

Package ‘rsofun’

July 23, 2025

Title The P-Model and BiomeE Modelling Framework

Version 5.0.0

Description Implements the Simulating Optimal FUNctioning framework for site-scale simulations of ecosystem processes, including model calibration. It contains 'Fortran 90' modules for the P-model (Stocker et al. (2020) <[doi:10.5194/gmd-13-1545-2020](https://doi.org/10.5194/gmd-13-1545-2020)>), SPLASH (Davis et al. (2017) <[doi:10.5194/gmd-10-689-2017](https://doi.org/10.5194/gmd-10-689-2017)>) and BiomeE (Weng et al. (2015) <[doi:10.5194/bg-12-2655-2015](https://doi.org/10.5194/bg-12-2655-2015)>).

URL <https://github.com/geco-bern/rsofun>

BugReports <https://github.com/geco-bern/rsofun/issues>

License GPL-3

Depends R (>= 4.1.0)

Imports dplyr, purrr, tidyr, magrittr, GenSA, BayesianTools,
multidplyr, stats, utils

LazyData true

LazyDataCompression xz

ByteCompile true

NeedsCompilation yes

RoxygenNote 7.3.2

Suggests covr, rcmdcheck, testthat, rmarkdown, ggplot2, knitr,
sensitivity

VignetteBuilder knitr

Encoding UTF-8

Author Benjamin Stocker [aut, cre] (ORCID:

<<https://orcid.org/0000-0003-2697-9096>>),

Koen Hufkens [aut] (ORCID: <<https://orcid.org/0000-0002-5070-8109>>),

Josefa Arán Paredes [aut] (ORCID:

<<https://orcid.org/0009-0006-7176-2311>>),

Laura Marqués [ctb] (ORCID: <<https://orcid.org/0000-0002-3593-5557>>),

Mayeul Marcadella [ctb] (ORCID:
<<https://orcid.org/0000-0001-8555-3808>>),
Ensheng Weng [ctb] (ORCID: <<https://orcid.org/0000-0002-1858-4847>>),
Fabian Bernhard [aut] (ORCID: <<https://orcid.org/0000-0003-0338-0961>>),
Geocomputation and Earth Observation, University of Bern [cph, fnd]

Maintainer Benjamin Stocker <benjamin.stocker@gmail.com>

Repository CRAN

Date/Publication 2024-11-28 23:10:02 UTC

Contents

biomee_gs_leuning_drivers	2
biomee_gs_leuning_output	5
biomee_p_model_drivers	6
biomee_p_model_output	6
biomee_validation	7
calib_sofun	7
cost_likelihood_biomee	9
cost_likelihood_pmodel	10
cost_rmse_biomee	12
cost_rmse_pmodel	13
init_dates_dataframe	14
p_model_drivers	15
p_model_drivers_vcmax25	17
p_model_output	18
p_model_output_vcmax25	18
p_model_validation	19
p_model_validation_vcmax25	19
runread_biomee_f	20
runread_pmodel_f	21
run_biomee_f_bysite	23
run_pmodel_f_bysite	28

Index	33
--------------	-----------

biomee_gs_leuning_drivers
rsofun BiomeE driver data (Leuning photosynthesis model)

Description

Small dataset representing the driver to run the BiomeE-model at the CH-LAE site using the Leuning photosynthesis specification (and half-hourly time step) It can also be used together with leaf trait data from CH-LAE ([biomee_validation](#)) to optimize model parameters.

Usage

biomee_gs_leuning_drivers

Format

A tibble of driver data.

sitename Site name

params_siml Simulation parameters as a data.frame, including the following data:

spinup Flag indicating whether this simulation does spin-up.

spinupyears Number of spin-up years.

recycle Length of standard recycling period (years).

firstyeartrend First transient year.

nyeartrend Number of transient years.

steps_per_day Time resolution (day-1).

do_U_shaped_mortality Flag indicating whether U-shaped mortality is used.

update_annualLAI Flag indicating whether updating LAI according to mineral N in soil.

do_closedN_run Flag indicating whether doing N closed runs to recover N balance enforcing 0.2 kg N m⁻² in the inorganic N pool.

code_method_photosynth String specifying the method of photosynthesis used in the model, either "pmodel" or "gs_leuning".document()

code_method_mortality String indicating the type of mortality in the model. One of the following: "dbh" is size-dependent mortality, "const_selfthin" is constant self thinning (in development), "cstarvation" is carbon starvation, and "growthrate" is growth rate dependent mortality.

site_info Site meta info in a data.frame. This data structure can be freely used for documenting the dataset, but must include at least the following data:

lon Longitude of the site location.

lat Latitude of the site location.

elv Elevation of the site location, in meters.

forcing Forcing data.frame used as input

ppfd Photosynthetic photon flux density (mol s⁻¹ m⁻²)

tair Air temperature (deg C)

vpd Vapor pressure deficit (Pa)

rain Precipitation (kgH₂O m⁻² s⁻¹ == mm s⁻¹)

wind Wind velocity (m s⁻¹)

pair Atmospheric pressure (pa)

co2 CO₂ atmospheric concentration (ppm)

params_tile Tile-level model parameters, into a single row data.frame, including the following data:

soiltype Integer indicating the type of soil: Sand = 1, LoamySand = 2, SandyLoam = 3, SiltLoam = 4, FrittedClay = 5, Loam = 6, Clay = 7.

- FLDCAP** Field capacity (vol/vol). Water remaining in a soil after it has been thoroughly saturated and allowed to drain freely.
- WILTPT** Wilting point (vol/vol). Water content of a soil at which plants wilt and fail to recover.
- K1** Fast soil C decomposition rate (year^{-1}).
- K2** Slow soil C decomposition rate (year^{-1}).
- K_nitrogen** Mineral Nitrogen turnover rate (year^{-1}).
- MLmixRatio** Ratio of C and N returned to litters from microbes.
- etaN** N loss rate through runoff (organic and mineral) (year^{-1}).
- LMamin** Minimum LMA, leaf mass per unit area, kg C m^{-2} .
- fsc_fine** Fraction of fast turnover carbon in fine biomass.
- fsc_wood** Fraction of fast turnover carbon in wood biomass.
- GR_factor** Growth respiration factor.
- l_fract** Fraction of the carbon retained after leaf drop.
- retransN** Retranslocation coefficient of nitrogen.
- f_initialBSW** Coefficient for setting up initial sapwood.
- f_N_add** Re-fill of N for sapwood.
- tf_base** Calibratable scalar for respiration, used to increase LUE levels.
- par_mort** Canopy mortality parameter.
- par_mort_under** Parameter for understory mortality.
- params_species** A data.frame containing species-specific model parameters, with one species per row, including the following data:
- lifeform** Integer set to 0 for grasses and 1 for trees.
- phenotype** Integer set to 0 for deciduous and 1 for evergreen.
- pt** Integer indicating the type of plant according to photosynthesis: 0 for C3; 1 for C4
- alpha_FR** Fine root turnover rate (year^{-1}).
- rho_FR** Material density of fine roots (kg C m^{-3}).
- root_r** Radius of the fine roots, in m.
- root_zeta** e-folding parameter of root vertical distribution, in m.
- Kw_root** Fine root water conductivity ($\text{mol m}^{-2} \text{s}^{-1} \text{MPa}^{-1}$).
- leaf_size** Characteristic leaf size.
- Vmax** Max RuBisCo rate, in $\text{mol m}^{-2} \text{s}^{-1}$.
- Vannual** Annual productivity per unit area at full sun ($\text{kg C m}^{-2} \text{year}^{-2}$).
- wet_leaf_dreg** Wet leaf photosynthesis down-regulation.
- m_cond** Factor of stomatal conductance.
- alpha_phot** Photosynthesis efficiency.
- gamma_L** Leaf respiration coefficient, in year^{-1} .
- gamma_LN** Leaf respiration coefficient per unit N.
- gamma_SW** Sapwood respiration rate, in $\text{kg C m}^{-2} \text{year}^{-1}$.
- gamma_FR** Fine root respiration rate, $\text{kg C kg C}^{-1} \text{year}^{-1}$.
- tc_crit** Critical temperature triggerng offset of phenology, in Kelvin.
- tc_crit_on** Critical temperature triggerng onset of phenology, in Kelvin.

gdd_crit Critical value of GDD5 for turning ON growth season.
betaON Critical soil moisture for phenology onset.
betaOFF Critical soil moisture for phenology offset.
seedlingsize Initial size of seedlings, in kg C per individual.
LNbase Basal leaf N per unit area, in kg N m⁻².
IAImax Maximum crown LAI (leaf area index).
Nfixrate0 Reference N fixation rate (kg N kg C⁻¹ root).
NfixCost0 Carbon cost of N fixation (kg C kg N⁻¹).
phiCSA Ratio of sapwood area to leaf area.
mortrate_d_c Canopy tree mortality rate (year⁻¹).
mortrate_d_u Understory tree mortality rate (year⁻¹).
maturalage Age at which trees can reproduce (years).
v_seed Fraction of G_SF to G_F.
fNSmax Multiplier for NSNmax as sum of potential bl and br.
LMA Leaf mass per unit area (kg C m⁻²).
rho_wood Wood density (kg C m⁻³).
alphaBM Coefficient for allometry (biomass = alphaBM * DBH ** thetaBM).
thetaBM Coefficient for allometry (biomass = alphaBM * DBH ** thetaBM).
kphio Quantum yield efficiency φ_0 , in mol mol⁻¹.
phiRL Ratio of fine root to leaf area.
LAI_light Maximum LAI limited by light.
init_cohort A data.frame of initial cohort specifications, including the following data:
 init_cohort_species Index of a species described in param_species.
 init_cohort_nindivs Initial individual density, in individuals per m².
 init_cohort_bsw Initial biomass of sapwood, in kg C per individual.
 init_cohort_bHW Initial biomass of heartwood, in kg C per tree.
 init_cohort_nsc Initial non-structural biomass.
init_soil A data.frame of initial soil pools, including the following data:
 init_fast_soil_C Initial fast soil carbon, in kg C m⁻².
 init_slow_soil_C Initial slow soil carbon, in kg C m⁻².
 init_Nmineral Mineral nitrogen pool, in kg N m⁻².
 N_input Annual nitrogen input to soil N pool, in kg N m⁻² year⁻¹.

biomee_gs_leuning_output

rsofun BiomeE (gs_leuning) output data

Description

Example output dataset from a BiomeE-model run (gs_leuning)

Usage

```
biomee_gs_leuning_output
```

Format

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1 rows and 2 columns.

```
biomee_p_model_drivers
```

rsofun BiomeE driver data (P-model photosynthesis model)

Description

Small dataset representing the driver to run the BiomeE-model at the CH-LAE site using the P-model photosynthesis specification (and daily time step). It can also be used together with leaf trait data from CH-LAE ([biomee_validation](#)) to optimize model parameters.

Usage

```
biomee_p_model_drivers
```

Format

See [biomee_gs_leuning_drivers](#)

```
biomee_p_model_output
```

rsofun BiomeE (P-model) output data

Description

Example output dataset from a BiomeE-model run (p-model)

Usage

```
biomee_p_model_output
```

Format

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1 rows and 2 columns.

biomee_validation	<i>rsofun BiomeE targets validation data</i>
-------------------	--

Description

Small example dataset of target observations (leaf trait data) at the CH-LAE site to optimize model parameters with the function [calib_sofun](#)

Usage

```
biomee_validation
```

Format

A tibble of validation data:

sitename site name

data validation data

Source

Lukas Hörtnagl, Werner Eugster, Nina Buchmann, Eugenie Paul-Limoges, Sophia Etzold, Matthias Haeni, Peter Pluess, Thomas Baur (2004-2014) FLUXNET2015 CH-Lae Laegern, Dataset. <https://doi.org/10.18140/FLX/14>

calib_sofun	<i>Calibrates SOFUN model parameters</i>
-------------	--

Description

This is the main function that handles the calibration of SOFUN model parameters.

Usage

```
calib_sofun(drivers, obs, settings, optim_out = TRUE, ...)
```

Arguments

drivers	A data frame with driver data. See p_model_drivers for a description of the data structure.
obs	A data frame containing observational data used for model calibration. See p_model_validation for a description of the data structure.
settings	A list containing model calibration settings. See the 'P-model usage' vignette for more information and examples.
method	A string indicating the optimization method, either 'GenSA' or 'BayesianTools'.

	par A list of model parameters. For each parameter, an initial value and lower and upper bounds should be provided. The calibratable parameters include model parameters 'kphio', 'kphio_par_a', 'kphio_par_b', 'soilm_thetastar', 'soilm_betao', 'beta_costunitratio', 'rd_to_vcmax', 'tau_acclim', 'kc_jmax' and 'rootzone_whc', and (if doing Bayesian calibration) error parameters for each target variable, named for example 'err_gpp'. This list must match the input parameters of the calibration metric and the parameters should be given in the order above. metric A cost function. See the 'Cost functions for parameter calibration' vignette for examples. control A list of arguments passed on to the optimization function. If method = 'GenSA', see GenSA. If method = 'BayesianTools' the list should include at least settings and sampler, see BayesianTools::runMCMC.
optim_out	A logical indicating whether the function returns the raw output of the optimization functions (defaults to TRUE).
...	Optional arguments passed on to the cost function specified as settings\$metric.

Value

A named list containing the calibrated parameter vector 'par' and the output object from the optimization 'mod'. For more details on this output and how to evaluate it, see [runMCMC](#) (also [this post](#)) and [GenSA](#).

Examples

```
# Fix model parameters that won't be calibrated
params_fix <- list(
  kphio_par_a      = 0,
  kphio_par_b      = 1.0,
  soilm_thetastar  = 0.6*240,
  soilm_betao      = 0.01,
  beta_unitcostratio = 146,
  rd_to_vcmax      = 0.014,
  tau_acclim       = 30,
  kc_jmax          = 0.41
)

# Define calibration settings
settings <- list(
  method = "BayesianTools",
  par = list(
    kphio = list(lower=0.04, upper=0.09, init=0.05),
    err_gpp = list(lower = 0.01, upper = 4, init = 2)
  ),
  metric = rsofun::cost_likelihood_pmodel,
  control = list(
    sampler = "DEzs",
    settings = list(
      nrChains = 1,
```

```

        burnin = 0,
        iterations = 50      # kept artificially low
    )
  )
)

# Run the calibration for GPP data
calib_output <- rsofun::calib_sofun(
  drivers = rsofun::p_model_drivers,
  obs = rsofun::p_model_validation,
  settings = settings,
  # extra arguments for the cost function
  par_fixed = params_fix,
  targets = c("gpp")
)

```

cost_likelihood_biomee

Log-likelihood cost function for BiomeE with different targets

Description

Cost function for parameter calibration, which computes the log-likelihood for the biomee model fitting several target variables for a given set of parameters.

Usage

```
cost_likelihood_biomee(par, obs, drivers, targets)
```

Arguments

par	A vector containing parameter values for 'phiRL', 'LAI_light', 'tf_base', 'par_mort' in that order, and for the error terms corresponding to the target variables, e.g. 'err_GPP' if GPP is a target. Make sure that the order of the error terms in par coincides with the order provided in the targets argument.
obs	A nested data frame of observations, following the structure of biomee_validation, for example.
drivers	A nested data frame of driver data, for example biomee_gs_leuning_drivers.
targets	A character vector indicating the target variables for which the optimization will be done. This should be a subset of c("GPP", "LAI", "Density", "Biomass").

Details

The cost function performs a BiomeE model run for the value of par given as argument. The likelihood is calculated assuming that the predicted targets are independent, normally distributed and centered on the observations. The optimization should be run using BayesianTools, so the likelihood is maximized.

Value

The log-likelihood of the simulated targets by the biomee model versus the observed targets.

Examples

```
# Compute the likelihood for a set of
# BiomeE model parameter values
# and the example data
cost_likelihood_biomee(
  par = c(3.5, 3.5, 1, 1,      # model params
          0.5),              # err_GPP
  obs = biomee_validation,
  drivers = biomee_gs_leuning_drivers,
  targets = c("GPP")
)
```

cost_likelihood_pmodel

Cost function computing a log-likelihood for calibration of P-model parameters

Description

The cost function performs a P-model run for the input drivers and model parameter values, and computes the outcome's normal log-likelihood centered at the input observed values and with standard deviation given as an input parameter (calibratable).

Usage

```
cost_likelihood_pmodel(
  par,
  obs,
  drivers,
  targets,
  par_fixed = NULL,
  parallel = FALSE,
  ncores = 2
)
```

Arguments

par	A vector of values for the parameters to be calibrated, including a subset of model parameters (described in runread_pmodel_f), in order, and error terms for each target variable (for example 'gpp_err'), in the same order as the targets appear in targets.
-----	--

obs	A nested data.frame of observations, with columns 'sitename' and 'data' (see p_model_validation or p_model_validation_vcmax25 to check their structure).
drivers	A nested data.frame of driver data. See p_model_drivers for a description of the data structure.
targets	A character vector indicating the target variables for which the optimization will be done and the RMSE computed. This string must be a column name of the data data.frame belonging to the validation nested data.frame (for example 'gpp').
par_fixed	A named list of model parameter values to keep fixed during the calibration. These should complement the input par such that all model parameters are passed on to runread_pmodel_f .
parallel	A logical specifying whether simulations are to be parallelised (sending data from a certain number of sites to each core). Defaults to FALSE.
ncores	An integer specifying the number of cores used for parallel computing. Defaults to 2.

Details

To run the P-model, all model parameters must be given. The cost function uses arguments `par` and `par_fixed` such that, in the calibration routine, `par` can be updated by the optimizer and `par_fixed` are kept unchanged throughout calibration.

If the validation data contains a "date" column (fluxes), the simulated target time series is compared to the observed values on those same dates (e.g. for GPP). Otherwise, there should only be one observed value per site (leaf traits), and the outputs (averaged over the growing season, weighted by predicted GPP) will be compared to this single value representative of the site (e.g. Vcmax25). As an exception, when the date of a trait measurement is available, it will be compared to the trait value predicted on that date.

Value

The log-likelihood of the observed target values, assuming that they are independent, normally distributed and centered on the predictions made by the P-model run with standard deviation given as input (via 'par' because the error terms are estimated through the calibration with 'BayesianTools', as shown in the "Parameter calibration and cost functions" vignette).

Examples

```
# Compute the likelihood for a set of
# model parameter values involved in the
# temperature dependence of kphio
# and example data
cost_likelihood_pmodel(
  par = c(0.05, -0.01, 1,      # model parameters
          2),                 # err_gpp
  obs = p_model_validation,
  drivers = p_model_drivers,
  targets = c('gpp'),
```

```

par_fixed = list(
  soilm_thetastar = 0.6 * 240, # old setup with soil moisture stress
  soilm_betao     = 0.0,
  beta_unitcostratio = 146.0,
  rd_to_vcmax     = 0.014,      # from Atkin et al. 2015 for C3 herbaceous
  tau_acclim      = 30.0,
  kc_jmax         = 0.41
)
)

```

cost_rmse_biomee	<i>RMSE cost function for BiomeE</i>
------------------	--------------------------------------

Description

Cost function for parameter calibration, which computes the root mean squared error (RMSE) between BiomeE simulations (using the input set of parameters) and observed target variables. Cost function for parameter calibration, which computes the RMSE for the biomee model fitting target variables 'GPP', 'LAI', 'Density' and 'Biomass' for a given set of parameters.

Usage

```
cost_rmse_biomee(par, obs, drivers)
```

Arguments

par	A vector containing parameter values for 'phiRL', 'LAI_light', 'tf_base', 'par_mort' in that order.
obs	A nested data frame of observations, following the structure of biomee_validation, for example.
drivers	A nested data frame of driver data, for example biomee_gs_leuning_drivers.

Value

The root mean squared error (RMSE) between the observed and simulated values of 'GPP', 'LAI', 'Density' and 'Biomass' (all variables have the same weight). Relative errors (difference divided by observed values) are used instead of absolute errors. The cost function performs a BiomeE model run for parameter values par and model drivers drivers given as arguments, producing the simulated values used to compute the RMSE.

Examples

```

# Compute RMSE for a set of
# model parameter values
# and example data
cost_rmse_biomee(
  par = c(3.5, 3.5, 1, 1),
  obs = biomee_validation,

```

```

    drivers = biomee_gs_leuning_drivers
  )

```

cost_rmse_pmodel	<i>Cost function computing RMSE for calibration of P-model parameters</i>
------------------	---

Description

The cost function performs a P-model run for the input drivers and parameter values, and compares the output to observations of various targets by computing the root mean squared error (RMSE).

Usage

```

cost_rmse_pmodel(
  par,
  obs,
  drivers,
  targets,
  par_fixed = NULL,
  target_weights = NULL,
  parallel = FALSE,
  ncores = 2
)

```

Arguments

par	A vector of values for the parameters to be calibrated (a subset of those described in runread_pmodel_f , in order).
obs	A nested data.frame of observations, with columns 'sitename' and 'data' (see p_model_validation or p_model_validation_vcmax25 to check their structure).
drivers	A nested data.frame of driver data. See p_model_drivers for a description of the data structure.
targets	A character vector indicating the target variables for which the optimization will be done and the RMSE computed. This string must be a column name of the data data.frame belonging to the validation nested data.frame (for example 'gpp').
par_fixed	A named list of model parameter values to keep fixed during the calibration. These should complement the input par such that all model parameters are passed on to runread_pmodel_f .
target_weights	A vector of weights to be used in the computation of the RMSE if using several targets. By default (target_weights = NULL) the RMSE is computed separately for each target and then averaged. The provided weights are used to compute a weighted average of RMSE across targets.

parallel	A logical specifying whether simulations are to be parallelised (sending data from a certain number of sites to each core). Defaults to FALSE.
ncores	An integer specifying the number of cores used for parallel computing. Defaults to 2.

Details

To run the P-model, all model parameters must be given. The cost function uses arguments `par` and `par_fixed` such that, in the calibration routine, `par` can be updated by the optimizer and `par_fixed` are kept unchanged throughout calibration.

If the validation data contains a "date" column (fluxes), the simulated target time series is compared to the observed values on those same dates (e.g. for GPP). Otherwise, there should only be one observed value per site (leaf traits), and the outputs (averaged over the growing season, weighted by predicted GPP) will be compared to this single value representative of the site (e.g. `Vcmax25`). As an exception, when the date of a trait measurement is available, it will be compared to the trait value predicted on that date.

Value

The root mean squared error (RMSE) between observed values and P-model predictions. The RMSE is computed for each target separately and then aggregated (mean or weighted average).

Examples

```
# Compute RMSE for a set
# of model parameter values
# and example data
cost_rmse_pmodel(
  par = c(0.05, -0.01, 0.5), # kphio related parameters
  obs = p_model_validation,
  drivers = p_model_drivers,
  targets = c('gpp'),
  par_fixed = list(
    soilm_thetastar = 0.6 * 240, # old setup with soil moisture stress
    soilm_betao = 0.0,
    beta_unitcostratio = 146.0,
    rd_to_vcmax = 0.014, # from Atkin et al. 2015 for C3 herbaceous
    tau_acclim = 30.0,
    kc_jmax = 0.41
  )
)
```

`init_dates_dataframe` *Initialises a tibble with dates*

Description

Creates a tibble with rows for each date from 'yrstart' to 'yrend' in 'yyyy-mm-dd' format. Intervals of dates are specified by argument 'freq'. `ddf <- init_dates_dataframe(2000, 2003, start-moy=1, startdoy=1, freq="days", endmoy=12, enddoy=31, noleap=FALSE)`

Usage

```
init_dates_dataframe(
  yrstart,
  yrend,
  startmoy = 1,
  startdoy = 1,
  freq = "days",
  endmoy = 12,
  enddom = 31,
  noleap = FALSE
)
```

Arguments

yrstart	An integer defining the start year of dates covered by the dataframe.
yrend	An integer defining the end year of dates covered by the dataframe.
startmoy	An integer defining the start month-of-year of dates covered by the dataframe. Defaults to 1.
startdoy	An integer defining the start day-of-year of dates covered by the dataframe. Defaults to 1.
freq	A character string specifying the time steps of dates (in rows). Defaults to "days". Any of "days", "months", "years". If freq = "months" the 15 th day of the months is used as date, and if freq = "years" the 1 st of January of each year is returned.
endmoy	An integer defining the end month-of-year of dates covered by the dataframe. Defaults to 12.
enddom	An integer defining the end day-of-year of dates covered by the dataframe. Defaults to 31.
noleap	Whether leap years are ignored, that is, whether the 29 th of February is removed. Defaults to FALSE.

Value

A tibble with dates.

p_model_drivers	<i>rsosfun P-model driver data</i>
-----------------	------------------------------------

Description

Small dataset representing the driver to run the P-model at the FR-Pue site. It can also be used together with daily GPP flux time series data from CH-LAE ([p_model_validation](#)) to optimize model parameters. To optimize model parameters to leaf traits data use the datasets [p_model_drivers_vcmax25](#) and [p_model_validation_vcmax25](#).

Usage

`p_model_drivers`

Format

A tibble of driver data:

sitename A character string containing the site name.

forcing A tibble of a time series of forcing climate data, including the following data:

date Date of the observation in YYYY-MM-DD format.

temp Daytime average air temperature in °C.

vpd Daytime average vapour pressure deficit in Pa.

ppfd Photosynthetic photon flux density (PPFD) in $\text{mol m}^{-2} \text{s}^{-1}$. If all values are NA, it indicates that PPFD should be calculated by the SPLASH model.

netrad Net radiation in W m^{-2} . This is currently ignored as a model forcing.

patm Atmospheric pressure in Pa.

snow Snow in water equivalents mm s^{-1} .

rain Rain as precipitation in liquid form in mm s^{-1} .

tmin Daily minimum air temperature in °C.

tmax Daily maximum air temperature in °C.

fapar Fraction of photosynthetic active radiation (fAPAR), taking values between 0 and 1.

co2 Atmospheric CO₂ concentration.

ccov Cloud coverage in %. This is only used when either PPFD or net radiation are not prescribed.

params_siml A tibble of simulation parameters, including the following data:

spinup A logical value indicating whether this simulation does spin-up.

spinupyears Number of spin-up years.

recycle Length of standard recycling period, in years.

outdt An integer indicating the output periodicity.

ltre A logical value, TRUE if evergreen tree.

ltne A logical value, TRUE if evergreen tree and N-fixing.

ltrd A logical value, TRUE if deciduous tree.

ltnd A logical value, TRUE if deciduous tree and N-fixing.

lgr3 A logical value, TRUE if grass with C3 photosynthetic pathway.

lgn3 A logical value, TRUE if grass with C3 photosynthetic pathway and N-fixing.

lgr4 A logical value, TRUE if grass with C4 photosynthetic pathway.

site_info A tibble containing site meta information. This data structure can be freely used for documenting the dataset, but must include at least the following data:

lon Longitude of the site location in degrees east.

lat Latitude of the site location in degrees north.

elv Elevation of the site location, in meters above sea level.

whc A numeric value for the rooting zone water holding capacity (in mm)

Source

Pastorello, G., Trotta, C., Canfora, E. et al. The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data. *Sci Data* 7, 225 (2020). <https://doi.org/10.1038/s41597-020-0534-3>

University of East Anglia Climatic Research Unit; Harris, I.C.; Jones, P.D.; Osborn, T. (2021): CRU TS4.05: Climatic Research Unit (CRU) Time-Series (TS) version 4.05 of high-resolution gridded data of month-by-month variation in climate (Jan. 1901- Dec. 2020). NERC EDS Centre for Environmental Data Analysis, date of citation. <https://catalogue.ceda.ac.uk/uuid/c26a65020a5e4b80b20018f148556681>

Weedon, G. P., G. Balsamo, N. Bellouin, S. Gomes, M. J. Best, and P. Viterbo (2014), The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data, *Water Resour. Res.*, 50, 7505–7514, doi:10.1002/2014WR015638.

Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37 (12): 4302-4315.

p_model_drivers_vcmax25

rsosfun P-model driver data (for leaf traits)

Description

Small dataset representing the driver to run the P-model at four separate sites. It can also be used together with leaf traits data from these four sites ([p_model_validation_vcmax25](#)) to optimize model parameters. To optimize model parameters to GPP flux data use the datasets [p_model_drivers](#) and [p_model_validation](#).

Usage

p_model_drivers_vcmax25

Format

See [p_model_drivers](#)

Source

Atkin, O. K., Bloomfield, K. J., Reich, P. B., Tjoelker, M. G., Asner, G. P., Bonal, D., et al. (2015). Global variability in leaf respiration in relation to climate, plant functional types and leaf traits. *New Phytol.* 206 (2), 614–636. doi:10.1111/nph.13253

University of East Anglia Climatic Research Unit; Harris, I.C.; Jones, P.D.; Osborn, T. (2021): CRU TS4.05: Climatic Research Unit (CRU) Time-Series (TS) version 4.05 of high-resolution gridded data of month-by-month variation in climate (Jan. 1901- Dec. 2020). NERC EDS Centre for Environmental Data Analysis, date of citation. <https://catalogue.ceda.ac.uk/uuid/c26a65020a5e4b80b20018f148556681>

Weedon, G. P., G. Balsamo, N. Bellouin, S. Gomes, M. J. Best, and P. Viterbo (2014), The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data, *Water Resour. Res.*, 50, 7505–7514, doi:10.1002/2014WR015638.

Fick, S.E. and R.J. Hijmans, 2017. WorldClim 2: new 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37 (12): 4302-4315.

C.D. Keeling, R.B. Bacastow, A.E. Bainbridge, C.A. Ekdahl, P.R. Guenther, and L.S. Waterman, (1976), Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii, *Tellus*, vol. 28, 538-551

p_model_output	<i>rsofun P-model output data</i>
----------------	-----------------------------------

Description

Example output dataset from a p-model run using [p_model_drivers](#)

Usage

p_model_output

Format

An object of class tbl_df (inherits from tbl, data.frame) with 1 rows and 3 columns.

p_model_output_vcmax25	<i>rsofun P-model output data (using vcmax25 drivers)</i>
------------------------	---

Description

Example output dataset from a p-model run using [p_model_drivers_vcmax25](#)

Usage

p_model_output_vcmax25

Format

An object of class tbl_df (inherits from tbl, data.frame) with 4 rows and 3 columns.

p_model_validation	<i>rsofun P-model GPP validation data</i>
--------------------	---

Description

Small example dataset of target observations (daily GPP flux data) to optimize model parameters with the function `calib_sofun`

Usage

```
p_model_validation
```

Format

A tibble of validation data:

sitename A character string containing the site name (e.g. 'FR-Pue').

data A tibble [2,920 x 3] with time series for the following variables:

date Date vector with format YYYY-MM-DD.

gpp The observed Gross Primary Productivity (GPP) for each time stamp (in $\text{gC m}^{-2} \text{d}^{-1}$).

gpp_unc The uncertainty of the GPP (in $\text{gC m}^{-2} \text{d}^{-1}$).

Source

Pastorello, G., Trotta, C., Canfora, E. et al. The FLUXNET2015 dataset and the ONEFlux processing pipeline for eddy covariance data. Sci Data 7, 225 (2020). <https://doi.org/10.1038/s41597-020-0534-3>

Examples

```
require(ggplot2); require(tidyr)
p_model_validation %>% tidyr::unnest(data)
```

p_model_validation_vcmax25	<i>rsofun P-model Vcmax25 validation data</i>
----------------------------	---

Description

Small example dataset of target observations (leaf trait data) to optimize model parameters with the function `calib_sofun`

Usage

```
p_model_validation_vcmax25
```

Format

A tibble of validation data:

sitename A character string containing the site names (e.g. 'Reichetal_Colorado').

data A tibble [1 x 2] with observations for the following variables:

vcmax25 The observed maximum rate of carboxylation (V_{cmax}), normalised to 25° C (in $\text{mol C m}^{-2} \text{d}^{-1}$), aggregated over different plant species in each site.

vcmax25_unc The uncertainty of the V_{cmax25} (in $\text{mol C m}^{-2} \text{d}^{-1}$), calculated as the standard deviation among V_{cmax25} observations for several species per site or as the total standard deviation across sites for single-plant-species sites.

Source

Atkin, O. K., Bloomfield, K. J., Reich, P. B., Tjoelker, M. G., Asner, G. P., Bonal, D., et al. (2015). Global variability in leaf respiration in relation to climate, plant functional types and leaf traits. *New Phytol.* 206 (2), 614–636. doi:10.1111/nph.13253

Examples

```
require(ggplot2); require(tidyr)
p_model_validation_vcmax25 %>% tidyr::unnest(data)
```

runread_biomee_f

Run BiomeE

Description

Runs BiomeE model for multiple sites.

Usage

```
runread_biomee_f(drivers, makecheck = TRUE, parallel = FALSE, ncores = 2)
```

Arguments

drivers	A nested data frame with one row for each site and columns named according to the arguments of function 'runread_biomee_f_bysite()'. See '?run_biomee_f_bysite' for the list of parameters and forcing data required.
makecheck	Flag specifying whether checks are performed to verify forcings.
parallel	Flag specifying whether simulations are to be parallelised (sending data from a certain number of sites to each core). Defaults to FALSE.
ncores	An integer specifying the number of cores used for parallel computing. Defaults to 2.

Value

A tibble with one row for each site and model outputs stored in the nested column data. See ‘?run_biomee_f_bysite’ for a description of the BiomeE output variables.

Examples

```
# Example BiomeE model run

runread_biomee_f(
  drivers = biomee_gs_leuning_drivers
)
runread_biomee_f(
  drivers = biomee_p_model_drivers
)
```

runread_pmodel_f	<i>Run the P-model</i>
------------------	------------------------

Description

Runs the P-model and loads output in once.

Usage

```
runread_pmodel_f(drivers, par, makecheck = TRUE, parallel = FALSE, ncores = 1)
```

Arguments

drivers	A nested data frame with one row for each site and columns named according to the arguments of function <code>run_pmodel_f_bysite</code> , namely <code>sitename</code> , <code>params_siml</code> , <code>site_info</code> and <code>forcing</code> .
par	A named list of free (calibratable) model parameters. kphio The quantum yield efficiency at optimal temperature φ_0, in mol mol^{-1}. When temperature dependence is used, it corresponds to the multiplicative parameter c (see Details). kphio_par_a The shape parameter a of the temperature-dependency of quantum yield efficiency (see Details). To disable the temperature dependence, set <code>kphio_par_a = 0</code>. kphio_par_b The optimal temperature parameter b of the temperature dependent quantum yield efficiency (see Details), in $^{\circ}\text{C}$. soilm_thetastar The threshold parameter θ^* in the soil moisture stress function (see Details), given in mm. To turn off the soil moisture stress, set <code>soilm_thetastar = 0</code>. soilm_betao The intercept parameter β_0 in the soil moisture stress function (see Details). This is the parameter calibrated in Stocker et al. 2020 GMD.

	beta_unitcostratio The unit cost of carboxylation, corresponding to $\beta = b/a'$ in Eq. 3 of Stocker et al. 2020 GMD.
	rd_to_vcmax Ratio of Rdark (dark respiration) to Vcmax25.
	tau_acclim Acclimation time scale of photosynthesis, in days.
	kc_jmax Parameter for Jmax cost ratio (corresponding to c^* in Stocker et al. 2020 GMD).
makecheck	A logical specifying whether checks are performed to verify forcings. Defaults to TRUE.
parallel	A logical specifying whether simulations are to be parallelised (sending data from a certain number of sites to each core). Defaults to FALSE.
ncores	An integer specifying the number of cores used for parallel computing (by default ncores = 2).

Details

Depending on the input model parameters, it's possible to run the different P-model setups presented in Stocker et al. 2020 GMD. The P-model version implemented in this package allows more flexibility than the one presented in the paper, with the following functions:

The temperature dependence of the quantum yield efficiency is given by:

$$\varphi_0(T) = c(1 + a(T - b)^2) \text{ if } 0 < c(1 + a(T - b)^2) < 1,$$

$$\varphi_0(T) = 0 \text{ if } c(1 + a(T - b)^2) \leq 0, \text{ and}$$

$$\varphi_0(T) = 1 \text{ if } c(1 + a(T - b)^2) \geq 1.$$

The ORG setup can be reproduced by setting $k\phi_{io_par_a} = 0$ and calibrating the $k\phi_{io}$ parameter only. The BRC setup (which calibrates $c_L = \frac{a_L b_L}{4}$ in Eq. 18) is more difficult to reproduce, since the temperature-dependency has been reformulated and a custom cost function would be necessary for calibration. The new parameters are related to c_L as follows:

$$a = -0.0004919819$$

$$b = 32.35294$$

$$c = 0.6910823c_L$$

The soil moisture stress is implemented as

$$\beta(\theta) = \frac{\beta_0 - 1}{\theta^{*2}}(\theta - \theta^*)^2 + 1 \text{ if } 0 \leq \theta \leq \theta^* \text{ and}$$

$$\beta(\theta) = 1 \text{ if } \theta > \theta^*.$$

In Stocker et al. 2020 GMD, the threshold plant-available soil water is set as $\theta^* = 0.6 * whc$ where whc is the site's water holding capacity. Also, the β reduction at low soil moisture ($\beta_0 = \beta(0)$) was parameterized as a linear function of mean aridity (Eq. 20 in Stocker et al. 2020 GMD) but is considered a constant model parameter in this package. Hence, the FULL calibration setup cannot be exactly replicated.

Value

A data frame (tibble) with one row for each site, site information stored in the nested column `site_info` and outputs stored in the nested column `data`. See `run_pmodel_f_bysite` for a detailed description of the outputs.

Examples

```
# Define model parameter values from previous work
```

```

params_modl <- list(
  kphio          = 0.04998,    # setup ORG in Stocker et al. 2020 GMD
  kphio_par_a    = 0.0,        # disable temperature-dependence of kphio
  kphio_par_b    = 1.0,
  soilm_thetastar = 0.6 * 240, # old setup with soil moisture stress
  soilm_betao    = 0.0,
  beta_unitcostratio = 146.0,
  rd_to_vcmax    = 0.014,      # from Atkin et al. 2015 for C3 herbaceous
  tau_acclim     = 30.0,
  kc_jmax        = 0.41
)

# Run the model for these parameters and the example drivers
output <- rsofun::runread_pmodel_f(
  drivers = rsofun::p_model_drivers,
  par = params_modl)
output_vcmax25 <- rsofun::runread_pmodel_f(
  drivers = rsofun::p_model_drivers_vcmax25,
  par = params_modl)

```

run_biomee_f_bysite	<i>Run BiomeE (R wrapper)</i>
---------------------	-------------------------------

Description

Run BiomeE Fortran model on single site.

Usage

```

run_biomee_f_bysite(
  sitename,
  params_siml,
  site_info,
  forcing,
  params_tile,
  params_species,
  init_cohort,
  init_soil,
  makecheck = TRUE
)

```

Arguments

sitename	Site name.
params_siml	Simulation parameters. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
site_info	Site meta info in a data.frame. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers

forcing	Forcing data.frame used as input. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
params_tile	Tile-level model parameters, into a single row data.frame. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
params_species	A data.frame containing species-specific model parameters, with one species per row. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
init_cohort	A data.frame of initial cohort specifications. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
init_soil	A data.frame of initial soil pools. See examples biomee_gs_leuning_drivers or biomee_p_model_drivers
makecheck	Flag specifying whether checks are performed to verify model inputs and parameters.

Value

Model output is provided as a list, with elements:

output_hourly_tile A data.frame containing hourly predictions .

year Year of the simulation.
doy Day of the year.
hour Hour of the day.
rad Radiation, in W m^{-2} .
Tair Air temperature, in Kelvin.
Prcp Precipitation, in mm m^{-2} .
GPP Gross primary production ($\text{kg C m}^{-2} \text{ hour}^{-1}$).
Resp Plant respiration ($\text{kg C m}^{-2} \text{ hour}^{-1}$).
Transp Transpiration (mm m^{-2}).
Evap Evaporation (mm m^{-2}).
Runoff Water runoff (mm m^{-2}).
Soilwater Soil water content in root zone (kg m^{-2}).
wcl Volumetric soil water content for each layer (vol/vol).
FLDCAP Field capacity (vol/vol).
WILTPT Wilting point (vol/vol).

output_daily_tile A data.frame with daily outputs at a tile level.

year Year of the simulation.
doy Day of the year.
Tc Air temperature (Kelvin).
Prcp Precipitation (mm m^{-2}).
totWs Soil water content in root zone (kg m^{-2}).
Trsp Transpiration (mm m^{-2}).
Evap Evaporation (mm m^{-2}).
Runoff Water runoff (mm m^{-2}).
ws1 Volumetric soil water content for layer 1.

ws2 Volumetric soil water content for layer 2.
ws3 Volumetric soil water content for layer 3.
LAI Leaf area index (m^2/m^2).
GPP Gross primary production ($\text{kg C m}^{-2} \text{ day}^{-1}$).
Rauto Plant autotrophic respiration ($\text{kg C m}^{-2} \text{ day}^{-1}$).
Rh Heterotrophic respiration ($\text{kg C m}^{-2} \text{ day}^{-1}$).
NSC Non-structural carbon (kg C m^{-2}).
seedC Biomass of seeds (kg C m^{-2}).
leafC Biomass of leaves (kg C m^{-2}).
rootC Biomass of fine roots (kg C m^{-2}).
SW_C Biomass of sapwood (kg C m^{-2}).
HW_C biomass of heartwood (kg C m^{-2}).
NSN Non-structural N pool (kg N m^{-2}).
seedN Nitrogen of seeds (kg N m^{-2}).
leafN Nitrogen of leaves (kg N m^{-2}).
rootN Nitrogen of roots (kg N m^{-2}).
SW_N Nitrogen of sapwood (kg N m^{-2}).
HW_N Nitrogen of heartwood (kg N m^{-2}).
McrbC Microbial carbon (kg C m^{-2}).
fastSOM Fast soil carbon pool (kg C m^{-2}).
slowSOM Slow soil carbon pool (kg C m^{-2}).
McrbN Microbial nitrogen (kg N m^{-2}).
fastSoilN Fast soil nitrogen pool (kg N m^{-2}).
slowSoilN Slow soil nitrogen pool (kg N m^{-2}).
mineralN Mineral nitrogen pool (kg N m^{-2}).
N_uptk Nitrogen uptake (kg N m^{-2}).

output_daily_cohorts A data.frame with daily predictions for each canopy cohort.

year Year of the simulation.
day Day of the year.
hour Hour of the day.
cID An integer indicating the cohort identity.
PFT An integer indicating the Plant Functional Type.
layer An integer indicating the crown layer, numbered from top to bottom.
density Number of trees per area (trees ha^{-1}).
f_layer Fraction of layer area occupied by this cohort.
LAI Leaf area index (m^2/m^2).
gpp Gross primary productivity ($\text{kg C tree}^{-1} \text{ day}^{-1}$).
resp Plant autotrophic respiration ($\text{kg C tree}^{-1} \text{ day}^{-1}$).
transp Transpiration ($\text{mm tree}^{-1} \text{ day}^{-1}$).
NPpleaf Carbon allocated to leaves ($\text{kg C tree}^{-1} \text{ day}^{-1}$).
NPProot Carbon allocated to fine roots ($\text{kg C tree}^{-1} \text{ day}^{-1}$).
NPPwood Carbon allocated to wood ($\text{kg C tree}^{-1} \text{ day}^{-1}$).

NSC Nonstructural carbohydrates of a tree in this cohort (kg C tree⁻¹).

seedC Seed biomass of a tree in this cohort (kg C tree⁻¹).

leafC Leaf biomass of a tree in this cohort (kg C tree⁻¹).

rootC Fine root biomass of a tree in this cohort (kg C tree⁻¹).

SW_C Sapwood biomass of a tree in this cohort (kg C tree⁻¹).

HW_C Heartwood biomass of a tree in this cohort (kg C tree⁻¹).

NSN Nonstructural nitrogen of a tree in this cohort (kg N tree⁻¹).

seedN Seed nitrogen of a tree in this cohort (kg N tree⁻¹).

leafN Leaf nitrogen of a tree in this cohort (kg N tree⁻¹).

rootN Fine root nitrogen of a tree in this cohort (kg N tree⁻¹).

SW_N Sapwood nitrogen of a tree in this cohort (kg N tree⁻¹).

HW_N Heartwood nitrogen of a tree in this cohort (kg N tree⁻¹).

output_annual_tile A data.frame with annual outputs at tile level.

year Year of the simulation.

CAI Crown area index (m²/m²).

LAI Leaf area index (m²/m²).

Density Number of trees per area (trees ha⁻¹).

DBH Diameter at tile level (cm).

Density12 Tree density for trees with DBH > 12 cm (individuals ha⁻¹).

DBH12 Diameter at tile level considering trees with DBH > 12 cm (cm).

QMD12 Quadratic mean diameter at tile level considering trees with DBH > 12 cm (cm).

NPP Net primary productivity (kg C m⁻² yr⁻¹).

GPP Gross primary productivity (kg C m⁻² yr⁻¹).

Rauto Plant autotrophic respiration (kg C m⁻² yr⁻¹).

Rh Heterotrophic respiration (kg C m⁻² yr⁻¹).

rain Annual precipitation (mm m⁻² yr⁻¹).

SoilWater Soil water content in root zone (kg m⁻²).

Transp Transpiration (mm m⁻² yr⁻¹).

Evap Evaporation (mm m⁻² yr⁻¹).

Runoff Water runoff (mm m⁻² yr⁻¹).

plantC Plant biomass (kg C m⁻²).

soilC Soil carbon (kg C m⁻²).

plantN Plant nitrogen (kg N m⁻²).

soilN Soil nitrogen (kg N m⁻²).

totN Total nitrogen in plant and soil (kg N m⁻²).

NSC Nonstructural carbohydrates (kg C m⁻²).

SeedC Seed biomass (kg C m⁻²).

leafC Leaf biomass (kg C m⁻²).

rootC Fine root biomass (kg C m⁻²).

SapwoodC Sapwood biomass (kg C m⁻²).

WoodC Heartwood biomass (kg C m⁻²).

NSN Nonstructural nitrogen (kg N m⁻²).

SeedN Seed nitrogen (kg N m^{-2}).
leafN Leaf nitrogen (kg N m^{-2}).
rootN Fine root nitrogen (kg N m^{-2}).
SapwoodN Sapwood nitrogen (kg N m^{-2}).
WoodN Heartwood nitrogen (kg N m^{-2}).
McrbC Microbial carbon (kg C m^{-2}).
fastSOM Fast soil carbon pool (kg C m^{-2}).
SlowSOM Slow soil carbon pool (kg C m^{-2}).
McrbN Microbial nitrogen (kg N m^{-2}).
fastSoilN Fast soil nitrogen pool (kg N m^{-2}).
slowsoilN Slow soil nitrogen pool (kg N m^{-2}).
mineralN Mineral nitrogen pool (kg N m^{-2}).
N_fixed Nitrogen fixation (kg N m^{-2}).
N_uptk Nitrogen uptake (kg N m^{-2}).
N_yrMin Annual available nitrogen (kg N m^{-2}).
N_P25 Annual nitrogen from plants to soil (kg N m^{-2}).
N_loss Annual nitrogen loss (kg N m^{-2}).
totseedC Total seed carbon (kg C m^{-2}).
totseedN Total seed nitrogen (kg N m^{-2}).
Seedling_C Total carbon from all compartments but seeds (kg C m^{-2}).
Seedling_N Total nitrogen from all compartments but seeds (kg N m^{-2}).
MaxAge Age of the oldest tree in the tile (years).
MaxVolume Maximum volume of a tree in the tile (m^3).
MaxDBH Maximum DBH of a tree in the tile (m).
NPPL Growth of a tree, including carbon allocated to leaves ($\text{kg C m}^{-2} \text{ year}^{-1}$).
NPPW Growth of a tree, including carbon allocated to sapwood ($\text{kg C m}^{-2} \text{ year}^{-1}$).
n_deadtrees Number of trees that died ($\text{trees m}^{-2} \text{ year}^{-1}$).
c_deadtrees Carbon biomass of trees that died ($\text{kg C m}^{-2} \text{ year}^{-1}$).
m_turnover Continuous biomass turnover ($\text{kg C m}^{-2} \text{ year}^{-1}$).
c_turnover_time Carbon turnover rate, calculated as the ratio between plant biomass and NPP (year^{-1}).

output_annual_cohorts A data.frame of annual outputs at the cohort level.

year Year of the simulation.
cID An integer indicating the cohort identity.
PFT An integer indicating the Plant Functional Type.
layer An integer indicating the crown layer, numbered from top to bottom.
density Number of trees per area (trees ha^{-1}).
f_layer Fraction of layer area occupied by this cohort.
dDBH Diameter growth of a tree in this cohort (cm year^{-1}).
dbh Tree diameter (cm).
height Tree height (m).
age Age of the cohort (years).

Acrow Crown area of a tree in this cohort (m^2).

wood Sum of sapwood and heartwood biomass of a tree in this cohort (kg C tree^{-1}).

nsc Nonstructural carbohydrates in a tree (kg C tree^{-1}).

NSN Nonstructural nitrogen of a tree (kg N tree^{-1}).

NPPtr Total growth of a tree, including carbon allocated to seeds, leaves, fine roots, and sapwood ($\text{kg C tree}^{-1} \text{ year}^{-1}$).

seed Fraction of carbon allocated to seeds to total growth.

NPPL Fraction of carbon allocated to leaves to total growth.

NPPR Fraction of carbon allocated to fine roots to total growth.

NPPW Fraction of carbon allocated to sapwood to total growth.

GPP_yr Gross primary productivity of a tree ($\text{kg C tree}^{-1} \text{ year}^{-1}$).

NPP_yr Net primary productivity of a tree ($\text{kg C tree}^{-1} \text{ year}^{-1}$).

Rauto Plant autotrophic respiration ($\text{kg C tree}^{-1} \text{ yr}^{-1}$).

N_uptk Nitrogen uptake ($\text{kg N tree}^{-1} \text{ yr}^{-1}$).

N_fix Nitrogen fixation ($\text{kg N tree}^{-1} \text{ yr}^{-1}$).

maxLAI Maximum leaf area index for a tree ($\text{m}^2 \text{ m}^{-2}$).

Volume Tree volume (m^3).

n_deadtrees Number of trees that died (trees yr^{-1}).

c_deadtrees Carbon biomass of trees that died (kg C yr^{-1}).

deathrate Mortality rate of this cohort (yr^{-1}).

Examples

```
# Example BiomeE model run

# Use example drivers data
drivers <- biomee_gs_leuning_drivers

# Run BiomeE for the first site
mod_output <- run_biomee_f_bysite(
  sitename = drivers$sitename[1],
  params_siml = drivers$params_siml[[1]],
  site_info = drivers$site_info[[1]],
  forcing = drivers$forcing[[1]],
  params_tile = drivers$params_tile[[1]],
  params_species = drivers$params_species[[1]],
  init_cohort = drivers$init_cohort[[1]],
  init_soil = drivers$init_soil[[1]]
)
```

run_pmodel_f_bysite *R wrapper for SOFUND P-model*

Description

Call to the Fortran P-model

Usage

```
run_pmodel_f_bysite(
  sitename,
  params_siml,
  site_info,
  forcing,
  params_modl,
  makecheck = TRUE,
  verbose = TRUE
)
```

Arguments

sitename	Site name.
params_siml	Simulation parameters. spinup A logical value indicating whether this simulation does spin-up. spinupyears Number of spin-up years. recycle Length of standard recycling period, in years. outdt An integer indicating the output periodicity. ltre A logical value, TRUE if evergreen tree. ltne A logical value, TRUE if evergreen tree and N-fixing. ltrd A logical value, TRUE if deciduous tree. ltnd A logical value, TRUE if deciduous tree and N-fixing. lgr3 A logical value, TRUE if grass with C3 photosynthetic pathway. lgn3 A logical value, TRUE if grass with C3 photosynthetic pathway and N-fixing. lgr4 A logical value, TRUE if grass with C4 photosynthetic pathway.
site_info	A list of site meta info. Required: lon Longitude of the site location. lat Latitude of the site location. elv Elevation of the site location, in meters. whc A numeric value for the total root zone water holding capacity (in mm), used for simulating the soil water balance.
forcing	A data frame of forcing climate data, used as input (see p_model_drivers for a detailed description of its structure and contents).
params_modl	A named list of free (calibratable) model parameters. kphio The quantum yield efficiency at optimal temperature φ_0 , in mol mol^{-1} . When temperature dependence is used, it corresponds to the multiplicative parameter c (see Details). kphio_par_a The shape parameter a of the temperature-dependency of quantum yield efficiency (see Details). To disable the temperature dependence, set <code>kphio_par_a = 0</code> . kphio_par_b The optimal temperature parameter b of the temperature dependent quantum yield efficiency (see Details), in $^{\circ}\text{C}$.

	soilm_thetastar The threshold parameter θ^* in the soil moisture stress function (see Details), given in mm. To turn off the soil moisture stress, set <code>soilm_thetastar = 0</code> .
	soilm_betao The intercept parameter β_0 in the soil moisture stress function (see Details). This is the parameter calibrated in Stocker et al. 2020 GMD.
	beta_unitcostratio The unit cost of carboxylation, corresponding to $\beta = b/a'$ in Eq. 3 of Stocker et al. 2020 GMD.
	rd_to_vcmax Ratio of R_{dark} (dark respiration) to V_{cmax25} .
	tau_acclim Acclimation time scale of photosynthesis, in days.
	kc_jmax Parameter for J_{max} cost ratio (corresponding to c^* in Stocker et al. 2020 GMD).
<code>makecheck</code>	A logical specifying whether checks are performed to verify forcings and model parameters. TRUE by default.
<code>verbose</code>	A logical specifying whether to print warnings. Defaults to TRUE.

Details

Depending on the input model parameters, it's possible to run the different P-model setups presented in Stocker et al. 2020 GMD. The P-model version implemented in this package allows more flexibility than the one presented in the paper, with the following functions:

The temperature dependence of the quantum yield efficiency is given by:

$$\varphi_0(T) = c(1 + a(T - b)^2) \text{ if } 0 < c(1 + a(T - b)^2) < 1,$$

$$\varphi_0(T) = 0 \text{ if } c(1 + a(T - b)^2) \leq 0, \text{ and}$$

$$\varphi_0(T) = 1 \text{ if } c(1 + a(T - b)^2) \geq 1.$$

The ORG setup can be reproduced by setting `kphio_par_a = 0` and calibrating the `kphio` parameter only. The BRC setup (which calibrates $c_L = \frac{a_L b_L}{4}$ in Eq. 18) is more difficult to reproduce, since the temperature-dependency has been reformulated and a custom cost function would be necessary for calibration. The new parameters are related to c_L as follows:

$$a = -0.0004919819$$

$$b = 32.35294$$

$$c = 0.6910823c_L$$

The soil moisture stress is implemented as

$$\beta(\theta) = \frac{\beta_0 - 1}{\theta^{*2}}(\theta - \theta^*)^2 + 1 \text{ if } 0 \leq \theta \leq \theta^* \text{ and}$$

$$\beta(\theta) = 1 \text{ if } \theta > \theta^*.$$

In Stocker et al. 2020 GMD, the threshold plant-available soil water is set as $\theta^* = 0.6 * whc$ where `whc` is the site's water holding capacity. Also, the β reduction at low soil moisture ($\beta_0 = \beta(0)$) was parameterized as a linear function of mean aridity (Eq. 20 in Stocker et al. 2020 GMD) but is considered a constant model parameter in this package. Hence, the FULL calibration setup cannot be exactly replicated.

Value

Model output is provided as a tidy dataframe, with columns:

`date` Date of the observation in YYYY-MM-DD format.

`year_dec` Decimal representation of year and day of the year (for example, 2007.000 corresponds to 2007-01-01 and 2007.003 to 2007-01-02).

fapar Fraction of photosynthetic active radiation (fAPAR), taking values between 0 and 1.

gpp Gross Primary Productivity (GPP) for each time stamp (in $\text{gC m}^{-2} \text{d}^{-1}$).

aet Actual evapotranspiration (AET), calculated by SPLASH following Priestly-Taylor (in mm d^{-1}).

le Latent heat flux (in $\text{J m}^{-2} \text{d}^{-1}$).

pet Potential evapotranspiration (PET), calculated by SPLASH following Priestly-Taylor (in mm d^{-1}).

vcmax Maximum rate of RuBisCO carboxylation (Vcmax) (in $\text{mol C m}^{-2} \text{d}^{-1}$).

jmax Maximum rate of electron transport for RuBP regeneration (in $\text{mol CO}_2 \text{m}^{-2} \text{s}^{-1}$).

vcmax25 Maximum rate of carboxylation (Vcmax), normalised to 25°C (in $\text{mol C m}^{-2} \text{d}^{-1}$).

jmax25 Maximum rate of electron transport, normalised to 25°C (in $\text{mol C m}^{-2} \text{s}^{-1}$).

gs_accl Acclimated stomatal conductance (in $\text{mol C m}^{-2} \text{d}^{-1} \text{Pa}^{-1}$).

wscal Relative soil water content, between 0 (permanent wilting point, PWP) and 1 (field capacity, FC).

chi Ratio of leaf-internal to ambient CO_2 , $c_i:c_a$ (unitless).

iwue Intrinsic water use efficiency (iWUE) (in Pa).

rd Dark respiration (Rd) in $\text{gC m}^{-2} \text{d}^{-1}$.

tsoil Soil temperature, in $^\circ\text{C}$.

netrad Net radiation, in W m^{-2} . WARNING: this is currently ignored as a model forcing. Instead, net radiation is internally calculated by SPLASH.

wcont Soil water content, in mm.

snow Snow water equivalents, in mm.

cond Water input by condensation, in mm d^{-1} .

Examples

```
# Define model parameter values from previous work
params_mod1 <- list(
  kphio          = 0.04998,    # setup ORG in Stocker et al. 2020 GMD
  kphio_par_a    = 0.0,        # disable temperature-dependence of kphio
  kphio_par_b    = 1.0,
  soilm_thetastar = 0.6 * 240, # old setup with soil moisture stress
  soilm_betao    = 0.0,
  beta_unitcostratio = 146.0,
  rd_to_vcmax    = 0.014,      # from Atkin et al. 2015 for C3 herbaceous
  tau_acclim     = 30.0,
  kc_jmax        = 0.41
)

# Run the Fortran P-model
mod_output <- run_pmodel_f_bysite(
  # unnest drivers example data
  sitename = p_model_drivers$sitename[1],
  params_siml = p_model_drivers$params_siml[[1]],
  site_info = p_model_drivers$site_info[[1]],
)
```

```
    forcing = p_model_drivers$forcing[[1]],  
    params_modl = params_modl  
  )
```

Index

* datasets

- biomee_gs_leuning_drivers, [2](#)
- biomee_gs_leuning_output, [5](#)
- biomee_p_model_drivers, [6](#)
- biomee_p_model_output, [6](#)
- biomee_validation, [7](#)
- p_model_drivers, [15](#)
- p_model_drivers_vcmax25, [17](#)
- p_model_output, [18](#)
- p_model_output_vcmax25, [18](#)
- p_model_validation, [19](#)
- p_model_validation_vcmax25, [19](#)

BayesianTools::runMCMC, [8](#)
biomee_gs_leuning_drivers, [2](#), [6](#), [23](#), [24](#)
biomee_gs_leuning_output, [5](#)
biomee_p_model_drivers, [6](#), [23](#), [24](#)
biomee_p_model_output, [6](#)
biomee_validation, [2](#), [6](#), [7](#)

calib_sofun, [7](#), [7](#), [19](#)
cost_likelihood_biomee, [9](#)
cost_likelihood_pmodel, [10](#)
cost_rmse_biomee, [12](#)
cost_rmse_pmodel, [13](#)

GenSA, [8](#)

init_dates_dataframe, [14](#)

p_model_drivers, [7](#), [11](#), [13](#), [15](#), [17](#), [18](#), [29](#)
p_model_drivers_vcmax25, [15](#), [17](#), [18](#)
p_model_output, [18](#)
p_model_output_vcmax25, [18](#)
p_model_validation, [7](#), [11](#), [13](#), [15](#), [17](#), [19](#)
p_model_validation_vcmax25, [11](#), [13](#), [15](#),
[17](#), [19](#)

run_biomee_f_bysite, [23](#)
run_pmodel_f_bysite, [21](#), [22](#), [28](#)
runMCMC, [8](#)

runread_biomee_f, [20](#)
runread_pmodel_f, [10](#), [11](#), [13](#), [21](#)