric.
na.rm	logical. If TRUE link[stats]{na.omit} is first called on x.

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.

Value

If x is numeric, giving wavelengths (nm), a vector of numeric values giving the P_{fr}/P_{tot} at each wavelength or a generic_spct object with the wavelength values sorted in ascending order and the corresponding P_{fr}/P_{tot} values in column s.q.response.

If x is a source_spct object, a single numeric value giving the P_{fr}/P_{tot}.

Methods (by class)

- Pfr_Ptot(default): Default for generic function
- Pfr_Ptot(numeric): Specialization for numeric
- Pfr_Ptot(source_spct): Specialization for source_spct
  Calculate phytochrome photoequilibrium from spectral (photon) irradiance

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
Pfr_Ptot(sun.spct) # spectrum of terrestrial sunligth
```

`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,
  ...
)

## 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.
`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))
```

`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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