Package 'photobiologyWavebands'

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Type Package

Title Waveband Definitions for UV, VIS, and IR Radiation

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Maintainer Pedro J. Aphalo <pedro.aphalo@helsinki.fi>

Description Constructors of waveband objects for commonly used biological spectral weighting functions (BSWFs) and for different wavebands describing named ranges of wavelengths in the ultraviolet (UV), visible (VIS) and infrared (IR) regions of the electromagnetic spectrum. Part of the 'r4photobiology' suite, Aphalo P. J. (2015) <doi:10.19232/uv4pb.2015.1.14>.

VignetteBuilder knitr

Depends R (>= 4.0.0), photobiology (>= 0.13.0)

Suggests knitr (>= 1.50), rmarkdown (>= 2.29), testthat (>= 3.0.0)

LazyLoad yes

LazyData yes

ByteCompile true

Encoding UTF-8

URL https://docs.r4photobiology.info/photobiologyWavebands/,
https://github.com/aphalo/photobiologywavebands

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

RoxygenNote 7.3.3

Config/testthat/edition 3

NeedsCompilation no

Author Pedro J. Aphalo [aut, cre] (ORCID:
<https://orcid.org/0000-0003-3385-972X>),
Titta K. Kotilainen [ctb] (ORCID:
<https://orcid.org/0000-0002-2822-9734>)

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Contents

`photobiologyWavebands-package`

photobiologyWavebands: Waveband Definitions for UV, VIS, and IR Radiation

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Description

Constructors of waveband objects for commonly used biological spectral weighting functions (BSWFs) and for different wavebands describing named ranges of wavelengths in the ultraviolet (UV), visible (VIS) and infrared (IR) regions of the electromagnetic spectrum. Part of the 'r4photobiology' suite, Aphalo P. J. (2015) doi:10.19232/uv4pb.2015.1.14.

Details

Package 'photobiologyWavebands' provides constructors for objects of class `waveband` from package 'photobiology'. These contructors are based on standard definitions or frequently used non-standardized definitions. When different definitions are in common use for a given named waveband the constructors accept an argument to chose among them. Whenever an ISO standard provides a definition, this is used by default. In the infrared (IR) there are many different definitions and waveband names in use. We have tried to include most of the commonly used names and definitions.

Definitions "matching" the different bands of Landsat imagers are included. These are simple wavelength ranges for wavelengths at half-maximun response as given in the NASA literature, which in some cases presents small inconsistencies. These definitions cannot exactly reproduce instrument responses as they do not describe the real spectral responsiveness of the satellite imagers.

By necessity we cover only a subset of all definitions in use. These should be thought as convenience functions, as waveband objects according to any arbitrary definition can be constructed with the constructor provided by package `photobiology-package`.

Author(s)

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

Other contributors:

- Titta K. Kotilainen `<titta.kotilainen@helsinki.fi>` (ORCID) [contributor]

References

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See Also

Useful links:

- https://docs.r4photobiology.info/photobiologyWavebands/
- https://github.com/aphalo/photobiologywavebands
- Report bugs at https://github.com/aphalo/photobiologywavebands/issues

Examples

```
q_irrad(sun.spct, PAR())  # PAR photon irradiance
q_irrad(sun.spct, Blue("ISO")) # blue photon irradiance, ISO definition
q_irrad(sun.spct, Blue("Sellaro")) # blue photon irradiance, Sellaro et al.'s definition
e_irrad(sun.spct, VIS()) # VIS irradiance, ISO definition
q_irrad(sun.spct, VIS()) # VIS photon, ISO definition
```

Blue — *Constructor of blue waveband*

Description

Wavelength-range definitions for *blue* light according to ISO or as commonly used in plant or remote sensing applications.

Usage

```
Blue(std = "ISO")
```

Arguments

`std`	a character string "ISO", "Sellaro", "Broad", "RS" (remote sensing), or Landsat imagers, "LandsatTM", "LandsatETM", or "LandsatOLI".

Details

The different arguments passed to formal parameter `std` determine the range of wavelengths set as boundaries of the returned `waveband` object; `"ISO"` is standardized definition based on human colour vision; `"Sellaro"` and `"Broad"` are non-standard but used in plant sciences; `"RS"` is non-standard but frequently used in remote sensing; the remaining definitions are for the published wavelength sensitivity range of imagers (cameras) in the Landsat satellite missions.

Value

A waveband object defining a wavelength range.

Note

The bands are defined as square windows, these can be applied to spectral data to obtain the "true" values, but they do not simulate the sensitivity of broad-band sensors or the spectral transmittance of ionic filters. Some band-pass interference filters may have very sharp cut-in and cut-off, and their effect can be approximated by a square window, but filters based on light absorption will show gradual tails and bell-shaped wavelength-windows. The Landsat instruments have very steep cut-in and cut-off slopes and are well approximated.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

ISO (2007) Space environment (natural and artificial) - Process for determining solar irradiances. ISO Standard 21348. ISO, Geneva.

Sellaro, R., Crepy, M., Trupkin, S. A., Karayekov, E., Buchovsky, A. S., Rossi, C., & Casal, J. J. (2010). Cryptochrome as a sensor of the blue/green ratio of natural radiation in Arabidopsis. Plant physiology, 154(1), 401-409. doi:10.1104/pp.110.160820.

See Also

waveband

Other unweighted wavebands: Far_red(), Green(), IR(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS(), Yellow()

Examples

```
Blue()
Blue("ISO")
Blue("Sellaro")

e_irrad(sun.spct, Blue()) # W m-2
q_irrad(sun.spct, Blue()) # mol m-2
q_irrad(sun.spct, Blue(), scale.factor = 1e6) # umol m-2
```

CH4 *Constructor of CH4 production from pectin weighted waveband*

Description

Methane production from pectin BSWF

Usage

```
CH4(norm = 300, w.low = 275, w.high = 400)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

References

Bloom, A. A.; Lee-Taylor, J.; Madronich, S.; Messenger, D. J.; Palmer, P. I.; Reay, D. S. & McLeod, A. R. (2010) Global methane emission estimates from ultraviolet irradiation of terrestrial plant foliage. New Phytologist, Blackwell Publishing Ltd, 187, 417–425 .

See Also

waveband

Other BSWF weighted wavebands: DNA_GM(), DNA_N(), DNA_P(), FLAV(), GEN_G(), GEN_M(), GEN_T(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
CH4()
CH4(norm = 400)
```

CH4_e_fun — *Gives values for the CH4 production from pectin BSWF as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on quantum based effectiveness relative units.

Usage

```
CH4_e_fun(w.length)
```

Arguments

`w.length`	numeric array of wavelengths (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source (300 nm) and based on energy effectiveness.

References

Bloom, A. A.; Lee-Taylor, J.; Madronich, S.; Messenger, D. J.; Palmer, P. I.; Reay, D. S. & McLeod, A. R. (2010) Global methane emission estimates from ultraviolet irradiation of terrestrial plant foliage. New Phytologist, Blackwell Publishing Ltd, 187, 417–425 .

See Also

Other BSWF functions: `CH4_q_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_GM_q_fun()`, `DNA_P_q_fun()`, `FLAV_q_fun()`, `GEN_G_q_fun()`, `GEN_M_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
CH4_e_fun(293:400)
```

CH4_q_fun — *Gives values for the CH4 production from pectin BSWF as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on quantum based effectiveness relative units.

Usage

```
CH4_q_fun(w.length)
```

Arguments

`w.length`	numeric array of wavelengths (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source (300 nm) but based on quantum effectiveness.

See Also

Other BSWF functions: `CH4_e_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_GM_q_fun()`, `DNA_P_q_fun()`, `FLAV_q_fun()`, `GEN_G_q_fun()`, `GEN_M_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
CH4_q_fun(293:400)
```

CIE1924_lef.spct — *CIE1924 luminous efficiency function (photopic human vision)*

Description

A dataset containing the wavelengths at a 1 nm interval. Tabulated values for quantum luminous efficiency according to CIE1924.

Usage

```
CIE1924_lef.spct
```

Format

A response.spct object with 471 rows and 2 variables

Details

The variables are as follows:

- w.length (nm)
- s.q.response

Note

This luminous efficiency function understimates the renponse to short wavelengths.

References

http://www.cvrl.org/ downloaded on 2015-01-24

CIE1951_scotopic_lef.spct
Luminous efficiency function (scotopic human vision)

Description

A dataset containing the wavelengths at a 1 nm interval. Tabulated values for quantum luminous efficiency at low light levels according to CIE1951.

Usage

```
CIE1951_scotopic_lef.spct
```

Format

A response.spct object with 401 rows and 2 variables

Details

The variables are as follows:

- w.length (nm)
- s.q.response

References

http://www.cvrl.org/ downloaded on 2015-01-24

`CIE2008_lef2deg.spct` *CIE2008 luminous efficiency function (2-deg) (photopic human vision)*

Description

A dataset containing the wavelengths at a 1 nm interval. Tabulated values for quantum luminous efficiency according to CIE2008 for 2 degrees.

Usage

```
CIE2008_lef2deg.spct
```

Format

A response.spct object with 441 rows and 2 variables

Details

The variables are as follows:

- w.length (nm)
- s.q.response

References

http://www.cvrl.org/ downloaded on 2015-01-24

`CIE_e_fun` *Gives values for the erythemal BSWF as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on quantum based effectiveness relative units.

Usage

```
CIE_e_fun(w.length)
```

Arguments

`w.length`	numeric array of wavelengths (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source (298 nm) and based on energy effectiveness.

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_q_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), FLAV_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), GEN_T_q_fun(), ICNIRP_e_fun(), PG_q_fun()

Examples

```
CIE_e_fun(293:400)
```

CIE_q_fun *Gives values for the erythemal BSWF as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on quantum based effectiveness relative units.

Usage

```
CIE_q_fun(w.length)
```

Arguments

w.length	numeric array of wavelengths (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source (298 nm) and based on quantum effectiveness.

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_e_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), FLAV_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), GEN_T_q_fun(), ICNIRP_e_fun(), PG_q_fun()

Examples

```
CIE_q_fun(293:400)
```

DNA_GM *Constructor of DNA damage (SETLOW) weighted waveband*

Description

Naked DNA damage BSWF, Green and Miller's formulation.

Usage

```
DNA_GM(norm = 300, w.low = 275, w.high = 400)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

See Also

waveband

Other BSWF weighted wavebands: CH4(), DNA_N(), DNA_P(), FLAV(), GEN_G(), GEN_M(), GEN_T(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
DNA_GM()
DNA_GM(300)
```

DNA_GM_q_fun *Gives values for naked DNA BSWF (SETLOW) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. It uses the seldom used Green and Miller formulation.

Usage

```
DNA_GM_q_fun(w.length)
```

Arguments

w.length	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

See Also

Other BSWF functions: `CH4_e_fun()`, `CH4_q_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_P_q_fun()`, `FLAV_q_fun()`, `GEN_G_q_fun()`, `GEN_M_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
DNA_GM_q_fun(293:400)
```

DNA_N *Constructor of DNA damage (SETLOW) weighted waveband*

Description

Naked DNA damage BSWF

Usage

```
DNA_N(norm = 300, w.low = 275, w.high = 400)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

See Also

`waveband`

Other BSWF weighted wavebands: `CH4()`, `DNA_GM()`, `DNA_P()`, `FLAV()`, `GEN_G()`, `GEN_M()`, `GEN_T()`, `PAR()`, `PG()`, `UV_health_hazard()`, `erythema()`

Examples

```
DNA_N()
DNA_N(300)
```

`DNA_N_q_fun` *Gives values for naked DNA BSWF (SETLOW) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances.

Usage

```
DNA_N_q_fun(w.length)
```

Arguments

`w.length`	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

Note

The digitized data as used in the TUV model covers the wavelength range from 256 nm to 364 nm. For longer wavelengths we set the value to zero, and for shorter wavelengths we extrapolate the value for 256 nm.

Examples

```
DNA_N_q_fun(293:400)
```

DNA_P *Constructor of DNA damage (Quaite) weighted waveband*

Description

Plant DNA damage BSWF as formulated by Musil.

Usage

```
DNA_P(norm = 300, w.low = 275, w.high = 400)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

See Also

waveband

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), FLAV(), GEN_G(), GEN_M(), GEN_T(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
DNA_P()
DNA_P(300)
```

DNA_P_q_fun *Gives values for plant DNA BSWF (Quaite) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. It uses the formulation proposed by Musil.

Usage

```
DNA_P_q_fun(w.length)
```

Arguments

`w.length`	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

See Also

Other BSWF functions: `CH4_e_fun()`, `CH4_q_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_GM_q_fun()`, `FLAV_q_fun()`, `GEN_G_q_fun()`, `GEN_M_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
DNA_P_q_fun(293:400)
```

---

erythema — *Constructor of erythema-weighted waveband*

Description

Erythema BSWF (1998 update)

Usage

```
erythema(std = "CIE98", norm = 298, w.low = 250, w.high = 400)

CIE(norm = 298, w.low = 250, w.high = 400)
```

Arguments

`std`	a character string, currently only "CIE98" supported.
`norm`	normalization wavelength (nm)
`w.low`	short-end boundary wavelength (nm)
`w.high`	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

Note

The erythema BSWF from CIE is specified by a mathematical formula, and this is used directly in the definition of the returned waveband.

Standard DIN 5031-10:2018-03 defines BSWF *er* as a table of interpolated values derived from CIE's definition from 1998. So, the values computed using this R package do not necessarily exactly match those according to DIN 5031-10:2018-03. The range of wavelengths used, 250 to 400 nm, does agree, with those in the standard.

References

Webb, A. R.; Slaper, H.; Koepke, P. & Schmalwieser, A. W. (2011) Know your standard: clarifying the CIE erythema action spectrum. Photochemistry and photobiology, 2011, 87, 483-486

DIN (2018) Standard DIN 5031-10:2018-03 Optical radiation physics and illuminating engineering. Part 10: Photobiologically effective radiation, quantities, symbols and action spectra. Beuth Verlag, Berlin 2018.

See Also

`waveband`

Other BSWF weighted wavebands: `CH4()`, `DNA_GM()`, `DNA_N()`, `DNA_P()`, `FLAV()`, `GEN_G()`, `GEN_M()`, `GEN_T()`, `PAR()`, `PG()`, `UV_health_hazard()`

Other BSWF weighted wavebands: `CH4()`, `DNA_GM()`, `DNA_N()`, `DNA_P()`, `FLAV()`, `GEN_G()`, `GEN_M()`, `GEN_T()`, `PAR()`, `PG()`, `UV_health_hazard()`

Examples

```
erythema()
erythema("CIE98")
CIE()
CIE(norm = 300)
erythema(norm = 300)
```

`Far_red` *Constructor of far-red waveband*

Description

Wavelength-range definitions for *far-red* light according as commonly used in plant or remote sensing applications.

Usage

```
Far_red(std = "ISO")
```

Arguments

`std`	a character string, defaults to "ISO", as for other colour definitions, which in this case returns `NA`.

Details

The different arguments passed to formal parameter `std` determine the range of wavelengths set as boundaries of the returned `waveband` object; far-red in not defined by `"ISO"` standard definitions based on human colour vision, and included under red; `"Smith10"`, `"Smith20"`, `"Inada"`, `"Warrington"`, `"Sellaro"`, `"Broad"` and `"Apogee"` are non-standard but used in plant sciences; `"RedEdge20"` and `"RedEdge40"` are non-standard but frequently used in remote sensing.

In plant photobiology the definitions proposed by Prof. Harry Smith are the most widely used, specially to compute a red to far-red photon ratio relevant to phytochrome photoreceptors. However, other authors have used different definitions in their publications. "Smith10" (725-735 nm), "Smith20" (720-740 nm), "Inada" (700-800 nm), "Warrington" (700-850 nm), and "Sellaro" (700-750 nm). "Apogee" is a definition given by a sensor manufacturer that matches "Smith20" for far-red.

Other definitions used in remote sensing. For example the "red edge" is to detect the condition of vegetation based on light reflectance by green vegetation. These bands are centred at the reflectance transition in the far-red band (725 nm), and here we define "RedEdge40" (705-745 nm) and "RedEdge20" (715-735 nm).

Value

A waveband object defining a wavelength range.

Note

The bands are defined as square windows, these can be applied to spectral data to obtain the "true" values, but they do not simulate the sensitivity of broad-band sensors or the spectral transmittance of ionic filters. Some band-pass interference filters may have very sharp cut-in and cut-off, and their effect can be approximated by a square window, but filters based on light absorption will show gradual tails and bell-shaped wavelength-windows.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

ISO (2007) Space environment (natural and artificial) - Process for determining solar irradiances. ISO Standard 21348. ISO, Geneva.

Murakami, K., Aiga I. (1994) Red/Far-red photon flux ratio used as an index number for morphological control of plant growth under artificial lighting conditions. Proc. Int. Symp. Artificial Lighting, Acta Horticulturae, 418, ISHS 1997.

Sellaro, R., Crepy, M., Trupkin, S. A., Karayekov, E., Buchovsky, A. S., Rossi, C., & Casal, J. J. (2010). Cryptochrome as a sensor of the blue/green ratio of natural radiation in Arabidopsis. Plant physiology, 154(1), 401-409. doi:10.1104/pp.110.160820.

Smith, H. (1982) Light quality, photoperception and plant strategy. Annual Review of Plant Physiology, 33:481-518. doi:10.1146/annurev.pp.33.060182.002405

See Also

NIR for wavebands close to the boundary between red and infrared regions.

waveband

Other unweighted wavebands: Blue(), Green(), IR(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS(), Yellow()

Examples

```
Far_red() # no ISO definition exists
Far_red("ISO") # no ISO definition exists
Far_red("Smith10") # 10 nm wide
Far_red("Smith20") # 20 nm wide
Far_red("Inada")
Far_red("Warrington")
Far_red("Sellaro")
Far_red("RedEdge40")
Far_red("RedEdge20")

e_irrad(sun.spct, Far_red("Smith10")) # W m-2
q_irrad(sun.spct, Far_red("Smith10")) # mol m-2
q_irrad(sun.spct, Far_red("Smith10"), scale.factor = 1e6) # umol m-2
```

FLAV — *Constructor of FLAV BSWF flavonoids*

Description

Mesembryanthin accumulation BSWF, data and formulation from Ibdah et al.

Usage

```
FLAV(norm = 300, w.low = 275, w.high = 346)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

References

Ibdah, M.; Krins, A.; Seidlitz, H. K.; Heller, W.; Strack, D. & Vogt, T. (2002) Spectral dependence of flavonol and betacyanin accumulation in Mesembryanthemum crystallinum under enhanced ultraviolet radiation. Plant, Cell & Environment, 25, 1145-1154. doi:10.1046/j.1365-3040.2002.00895.x

See Also

waveband

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), DNA_P(), GEN_G(), GEN_M(), GEN_T(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
FLAV()
FLAV(300)
```

FLAV_q_fun — *Gives values for FLAV BSWF (flavonoid) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. It is the action spectrum for the accumulation of mesembryanthin.

Usage

```
FLAV_q_fun(w.length)
```

Arguments

w.length	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_e_fun(), CIE_q_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), GEN_T_q_fun(), ICNIRP_e_fun(), PG_q_fun()

Examples

```
FLAV_q_fun(293:400)
```

GEN_G *Constructor of GPAS (Green's formulation) weighted waveband*

Description

Generalized Plant Action BSWF of Caldwell as formulated by Green et al.

Usage

```
GEN_G(norm = 300, w.low = 275, w.high = 313.3)
```

Arguments

norm	normalization wavelength (nm)
w.low	short-end boundary wavelength (nm)
w.high	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

Note

In the original publication [2] describing the formulation, the long-end wavelength boundary is specified as 313.3 nm. This is the default used here. However, in some cases it is of interest to vary this limit in sensitivity analyses. The effect on the RAF and doses of changing this boundary is substantial, and has been analysed by Micheletti et al. [3].

References

[1]Caldwell, M. M. (1971) Solar UV irradiation and the growth and development of higher plants. In Giese, A. C. (Ed.) Photophysiology, Academic Press, 1971, 6, 131-177

[2] Green, A. E. S.; Sawada, T. & Shettle, E. P. (1974) The middle ultraviolet reaching the ground Photochemistry and Photobiology, 1974, 19, 251-259

[3] Micheletti, M. I.; Piacentini, R. D. & Madronich, S. (2003) Sensitivity of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range Photochemistry and Photobiology, 78, 456-461

See Also

waveband

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), DNA_P(), FLAV(), GEN_M(), GEN_T(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
GEN_G()
GEN_G(300)
```

GEN_G_q_fun — *Gives values for GPAS BSWF (Green's formulation) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The BSWF is normalized at 280 nm.

Usage

```
GEN_G_q_fun(w.length)
```

Arguments

w.length	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

Note

In the original publication [2] describing the formulation, the long-end wavelength boundary is specified as 313.3 nm. The equation is coded here with no such limit so that any limit can be set when defining the waveband. We do so because in some cases it is of interest to vary this limit in sensitivity analyses. The effect on the RAF and doses of changing this boundary is substantial, and has been analysed by Micheletti et al. [3].

References

[1] Caldwell, M. M. (1971) Solar UV irradiation and the growth and development of higher plants. In Giese, A. C. (Ed.) Photophysiology, Academic Press, 1971, 6, 131-177

[2] Green, A. E. S.; Sawada, T. & Shettle, E. P. (1974) The middle ultraviolet reaching the ground Photochemistry and Photobiology, 1974, 19, 251-259

[3] Micheletti, M. I.; Piacentini, R. D. & Madronich, S. (2003) Sensitivity of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range Photochemistry and Photobiology, 78, 456-461

See Also

Other BSWF functions: `CH4_e_fun()`, `CH4_q_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_GM_q_fun()`, `DNA_P_q_fun()`, `FLAV_q_fun()`, `GEN_M_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
GEN_G_q_fun(293:400)
```

GEN_M — *Constructor of GPAS (Micheletti's formulation) weighted waveband*

Description

Generalized Plant Action BSWF of Caldwell [1] as formulated by Micheletti et al. [2]

Usage

```
GEN_M(norm = 300, w.low = 275, w.high = 313.3)
```

Arguments

`norm`	normalization wavelength (nm)
`w.low`	short-end boundary wavelength (nm)
`w.high`	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

Note

In the original publication [2] describing the formulation, the long-end wavelength boundary is specified as 313.3 nm. This is the default used here. However, in some cases it is of interest to vary this limit in sensitivity analyses. The effect on the RAF and doses of changing this boundary is substantial, and has been analysed by Micheletti et al. [3].

References

[1]Caldwell, M. M. (1971) Solar UV irradiation and the growth and development of higher plants. In Giese, A. C. (Ed.) Photophysiology, Academic Press, 1971, 6, 131-177

[2] Micheletti, M. I.; Piacentini, R. D. & Madronich, S. (2003) Sensitivity of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range Photochemistry and Photobiology, 78, 456-461

See Also

`waveband`

Other BSWF weighted wavebands: `CH4()`, `DNA_GM()`, `DNA_N()`, `DNA_P()`, `FLAV()`, `GEN_G()`, `GEN_T()`, `PAR()`, `PG()`, `UV_health_hazard()`, `erythema()`

Examples

```
GEN_M()
GEN_M(300)
```

GEN_M_q_fun — *Gives values for GPAS BSWF (Micheletti's formulation) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The BSWF is normalized at 300 nm.

Usage

```
GEN_M_q_fun(w.length)
```

Arguments

`w.length`	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

Note

In the original publication [2] describing the formulation, the long-end wavelength boundary is not specified, but 313.3 nm is usually used. The equation is coded here with the limit at 342 nm as at longer wavelengths the values increase with increasing wavelength. The effect on the RAF and doses of changing this boundary ican be substantial, and has been analysed by Micheletti et al. [3].

References

[1]Caldwell, M. M. (1971) Solar UV irradiation and the growth and development of higher plants. In Giese, A. C. (Ed.) Photophysiology, Academic Press, 1971, 6, 131-177

[2] Micheletti, M. I. and R. D. Piacentini (2002) Irradiancia espetral solar UV-B y su relación con la efectividad de daño biológico a las plantas. ANALES AFA, 13, 242-248

[3] Micheletti, M. I.; Piacentini, R. D. & Madronich, S. (2003) Sensitivity of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range Photochemistry and Photobiology, 78, 456-461

See Also

Other BSWF functions: `CH4_e_fun()`, `CH4_q_fun()`, `CIE_e_fun()`, `CIE_q_fun()`, `DNA_GM_q_fun()`, `DNA_P_q_fun()`, `FLAV_q_fun()`, `GEN_G_q_fun()`, `GEN_T_q_fun()`, `ICNIRP_e_fun()`, `PG_q_fun()`

Examples

```
GEN_M_q_fun(293:400)
```

GEN_T   *Constructor of GPAS (Thimijan's formulation) weighted waveband*

Description

Generalized Plant Action BSWF of Caldwell [1] as formulated by Timijan et al. [2]

Usage

```
GEN_T(norm = 300, w.low = 275, w.high = 345)
```

Arguments

`norm`	normalization wavelength (nm)
`w.low`	short-end boundary wavelength (nm)
`w.high`	long-end boundary wavelength (nm)

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

References

[1] Caldwell, M. M. (1971) Solar UV irradiation and the growth and development of higher plants. In Giese, A. C. (Ed.) Photophysiology, Academic Press, 1971, 6, 131-177

[2] Thimijan RW, Cams HR, Campbell L. (1978) Radiation sources and related environmental control for biological and climatic eflFects of UV research. Final report EPA-IAG-D6-0168. Washington: Environmental Protection Agency.

See Also

GEN.G GEN.M PG and waveband

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), DNA_P(), FLAV(), GEN_G(), GEN_M(), PAR(), PG(), UV_health_hazard(), erythema()

Examples

```
GEN_T()
GEN_T(300)
```

GEN_T_q_fun   *Gives values for GPAS BSWF (Timijan's formulation) as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances.

Usage

```
GEN_T_q_fun(w.length)
```

Arguments

`w.length`	numeric array of w.length (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source. The returned values are based on quantum effectiveness units.

Note

For wavelengths shorter than 256 nm the value returned by the equation starts decreasing, but we instead extrapolate this maximum value, obtained at 256 nm, to shorter wavelengths. For wavelengths longer than 345 nm we return zero, as is usual parctice.

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_e_fun(), CIE_q_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), FLAV_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), ICNIRP_e_fun(), PG_q_fun()

Examples

```
GEN_T_q_fun(293:400)
```

Green *Constructor of green waveband*

Description

Wavelength-range definitions for *green* light according to ISO or as commonly used in plant or remote sensing applications.

Usage

```
Green(std = "ISO")
```

Arguments

std a character string "ISO", "Sellaro", "Broad", "RS", "LandsatOLI", "LandsatRBV", "LandsatTM", "LandsatETM", or "LandsatMSS".

Details

The different arguments passed to formal parameter `std` determine the range of wavelengths set as boundaries of the returned `waveband` object; `"ISO"` is an standardized definition based on human colour vision; `"Sellaro"` and `"Broad"` are non-standard but used in plant sciences; `"RS"` is non-standard but frequently used in remote sensing; the remaining definitions are for the published wavelength sensitivity range of imagers (cameras) in the Landsat satellite missions.

Value

A waveband object defining a wavelength range.

Note

The bands are defined as square windows, these can be applied to spectral data to obtain the "true" values, but they do not simulate the sensitivity of broad-band sensors or the spectral transmittance of ionic filters. Some band-pass interference filters may have very sharp cut-in and cut-off, and their effect can be approximated by a square window, but filters based on light absorption will show gradual tails and bell-shaped wavelength-windows. The Landsat instruments have very steep cut-in and cut-off slopes and are well approximated.

When released, this package will replace the package UVcalc.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

ISO (2007) Space environment (natural and artificial) - Process for determining solar irradiances. ISO Standard 21348. ISO, Geneva.

Sellaro, R., Crepy, M., Trupkin, S. A., Karayekov, E., Buchovsky, A. S., Rossi, C., & Casal, J. J. (2010). Cryptochrome as a sensor of the blue/green ratio of natural radiation in Arabidopsis. Plant physiology, 154(1), 401-409. doi:10.1104/pp.110.160820.

See Also

waveband

Other unweighted wavebands: Blue(), Far_red(), IR(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS(), Yellow()

Examples

```
Green()
Green("ISO") # 500 to 570
Green("Sellaro") # 500 to 570 nm

e_irrad(sun.spct, Green()) # W m-2
q_irrad(sun.spct, Green()) # mol m-2
q_irrad(sun.spct, Green(), scale.factor = 1e6) # umol m-2
```

ICNIRP_e_fun — *ICNIRP UV health hazard BSWF as a function of wavelength*

Description

This function returns a vector of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on energy based effectiveness relative units. The BSWF is formulated for the range 210 nm to 400 nm.

Usage

```
ICNIRP_e_fun(w.length)
```

Arguments

w.length	numeric array of wavelengths (nm)

Value

a numeric array of the same length as w.length with values for the BSWF normalized as in the original source (270 nm) and based on energy effectiveness.

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_e_fun(), CIE_q_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), FLAV_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), GEN_T_q_fun(), PG_q_fun()

Examples

```
ICNIRP_e_fun(210:400)
```

IR — *Constructors of infra-red wavebands*

Description

Wavelength-range definitions for *infrared* radiation according to ISO, CIE or as commonly defined in remote sensing applications.

Usage

```
IR(std = "ISO")

NIR(std = "ISO")

IRA(std = "CIE")

SWIR(std = "CIE")

IRB(std = "CIE")

SWIR1(std = "RS")

SWIR2(std = "RS")

MIR(std = "ISO")

IRC(std = "CIE")

FIR(std = "ISO")

TIR1(std = "RS")

TIR2(std = "RS")
```

Arguments

`std`	character string, "ISO", "CIE", "RS" or Landsat imagers "LandsatRBV", "LandsatMSS", "LandsatTIRS", "LandsatOLI", "LandsatTM", "LandsatETM", depending on the constructor.

Details

The values for std = "ISO" are according to ISO 20473. The values for std = "CIE" are suggested values according to Wikipedia, and need verification.

The wavelength limits for remote sensing std = "RS" and for Landsat imagers have been obtained from R package 'RStools' and NASA and USGS documentation.

The names NIR, SWIR and TIR are abbreviations of near infra-red, short-wave infra-red and thermal infra-red, respectively. The naming conventions are different for "CIE" than "ISO" standards, and the labels of the waveband objects reflect this with "IRA", "IRB", etc., used when appropriate.

Value

A waveband object defining a wavelength range.

See Also

Far_red for wavebands close to the boundary between red and infrared regions.

waveband

Other unweighted wavebands: Blue(), Far_red(), Green(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS(), Yellow()

Examples

```
SWIR1()
SWIR1("RS")
IR()
NIR()
MIR()
IRA()
IRB()
```

IR_bands — *Constructor of lists of infrared wavebands*

Description

Defined according to "ISO" or "CIE".

Usage

```
IR_bands(std = "ISO")
```

Arguments

std	a character string "ISO" or "CIE".

Value

a list of wavebands

See Also

waveband

Other lists of unweighted wavebands: Landsat_bands(), Plant_bands(), UV_bands(), VIS_bands()

Examples

```
IR_bands()
IR_bands("ISO")
IR_bands("CIE")
```

Landsat_bands *Constructor of lists of wavebands matching Landsat imagers*

Description

Defined according as ranges of wavelengths according to NASA and USGS manuals. The definitions are as *rectangular* windows, while the true response functions deviate to some extent from these ideal definitions.

Usage

```
Landsat_bands(std = "L8")

RBV_bands(std = "LandsatRBV")

MSS_bands(std = "LandsatMSS")

OLI_bands(std = "LandsatOLI")

TIRS_bands(std = "LandsatTIRS")

ETM_bands(std = "LandsatETM")
```

Arguments

std	a character string "L1"..."L9", for missions, "LandsarRBV", "LandsatMSS", etc. for imagers.

Details

See https://landsat.usgs.gov/spectral-characteristics-viewer for detailed sensitivity spectra for the different bands of the imaginers.

Value

a list of wavebands

See Also

waveband

Other lists of unweighted wavebands: IR_bands(), Plant_bands(), UV_bands(), VIS_bands()

Examples

```
Landsat_bands("L1")
Landsat_bands("L8")
OLI_bands()
TIRS_bands()
```

McCree_mean.mspct *McCree's mean action spectra for whole-leaf photosynthesis*

Description

Two action spectra computed as the mean of action spectra for different crop plant species. Grown under two different conditions: field or controlled environment chamber.

Usage

```
McCree_mean.mspct
```

Format

A source_mspct object containing two spectra. Two numeric variables w.length and s.q.response contain the data, and the member name identifies the spectra based on the conditions under plants where grown.

Details

These two spectra were published by McCree et al. (1972) with numeric data in Tables III and IV given from 350 nm to 740 nm. The wavelength resolution is 25 nm in the original data. The wavelength resolution was increased by natural spline interpolation and do not exactly match the hand-drawn plots in McCree et al. (1972). These spectra are used as biological spectral weighting functions in the computation of "Photosynthetic Yield Photon Flux" (YPD).

References

McCree, K. J. (1972) The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. *Agricultural Meteorology*, 9:191-216. doi:10.1016/00021571(71)900227.

See Also

PAR and McCree_photosynthesis.mspct.

NDVI *Normalized Vegetation Index*

Description

Compute the NDVI from spectral reflectance according to waveband definitions from standards or corresponding to satellite imagers.

Usage

```
NDVI(spct, imager = "LandsatOLI", wb.trim = FALSE)
```

Arguments

spct	reflectance_spct or reflectance_mspct object.
imager	character Name of the imager or standard to be used.
wb.trim	logical Flag telling if wavebands crossing spectral data boundaries are trimmed or ignored.

Details

NDVI is used in remote sensing to the diagnose the condition of vegetation, including crops. It is used for Landsat imagery but also at the farm or plot scale using cameras on drones. It is computed as:

NDVI = (NIR - Red) / (NIR + Red)

The waveband ranges used to compute reflectance vary. Even the imagers in the different Landsat satellites 1 to 8 have had somehow different wavelength sensitivities. The `NDVI()` function uses the waveband constructors Red and NIR defined in this package. Reflectance is averaged over the wavebands using function reflectance.

Value

A numeric vector. When the wavelength range of `spct` does not fully overlap with both wavebands `NA` is silently returned.

Note

The value passed as argument to `imager` must be a valid argument for both Red and NIR. If the desired return value is a data frame, function NDxI can be used to flexibly compute NDVI and any similar index.

Orange *Constructor of orange waveband*

Description

Wavelength-range definition for *orange* radiation according to ISO.

Usage

```
Orange(std = "ISO")
```

Arguments

std	a character string "ISO"

Details

Orange radiation (591...610 nm) as defined in ISO standards based on human colour vision.

Value

A waveband object defining a wavelength range.

References

ISO (2007) Space environment (natural and artificial) - Process for determining solar irradiances. ISO Standard 21348. ISO, Geneva.

See Also

waveband

Other unweighted wavebands: Blue(), Far_red(), Green(), IR(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS(), Yellow()

Examples

```
Orange()
Orange("ISO")

e_irrad(sun.spct, Orange()) # W m-2
q_irrad(sun.spct, Orange()) # mol m-2
q_irrad(sun.spct, Orange(), scale.factor = 1e6) # umol m-2
```

PAR *Constructors of PAR, ePAR, PQYR and PhR wavebands*

Description

Waveband definitions for *photosynthetic radiation* (PhR), *photosynthetically active radiation* (PAR = PPFD), *extended photosynthetically active radiation* (ePAR), *phosynthesis quantum action spectrum weighted radiation* (PQYR = YPD) according to different definitions in use for land plants.

Usage

```
PAR(std = "PAR", norm = 550)

PhR()

PQYR(std = "McCree.field.mean", norm = 550)
```

Arguments

std	a character string "Plant" (or "range"), "McCree" (or "photon", "PAR"), "Zhen" (or "ePAR"), "Gabrielsen" (or "Gaastra" or "energy") or "Nichiporovich", "McCree.field.mean" or "McCree.chamber.mean".
norm	normalization wavelength (nm)

Details

Photosynthetically active radiation (400-700 nm) as proposed by McCree (1972), and currently used in plant sciences, gives equal weight to photons within its range, thus weights increase with increasing wavelength when expressed as energy. PAR is normally expressed as photon irradiance or (photosynthetic photon flux density, PPFD) using implicitly 1 as weight for all wavelengths. This is a simple photon-based Biological Spectral Weighting Function (BSWF). It is also possible, but very unusual, to express the quantity PAR as defined in McCree (1972b) as an *energy* irradiance, in which case a BSWF with weights different from 1 needs to be used. In this case the default normalization wavelength for the PAR BSWF is set at 550 nm (at the center of the wavelength range). In some fields, such as meteorology, PAR is simply taken as a range of wavelengths used to integrate spectral energy irradiance. This is different to McCree's definition and in this package available under the name Photosynthetic Radiation (PhR). In the case of sunlight and using 550 nm for normalization the difference between the two is very small, while for artificial light sources the differences can be larger.

Instead of using the simplified square-shaped BSWF as in PAR, some authors have used an photon-based action spectrum (or "quantum yield" spectrum) as BSWF and called the quantity *Yield Flux Density* (YFD). A mean action spectrum from several crop species from McCree (1972a) is one of those that has been used in the literature. Here it is available under the name PQYR (Photosynthesis Quantum Yield Radiation) using two mean action spectra, for field-grown- and controlled-environment-chamber-grown crop plants.

A recent proposal (see Zhen et al., 2021), defines extended photosynthetically active radiation (400-750 nm) (abbreviated as ePAR) as an alternative to PAR. The need to consider far-red photons as drivers of photosynthesis has become apparent with the increasing use of LEDs for plant cultivation. Far-red light contributes significantly to photosynthesis only when added to PAR. WARNING: the proposed definition of ePAR limits photon irradiance in the range 700-750 nm to a maximum of 30 of the total ePAR: ePAR is zero as long as PAR is zero, and never larger than 1.4 times PAR even in the presence of far-red photons in excess, because far-red photons have only a synergistic effect on photosynthesis driven by VIS light. Ensuring this condition is fulfilled remains the responsibility of the user of the wavebands returned by `PAR(std = "ePAR")`, `PAR(std = "Zhen")`, and `ePAR()` as FR's contribution can be assessed only by computing irradiances integrated for two wavelength ranges and comparing them. Function `xPAR_irrad()` from package 'photobiologyPlants' returns the constrained ePAR under the name of xPAR as well as ePAR and its PAR and FR components.

Some earlier definitions, described by McCree (1972a), include Gabrielsen and Gaastra's, which used the same wavelength range as PAR but assuming wavelength-invariant response to energy. Thus, in this case weights decrease with increasing wavelength when expressed as photons. McCree (1972a) also cites Nichiporovich for a similar energy based quantity but covering a wider range of wavelengths (380-710 nm). Both of these definitions, even if mostly of historical interest, are also implemented. When used to compute photon irradiances the BSWFs are normalised at 550 nm.

McCree's definition from 1972b is currently the one preferred by most researchers and used almost universally in the plant sciences. Photosynthetic radiation (400-700 nm) (PhR) is defined as a wavelength range and does not implement the spectral weighting inherent to McCree's (1972) of PAR or Gabrielsen and Gaastra definition of photosynthetic energy irradiance described by McCree (1972a).

Value

For `PhR()`, a waveband object defining a wavelength range. For `PAR(std = "McCree")`, `ePAR()` and `PQYR()` a waveband object implementing different approximations of the action spectrum of photosynthesis in crop (land) plants as BSWF. In PAR() the BSWF is as defined by McCree (1972b), equal action per photon. and thus including a weighting function used in computation of energy-base PAR irradiances. The weights are normalized to 1 at 550 nm. The waveband label is set to "PAR" or "PhR" accordingly.

Warnings

PAR is sometimes described as a range of wavelengths (e.g., Both et al., 2015), which can be confusing as there is more to McCree's (1972b) definition, a spectral weighting function by which all photons within the range of PAR elicit the same strength of response. As long as PAR is expressed as a photon irradiance it is identical to PhR. Similarly, as long as Gabrielsen and Gaastra's definition is expressed as energy irradiance, it is equivalent as using PhR.

ePAR and PAR were designed to be use to quantify light sources with a broad spectrum, i.e., sources giving out white light or pale-coloured light. PAR and ePAR are technical measures of light useful for plants in the same way as illuminance is a measure of how bright light feels to an average human. None of them are meant to describe the response to be expected from an individual in particular, be it a plant or human. They are generalizations, that allow us to consistently measure light in different situations rather than directly predict the rate of photosynthesis. PQYR is similar in concept to PAR and ePAR as long as the same action spectrum is used consistently.

Note

PAR() and PhR() call the same function definition with different default arguments.

The default for the normalization wavelength at 550 nm keeps the average weights across the waveband equal to unity, except the special case of ePAR, where the photons in the extension to the range act by synergy.

Standard DIN 5031-10:2018-03 Defines two BSWFs *sy1* and *sy2* for photosynthesis. BSWF *sy2* is not implemented but is based on the same data as PQYR("McCree.field.mean") with a specific interpolation. BSWF *sy1* is not currently implemented in 'photobiologyWavebands'.

References

McCree, K. J. (1972a) The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. Agricultural Meteorology, 9, 191-216. doi:10.1016/00021571(71)900227

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

Both, A. J.; Benjamin, L.; Franklin, J.; Holroyd, G.; Incoll, L. D.; Lefsrud, M. G. & Pitkin, G. (2015) Guidelines for measuring and reporting environmental parameters for experiments in greenhouses. Plant Methods, 11:43. doi:10.1186/s1300701500835.

DIN (2018) Standard DIN 5031-10:2018-03 Optical radiation physics and illuminating engineering. Part 10: Photobiologically effective radiation, quantities, symbols and action spectra. Beuth Verlag, Berlin 2018.

See Also

waveband and PQYR_q_fun.

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), DNA_P(), FLAV(), GEN_G(), GEN_M(), GEN_T(), PG(), UV_health_hazard(), erythema()

Examples

```
PAR()
PhR()
PAR("Plant")

q_irrad(sun.spct, PhR(), scale.factor = 1e6) # umol m-2 s-2
q_irrad(sun.spct, PAR(), scale.factor = 1e6) # umol m-2 s-2
q_irrad(sun.spct, PAR(std = "ePAR"), scale.factor = 1e6) # umol m-2 s-2
q_irrad(sun.spct, PQYR(), scale.factor = 1e6) # umol m-2 s-2
e_irrad(sun.spct, PAR("Gabrielsen")) # W m-2
e_irrad(sun.spct, PhR()) # W m-2
e_irrad(sun.spct, PAR()) # BE W m-2, normalized at 700 nm
```

PG *Constructor of PG weighted waveband*

Description

Plant growth BSWF of Flint and Caldwell

Usage

```
PG(norm = 300, w.low = 275, w.high = 390)
```

Arguments

`norm`	normalization wavelength (nm)
`w.low`	short-end boundary wavelength (nm)
`w.high`	long-end boundary wavelength (nm)

Details

The mathematical formulation included by Flint and Caldwell (2003) as an appendix is used. While this formulation is consistently used, the range of wavelengths over which it has been applied has varied. We use the approach of the NSF UV network and extrapolate up to 390 nm. The widely used simulation program TUV uses, instead, 366 nm as the boundary, which makes a significant difference to the computed irradiance values in sunlight.

Value

a waveband object wavelength defining wavelength range, weighting function and normalization wavelength.

Note

In the original publication [1], the long-end wavelength boundary is not specified. The longest wavelength at which the plant response was measured is 366 nm. From the data there is no evidence that action would immediately drop to zero at longer wavelengths. We have used in earlier versions the same value as used by the 'NSF Polar Programs UV Monitoring Network' as described in https://web.archive.org/web/20220130091146/http://uv.biospherical.com/Version2/description-Version2-Database3.html.

We use 390 nm as default value for `w.high`, but make if possible for the user to set a different wavelength. To reproduce the output of the TUV simulation model [3] version 5.0 set `w.high = 366`. The effect on the RAF and doses of changing this wavelength boundary is substantial, as discussed by Micheletti et al. [2]. Consequently, the value used must be always reported to ensure reproducibility. For comparisons with previous reports one may need to recompute effective irradiances using matching wavelength boundaries on a case by case basis.

References

[1] Flint, S. and Caldwell M. M. (2003) A biological spectral weighting function for ozone depletion research with higher plants Physiologia Plantarum, 2003, 117, 137-144

[2] Micheletti, M. I.; Piacentini, R. D. & Madronich, S. (2003) Sensitivity of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range Photochemistry and Photobiology, 78, 456-461

[3] https://www2.acom.ucar.edu/modeling/tropospheric-ultraviolet-and-visible-tuv-radiation-model

See Also

GEN_G GEN_T GEN_M and waveband

Other BSWF weighted wavebands: CH4(), DNA_GM(), DNA_N(), DNA_P(), FLAV(), GEN_G(), GEN_M(), GEN_T(), PAR(), UV_health_hazard(), erythema()

Examples

```
PG()
PG(300)
```

PG_q_fun — *Gives values for the Plant Growth BSWF as a function of wavelength*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances. The returned values are on quantum based effectiveness relative units.

Usage

```
PG_q_fun(w.length)
```

Arguments

`w.length`	numeric array of wavelengths (nm)

Value

a numeric array of the same length as `w.length` with values for the BSWF normalized as in the original source (300 nm)

Note

We follow the original defition here for the equation, with no limtation to the wavelength range. However, be aware that in practice it is not used for long wavelengths (different limits between 366 nm and 400 nm have been used by different authors).

See Also

Other BSWF functions: CH4_e_fun(), CH4_q_fun(), CIE_e_fun(), CIE_q_fun(), DNA_GM_q_fun(), DNA_P_q_fun(), FLAV_q_fun(), GEN_G_q_fun(), GEN_M_q_fun(), GEN_T_q_fun(), ICNIRP_e_fun()

Examples

```
PG_q_fun(293:400)
```

---

photopic_sensitivity *Photopic sensitivity of the human eye*

Description

Constant value used in the definition of Lumen 1 W is equal to 683 Lumen at 555 nm

Usage

```
photopic_sensitivity
```

Format

A single numeric value

Details

A single numeric value

Plant_bands *Constructor of lists of wavebands used in plant biology*

Description

Defined according to different authors.

Usage

```
Plant_bands(std = "sensory20")
```

Arguments

std	a character string "sensory", "sensory10", "sensory20", "Sellaro", "ISO", "CIE", "none" or "", where "ISO", "CIE" and "none" affect only the UV bands.

Value

a list of wavebands

See Also

waveband, UVB, UVA, Blue, link{Green}, Red, Far_red and PAR.

Other lists of unweighted wavebands: IR_bands(), Landsat_bands(), UV_bands(), VIS_bands()

Examples

```
Plant_bands()
Plant_bands("sensory")
Plant_bands("sensory10")
Plant_bands("sensory20")
Plant_bands("ISO")
Plant_bands("CIE")
```

PQYR_q_fun *Gives values for mean photosynthesys action spectrum*

Description

This function gives a set of numeric multipliers that can be used as a weight to calculate effective doses and irradiances.

Usage

```
PQYR_q_fun(w.length, std = "McCree.field.mean")

PQYR_fld_q_fun(w.length)

PQYR_chb_q_fun(w.length)
```

Arguments

w.length	numeric array of w.length (nm).
std	character "McCree.field.mean" or "McCree.chamber.mean".

Details

These two spectra were published by McCree et al. (1972) with numeric data in Tables III and IV given from 350 nm to 740 nm. The wavelength resolution is 25 nm in the original data. The wavelength resolution was increased by natural spline interpolation and do not exactly match the hand-drawn plots in McCree et al. (1972). These spectra are used as biological spectral weighting functions in the computation of "Photosynthetic Yield Photon Flux" (YPD).

Value

a numeric vector of the same length as w.length with values for the BSWF normalized to one at 550 nm. The returned values are based on quantum effectiveness units.

References

McCree, K. J. (1972) The action spectrum, absorptance and quantum yield of photosynthesis in crop plants. *Agricultural Meteorology*, 9:191-216. doi:10.1016/00021571(71)900227.

Examples

```
PQYR_q_fun(seq(400, 700, by = 20))
```

`Purple` *Constructor of purple waveband*

Description

Wavelength-range definition for *purple* radiation according to ISO or imagers in the Landsat satellites.

Usage

```
Purple(std = "ISO")
```

Arguments

`std`	a character string "ISO", or Landsat imager "LandsatOLI".

Details

Purple (or violet) wavelengths as defined by ISO standards based on human vision overlap the UVA band as defined by a separate ISO standard. In other contexts like plant photobiology purple is included under blue, while some overoptimistic LED sellers call LEDs emitting in the violet region ultraviolet LEDs. In addition to the ISO definition of purple, a purple channel from Landsat imagers is implemented.

Value

A waveband object defining a wavelength range.

See Also

`waveband`

Other unweighted wavebands: `Blue()`, `Far_red()`, `Green()`, `IR()`, `Orange()`, `Red()`, `UV()`, `UVA()`, `UVB()`, `UVC()`, `VIS()`, `Yellow()`

Examples

```
Purple()
Purple("ISO")

e_irrad(sun.spct, Purple()) # W m-2
q_irrad(sun.spct, Purple()) # mol m-2
q_irrad(sun.spct, Purple(), scale.factor = 1e6) # umol m-2
```

Red — *Constructor of red waveband*

Description

Wavelength-range definitions for *red* light according to ISO or as commonly used in plant or remote sensing applications.

Usage

```
Red(std = "ISO")
```

Arguments

std	a character string, one of "ISO", "Smith10", "Smith20", "Inada", "Warrington", "Sellaro", "RS", "LandsatOLI", "LandsatTM", "LandsatETM", "LandsatMSS", and "LandsatRBV".

Details

The different arguments passed to formal parameter `std` determine the range of wavelengths set as boundaries of the returned `waveband` object; `"ISO"` is an standardized definition based on human colour vision; `"Smith10"`, `"Smith20"`, `"Inada"`, `"Warrington"`, `"Sellaro"`, `"Broad"` and `"Apogee"` are non-standard but used in plant sciences; `"RS"` is non-standard but frequently used in remote sensing; the remaining definitions are for the published wavelength sensitivity range of imagers (cameras) in the Landsat satellite missions.

In plant photobiology the definitions proposed by Prof. Harry Smith are the most widely used, specially to compute a red to far-red photon ratio relevant to phytochrome photoreceptors. However, other authors have used different definitions in their publications. "Smith10" (655-665 nm), "Smith20" (650-670 nm), "Inada" (600-700 nm), "Warrington" (625-675 nm), and "Sellaro" (620-680 nm). "Apogee" (645-665 nm) is a definition given by a sensor manufacturer that is shifted by 5 nm compared to "Smith20".

Value

a waveband object defining a wavelength range.

Note

The bands are defined as square windows, these can be applied to spectral data to obtain the "true" values, but they do not simulate the sensitivity of broad-band sensors or the spectral transmittance of ionic filters. Some band-pass interference filters may have very sharp cut-in and cut-off, and their effect can be approximated by a square window, but filters based on light absorption will show gradual tails and bell-shaped wavelength-windows. The Landsat instruments have very steep cut-in and cut-off slopes and are well approximated.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

ISO (2007) Space environment (natural and artificial) - Process for determining solar irradiances. ISO Standard 21348. ISO, Geneva.

Murakami, K., Aiga I. (1994) Red/Far-red photon flux ratio used as an index number for morphological control of plant growth under artificial lighting conditions. Proc. Int. Symp. Artificial Lighting, Acta Horticulturae, 418, ISHS 1997.

Sellaro, R., Crepy, M., Trupkin, S. A., Karayekov, E., Buchovsky, A. S., Rossi, C., & Casal, J. J. (2010). Cryptochrome as a sensor of the blue/green ratio of natural radiation in Arabidopsis. Plant physiology, 154(1), 401-409. doi:10.1104/pp.110.160820.

Smith, H. (1982) Light quality, photoperception and plant strategy. Annual Review of Plant Physiology, 33:481-518. doi:10.1146/annurev.pp.33.060182.002405

See Also

`waveband`

Other unweighted wavebands: `Blue()`, `Far_red()`, `Green()`, `IR()`, `Orange()`, `Purple()`, `UV()`, `UVA()`, `UVB()`, `UVC()`, `VIS()`, `Yellow()`

Examples

```
Red()
Red("ISO")
Red("Smith")
Red("Sellaro")

e_irrad(sun.spct, Red()) # W m-2
q_irrad(sun.spct, Red()) # mol m-2
q_irrad(sun.spct, Red(), scale.factor = 1e6) # umol m-2
```

scotopic_sensitivity *Scotopic sensitivity of the human eye*

Description

Constant value for human vision under very weak illumination 1 W is equal to 1699 Lumen at 507 nm

Usage

```
scotopic_sensitivity
```

Format

A single numeric value

Details

A single numeric value

SetlowTUV.spct *Setlow's action spectrum for DNA damage*

Description

A dataset containing the wavelengths at a 0.1 nm interval. Tabulated values for Setlow's naked DNA damage action spectrum as used in the TUV model.

Usage

```
SetlowTUV.spct
```

Format

A response.spct object with 1082 rows and 2 variables

Details

The variables are as follows:

- w.length (nm)
- s.e.response

References

https://web.archive.org/web/20220130091146/http://uv.biospherical.com/Version2/description-Version2 html downloaded 2015-02-07

UV *Constructor of ultraviolet waveband*

Description

Wavelength-range definition for *ultraviolet (UV)* radiation according to ISO and CIE standards.

Usage

```
UV(std = "ISO")
```

Arguments

std	"ISO" or "CIE"

Details

UV: 100–400 nm. The ranges agree between CIE and ISO standards, thus, the argument passed to parameter `std` only affects the labels in the returned `waveband` object.

Value

A waveband object defining a wavelength range.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

See Also

`waveband`

Other unweighted wavebands: `Blue()`, `Far_red()`, `Green()`, `IR()`, `Orange()`, `Purple()`, `Red()`, `UVA()`, `UVB()`, `UVC()`, `VIS()`, `Yellow()`

Examples

```
UV()
UV("ISO")
```

UVA *Constructor of ultraviolet-A waveband*

Description

Wavelength-range definitions for *ultraviolet-A (UV-A)* radiation, by default according to ISO or as commonly used in different application areas.

Usage

```
UVA(std = "ISO")

UVA1(std = "CIE")

UVA2(std = "CIE")

UVAsw(std = "plants")

UVAlw(std = "plants")

UVAsw(std = "plants")
```

Arguments

`std`	a character string `"CIE"`, `"ISO"`, `"none"`, `"medical"` or `"plants"`.

Details

Implemented definitions. UV-A according to CIE and ISO standards: 315-400 nm. UV-A according to common non-standard practice: 320-400 nm. UV-A2 according to CIE report 134/1: 315-340 nm. UV-A1 according to CIE report 134/1: 340-400 nm. UV-Asw according to non-standard use possibly suitable for plants: 315-350 nm. UV-Alw according to non-standard use possibly suitable for plants: 350-400 nm.

Value

A waveband object defining a wavelength range.

Note

The non-standard definitions of UV-A and UV-A2 using 320 nm as limit should not be used in any new publications or work as they deviate from the internationally recommended practice. Their continued use leads to confusion. Their inclusion in this package is to allow calculations needed to compare new results and methods against old publications. UV-A1 and UV-A2 definitions are in wide use in medicine, but not yet standardized. Recent research on the plant photoreceptor UVR8 suggests that UV-A1 and UV-A2 bands are also relevant to plants (Rai et al., 2021). UV-Alw and UV-Asw have been used for plants, but UV-A1 and UV-A2 seem now preferable.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

CIE (1999) 134/1 TC 6-26 report: Standardization of the Terms UV-A1, UV-A2 and UV-B. https://cie.co.at/publications/cie-collection-photobiology-photochemistry-1999

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

See Also

waveband

Other unweighted wavebands: Blue(), Far_red(), Green(), IR(), Orange(), Purple(), Red(), UV(), UVB(), UVC(), VIS(), Yellow()

Examples

```
UVA()
UVA("none")
UVA("ISO")
UVA("CIE")

UVA1()
UVA1("CIE")

UVA2()
UVA2("CIE")

e_irrad(sun.spct, UVA()) # W m-2
e_irrad(sun.spct, UVA1()) # W m-2
e_irrad(sun.spct, UVA2()) # W m-2
```

UVB — *Constructor of ultraviolet-B waveband*

Description

Wavelength-range definitions for *ultraviolet-B, UV-B* radiation, by default according to ISO or as commonly used in different application areas.

Usage

```
UVB(std = "ISO")
```

Arguments

`std` a character string "CIE", "ISO", "medical" or "none"

Details

Implemented definitions. UV-B according to CIE and ISO standrads: 280–315 nm. UV-B according to common non-standard practice: 280–320 nm. UV-B according to medical or dermatological non-standard practice: 280–320 nm.

Value

a waveband object defining a wavelength range.

Note

The non-standard definition of UV-B using 320 nm as limit should not be used in any new publications or work as it deviates from the internationally accepted standards and its use leads to confusion. Its inclusion in this package is to allow calculations needed to compare new results and methods against old publications.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

See Also

`waveband`

Other unweighted wavebands: `Blue()`, `Far_red()`, `Green()`, `IR()`, `Orange()`, `Purple()`, `Red()`, `UV()`, `UVA()`, `UVC()`, `VIS()`, `Yellow()`

Examples

```
UVB()
UVB("ISO")
UVB("CIE")
UVB("none")
UVB("medical")

e_irrad(sun.spct, UVB()) # W m-2
q_irrad(sun.spct, UVB()) # mol m-2
q_irrad(sun.spct, UVB(), scale.factor = 1e6) # umol m-2
```

UVC — *Constructor of ultraviolet-C waveband*

Description

Wavelength-range definitions for *ultraviolet-C (UV-C)* radiation, by default according to ISO or as commonly used in different application areas.

Usage

```
UVC(std = "ISO")
```

Arguments

`std`	a character string "CIE", "ISO", "none", or "medical".

Details

Implemented definitions. UV-C according to CIE and ISO standards: 100–280 nm. UV-c according to common non-standard practice: 200–280 nm. UV-C according to medical or dermatological non-standard practice, e.g. Diffey (1991): 200–290 nm.

Value

a waveband object wavelength defining a wavelength range.

References

Aphalo, P. J., Albert, A., Björn, 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 doi:10.31885/9789521083631.

See Also

`waveband`

Other unweighted wavebands: `Blue()`, `Far_red()`, `Green()`, `IR()`, `Orange()`, `Purple()`, `Red()`, `UV()`, `UVA()`, `UVB()`, `VIS()`, `Yellow()`

Examples

```
UVC()
UVC("CIE")
UVC("ISO")
UVC("none")
UVC("medical")
```

UVI *Calculate UV Index (UVI) from spectral irradiance*

Description

UVI (UV Index) is a unitless quantity based on erythema biological spectral weighting function (BSWF), that gives an easy to interpret UV measure, mainly meant for informing general public about sunburn risk.

Usage

```
UVI(spct, std = "NOAA", integer_UVI = FALSE)
```

Arguments

spct	a source.spct object
std	character One of "WWO", "NOAA".
integer_UVI	logical Return a positive integer value according to WWO recommended practice or a numeric value.

Details

Two different definitions of UV Index are implemented in this package. Setting std="NOAA" follows the definition in Kiedron et al. (2007) but using CIE98 as SWF. NOAA definition discards wavelengths shorter than 286.5 nm as when calculated based on spectral data from Brewer instruments. "WMO" uses the internationally accepted lower limit at 250 nm (see WHO, 2002). "NOAA" is the default as this is safer with noisy data for solar radiation measured at ground level, and in this case the value of UVI should be correct, and almost identical except for errors caused by noise at shorter wavelengths. However, when calculating UVI from radiation spectra from UV lamps, "WMO" should be used, as most UV lamps do emit some radiation between 250 nm and 286.5 nm.

Value

depending on the argument passed to `integer_UVI`, a numeric (`FALSE`) or integer (`TRUE`) value for the unitless UVI.

Note

The default is to return a numeric value not rounded into a value in the integer-number based recommended UVI scale. This is done to avoid loss of precision in cases when additional operations, such as averaging, are applied to the UVI values.

References

World Health Organization, World Meteorological Organization, United Nations Environment Programme & International Commission on Non-Ionizing Radiation Protection. (2002) Global Solar UV Index: A Practical Guide. World Health Organization, Geneva. ISBN 9241590076. https://apps.who.int/iris/handle/10665/42459

P. Kiedron, S. Stierle and K. Lantz (2007) Instantaneous UV Index and Daily UV Dose Calculations. NOAA-EPA Brewer Network. https://www.esrl.noaa.gov/gmd/grad/neubrew/docs/UVindex.pdf

See Also

waveband and UVI_wb

Examples

```
UVI(sun.spct)
UVI(sun.spct, "WMO")
UVI(sun.spct, integer_UVI = TRUE)
```

UV_bands   *Constructor of lists of UV wavebands*

Description

Defined according to "ISO" by default, but other definitions also supported.

Usage

```
UV_bands(std = "ISO")
```

Arguments

std	a character string "ISO", "CIE", "medical", "plants" or "none".

Value

a list of wavebands

See Also

waveband, UVC, UVB and UVA.

Other lists of unweighted wavebands: IR_bands(), Landsat_bands(), Plant_bands(), VIS_bands()

Examples

```
UV_bands()
UV_bands("ISO")
UV_bands("CIE")
UV_bands("medical")
UV_bands("plants")
UV_bands("none")
```

`UV_health_hazard` *Constructor of UV health hazard weighted waveband*

Description

Waveband constructor for ICNIRP UV health hazard 2004 BSWF.

Usage

```
UV_health_hazard(std = "ICNIRP", norm = 270, w.low = 210, w.high = 400)

ICNIRP(norm = 270, w.low = 210, w.high = 400)
```

Arguments

`std`	a character string "ICNIRP".
`norm`	normalization wavelength (nm)
`w.low`	short-end boundary wavelength (nm)
`w.high`	long-end boundary wavelength (nm)

Details

This BSWF is used for the determination of exposure limits (EL) for workers, and includes a safety margin as it is based on eye and the non-pathologic response of the most sensitive human skin types when not tanned. Values are interpolated according to equations 2a, 2b and 2c in ICNIRP (2004), which cover the range 210 nm to 400 nm.

The program code is provided as is, with no guarantee of suitability for any purpose, and should under no circumstances be used to assess actual health hazards.

Value

a waveband object defining wavelength range, weighting function and normalization wavelength.

Note

The weights at 180, 190, 200 and 205 nm are presented only in tabular in ICNIRP (2004) and all values at wavelengths < 210 nm taken as `NA`.

Standard DIN 5031-10:2018-03 defines BSWF *uvh* as a table of interpolated values derived from ICNIRP UV health hazard. So, the values computed using this R package do not necessarily exactly match those according to DIN 5031-10:2018-03. The range of wavelengths used here, 210 to 400 nm, does not agree, with those in the standard: 180 to 400 nm.

References

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION (2004) ICNIRP GUIDELINES ON LIMITS OF EXPOSURE TO ULTRAVIOLET RADIATION OF WAVELENGTHS BETWEEN 180 nm AND 400 nm (INCOHERENT OPTICAL RADIATION). HEALTH PHYSICS 87(2):171-186. https://www.icnirp.org/cms/upload/publications/ICNIRPUV2004.pdf

See Also

`waveband`

Other BSWF weighted wavebands: `CH4()`, `DNA_GM()`, `DNA_N()`, `DNA_P()`, `FLAV()`, `GEN_G()`, `GEN_M()`, `GEN_T()`, `PAR()`, `PG()`, `erythema()`

Examples

```
ICNIRP()
UV_health_hazard()
UV_health_hazard("ICNIRP")
```

`VIS` *Constructor of VIS waveband*

Description

Visible (to humans) radiation (380...760 nm) according to ISO standard definition, no weighting applied. For `std = "RS"` the returned range is the same as for `PAR()`. The panchromatic bands of Landsat missions are also supported.

Usage

```
VIS(std = "ISO")
```

Arguments

`std`	a character string "ISO" or "RS" (remote sensing).

Value

A waveband object wavelength defining a wavelength range.

See Also

waveband

Other unweighted wavebands: Blue(), Far_red(), Green(), IR(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), Yellow()

Examples

```
VIS()
VIS("ISO")
VIS("LandsatOLI")
VIS("Landsat7")
VIS("Pan.RBV.Landsat3")
```

VIS_bands — *Constructor of lists of VIS wavebands*

Description

Defined according to "ISO".

Usage

```
VIS_bands(std = "ISO")
```

Arguments

std	a character string "ISO".

Value

a list of wavebands

See Also

waveband, Purple, Blue, Green, Yellow, Orange, and Red.

Other lists of unweighted wavebands: IR_bands(), Landsat_bands(), Plant_bands(), UV_bands()

Examples

```
VIS_bands()
VIS_bands("ISO")
```

Yellow — *Constructor of yellow waveband*

Description

Wavelength-range definition for *yellow* radiation according to ISO.

Usage

```
Yellow(std = "ISO")
```

Arguments

std	a character string "ISO"

Details

Yellow radiation (570...591 nm) as defined in ISO standards based on human colour vision.

Value

a waveband object wavelength defining a wavelength range.

See Also

waveband

Other unweighted wavebands: Blue(), Far_red(), Green(), IR(), Orange(), Purple(), Red(), UV(), UVA(), UVB(), UVC(), VIS()

Examples

```
Yellow()
Yellow("ISO")

e_irrad(sun.spct, Yellow()) # W m-2
q_irrad(sun.spct, Yellow()) # mol m-2
q_irrad(sun.spct, Yellow(), scale.factor = 1e6) # umol m-2
```

Index