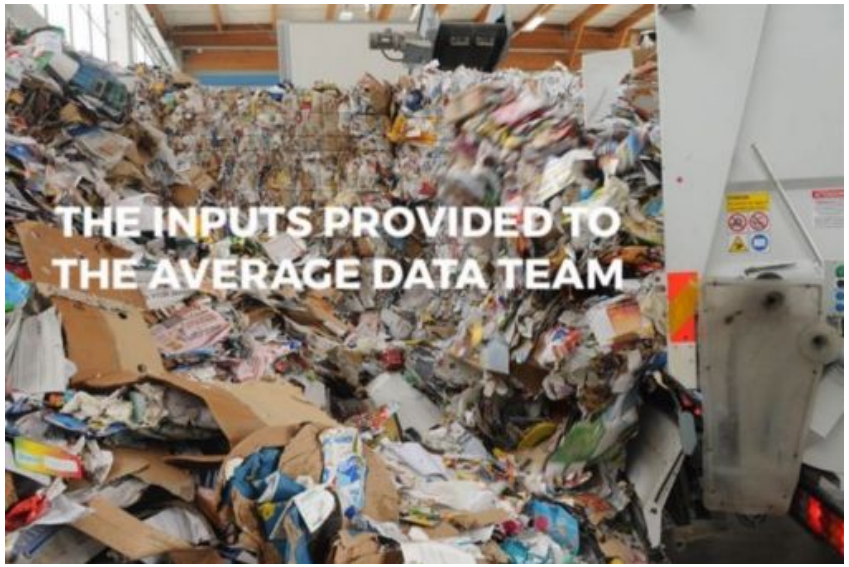
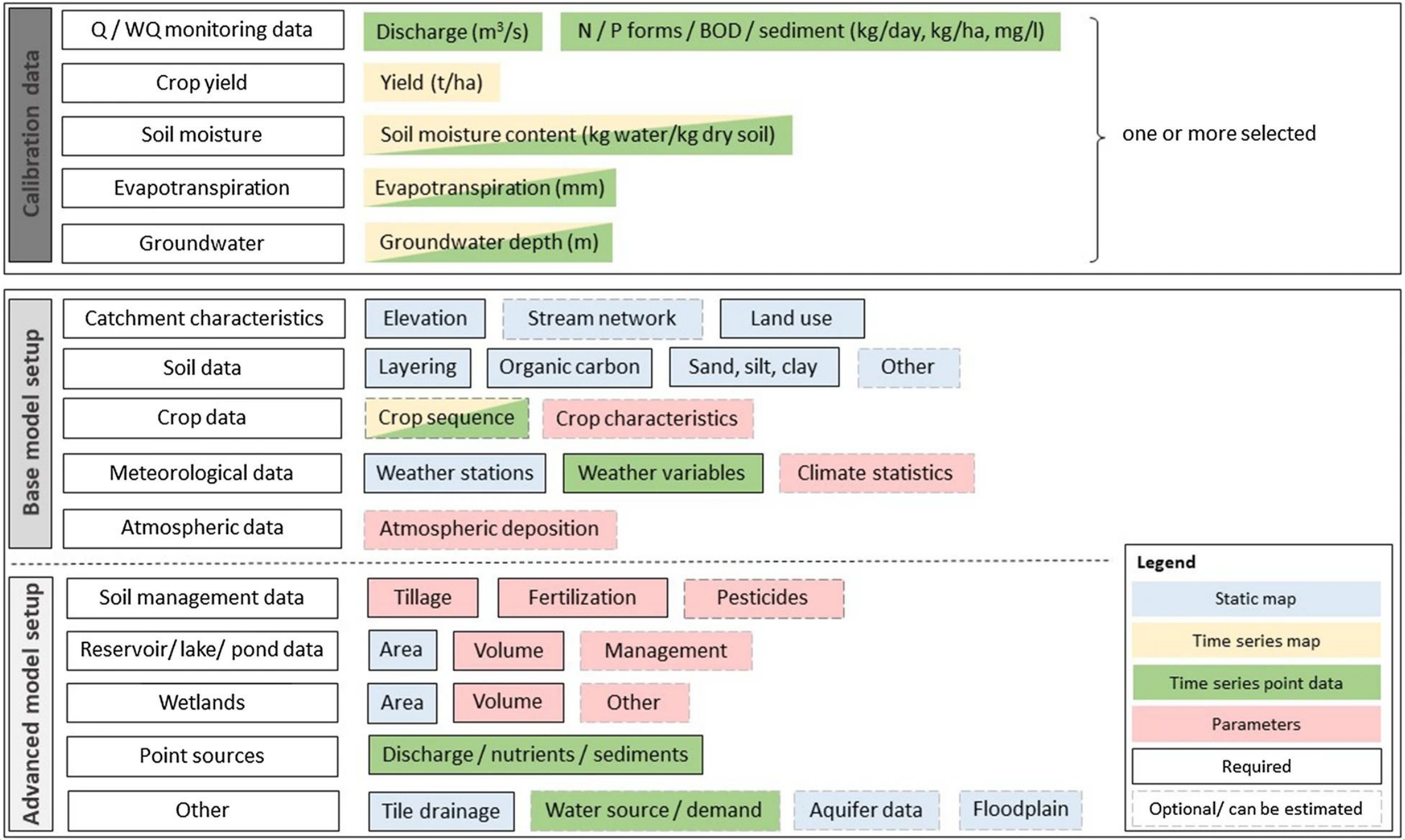
Modeling challenge #2

Prepare inputs and overcome data scarcity

Problems

- Accessing data
- Data quality questions
- Questions with preparing parameters from available information
- Manual work & steps, prone to errors
- Dealing with file formats and file formatting
- Extracting relevant data
- Repeatability of preparation operations
- Updating with new/additional data
- Multiple tools




Calibration data
Q / WQ monitoring data
Discharge (m³/s)
N / P forms / BOD / sediment (kg/day, kg/ha, mg/l)
Crop yield
Yield (t/ha)
Soil moisture
Soil moisture content (kg water/kg dry soil)
Evapotranspiration
Evapotranspiration (mm)
Groundwater
Groundwater depth (m)
one or more selected
Base model setup
Catchment characteristics
Elevation
Stream network
Land use
Soil data
Layering
Organic carbon
Sand, silt, clay
Other
Crop data
Crop sequence
Crop characteristics
Meteorological data
Weather stations
Weather variables
Climate statistics
Atmospheric data
Atmospheric deposition
Advanced model setup
Soil management data
Tillage
Fertilization
Pesticides
Reservoir/ lake/ pond data
Area
Volume
Management
Wetlands
Area
Volume
Other
Point sources
Discharge / nutrients / sediments
Other
Tile drainage
Water source / demand
Aquifer data
Floodplain
Legend
Static map
Time series map
Time series point data
Parameters
Required
Optional/ can be estimated

Workflow in R

SWATprepR
SWAT+ input data preparation

SWATdoctR
Model diagnostics tool
for SWAT+ model setups

SWATrunR
Running SWAT simulations in R

SWATmeasR
Implementation of NSWRMs in
SWATbuildR model setups

SWATbuildR
An object connectivity
based SWAT+ model builder

SWATfarmR
Simple rule based management
operation scheduling

SWATtunR
Tuning SWAT+ model parameters

Vision: SWAT+ modelling process fully scriptable in R

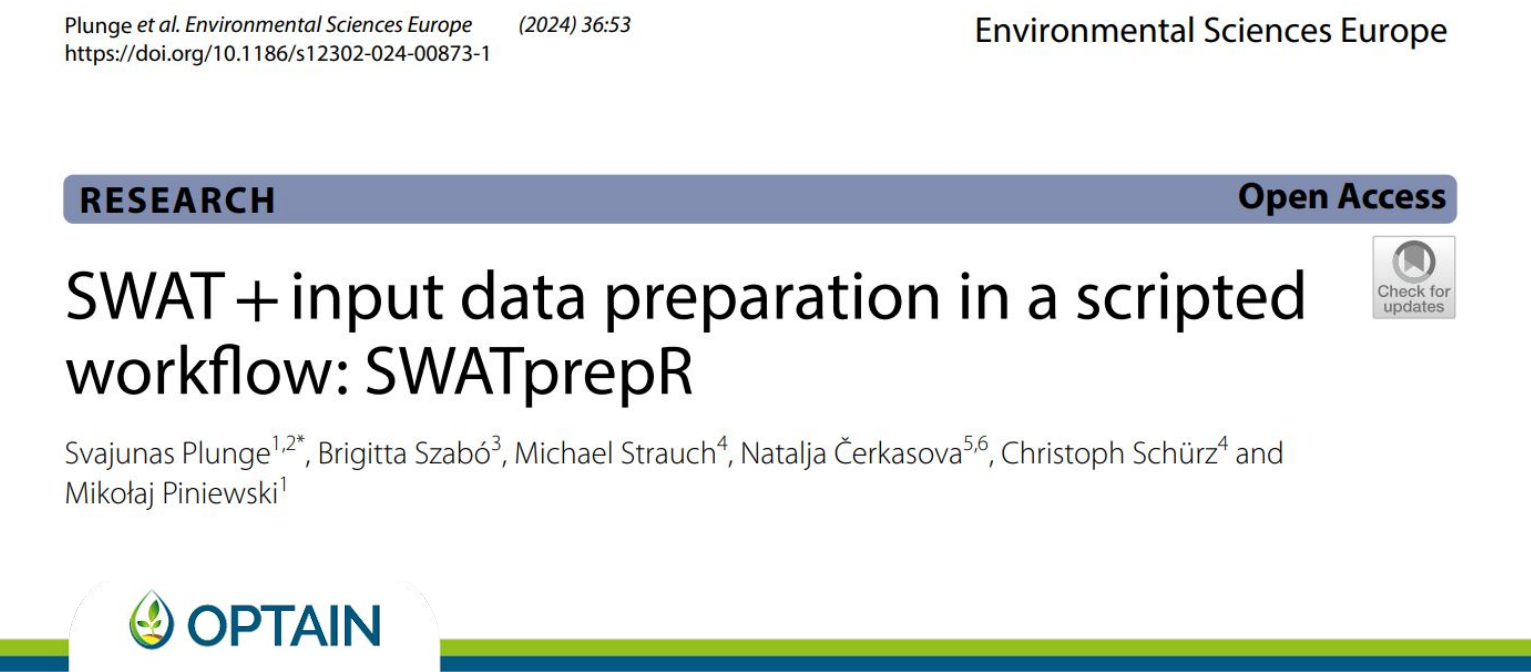
Package and git pages website

biopsichas.github.io/SWATprepR/

Newest version, updates

Plunge, S., Szabó, B., Strauch, M. *et al.* SWAT + input data preparation in a scripted workflow: SWATprepR. *Environ Sci Eur* 36, 53 (2024).

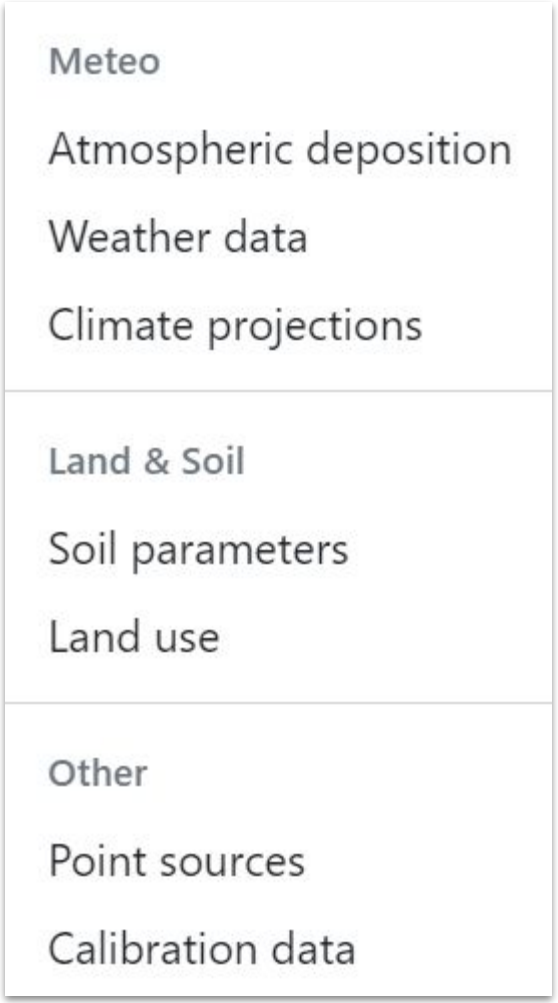
https://doi.org/10.1186/s12302-024-00873-1



What does it do?

SWATprepR package in R

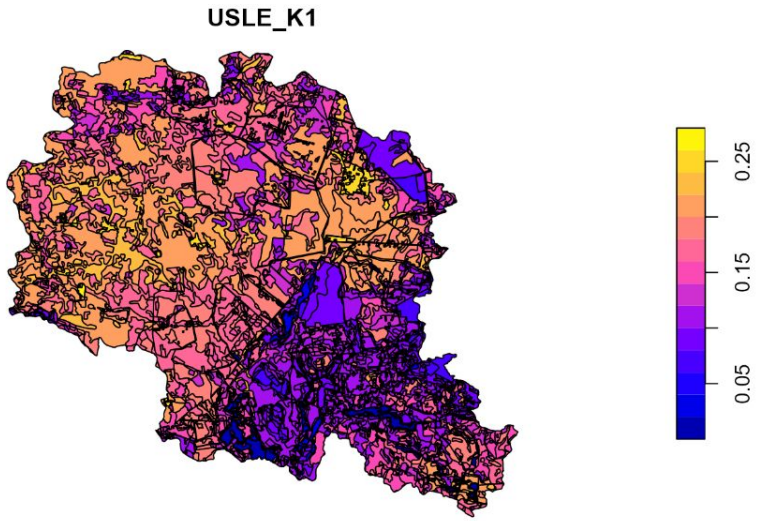
- Loading data in R from templates, files or directly internet databases
- Plotting in multiple ways and data cleaning
- Calculating SWAT+ model input parameters/data
- Preparing model SWAT+ model input files
- Adding into the setup
- Some extras



Example 1 - Soil parameters

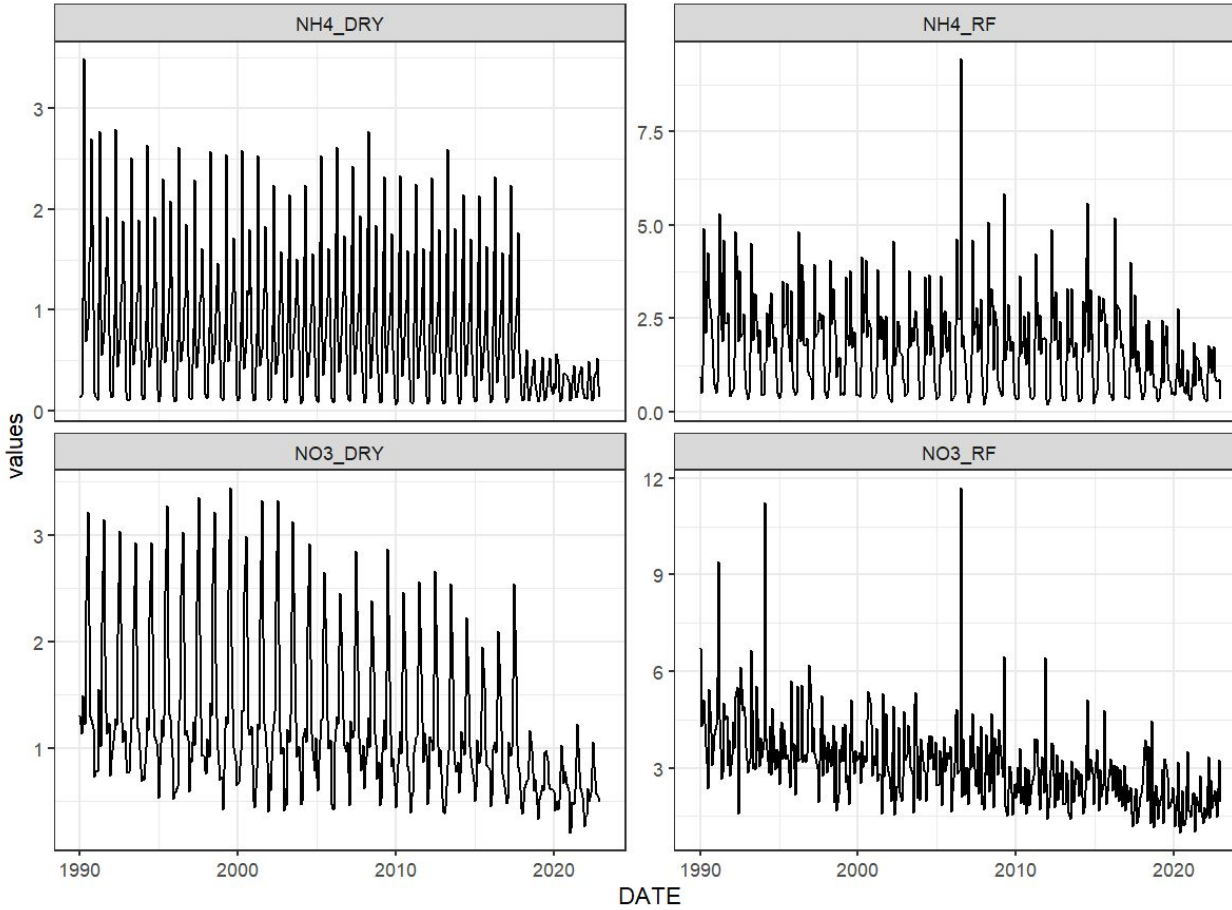
- If you have
  - *NLAYERS* value for soil type representing number of soil layers;
  - For each layer in soil type profile:
    - *SOL_Z* value for soil layer to represent max depth of soil layer;
    - *SAND* sand content in %;
    - *SILT* silt content in %;
    - *CLAY* clay content in %;
    - *SOL_CBN* organic carbon content in %.
- Apply single function `get_usersoil_table()`

and *voilà*…



Example 2 - Atmospheric deposition

- Download atmospheric deposition data directly from EMEP server `get_atmo_dep` (only basin shape file required)
- Add into into your setup with function `add_atmo_dep`



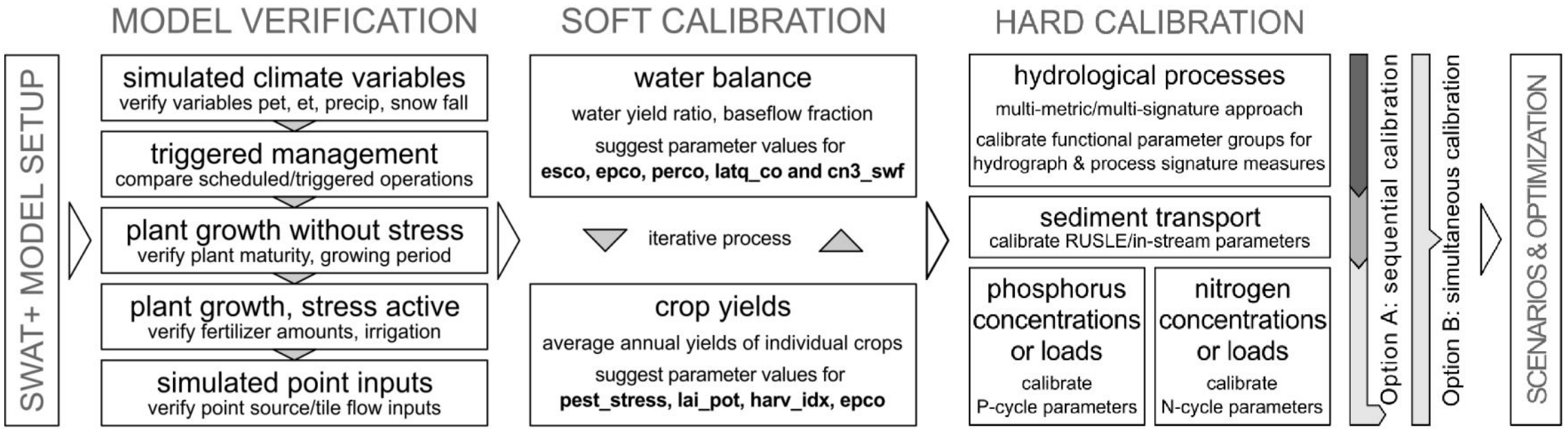
Modeling challenge #4

Ensure reliability in your model's results!

Proposed calibration workflow in OPTAIN (all scripted)

SWATrunR

SWATdoctR **SWATtunR**



SWATrunR tool to run SWAT+ model setups

```
define_output(
file,
variable = NULL,
unit = NULL)
```

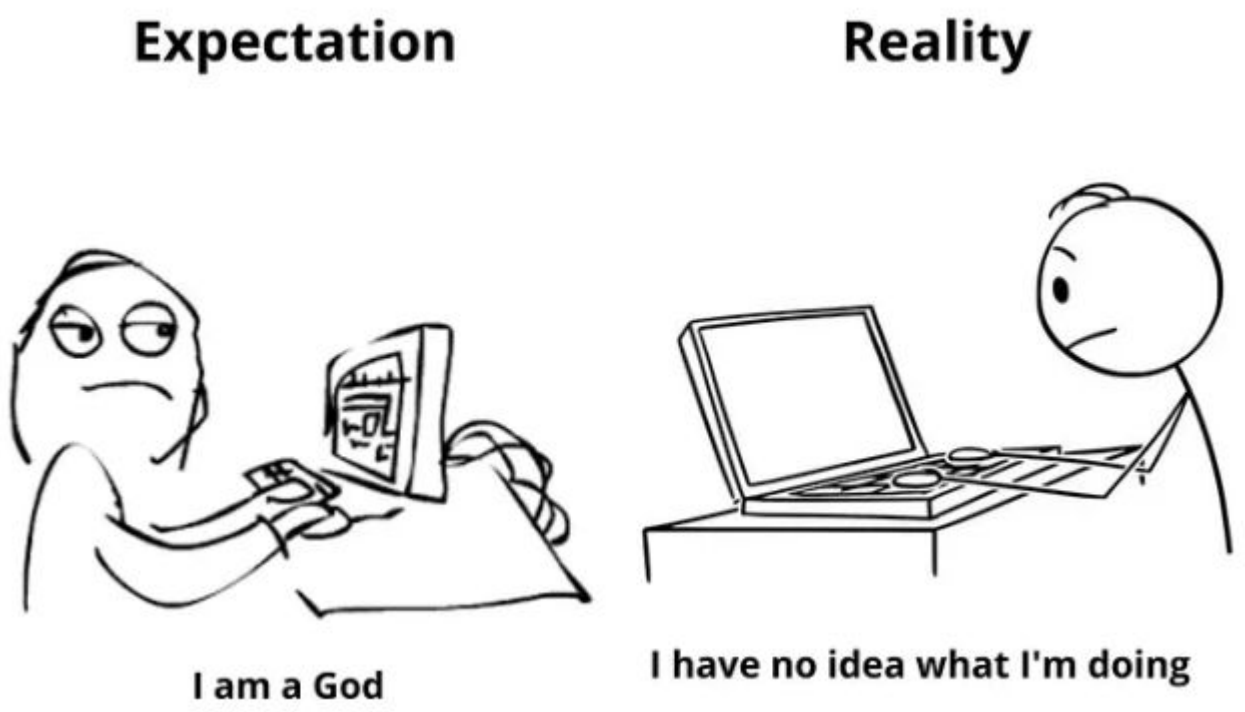
```
run_swatplus(
  project_path,
  output,
  parameter = NULL,
  start_date = NULL,
  end_date = NULL,
  years_skip = NULL,
  start_date_print = NULL,
  run_index = NULL,
  run_path = NULL,
  n_thread = NULL,
  save_path = NULL,
  save_file = NULL,
  return_output = TRUE,
  add_parameter = TRUE,
  add_date = TRUE,
  refresh = TRUE,
  keep_folder = FALSE,
  quiet = FALSE,
  revision = NULL,
  time_out = Inf)
```

Only 2 functions

https://chrisschuerz.github.io/SWATrunR

New concept - model setup verification

- Input data preparation
- Setup preparation
-
- Sensitivity assessment
- Calibration
- Validation
- Scenarios
- Reporting



Package website

https://git.ufz.de/schuerz/swatdoctr

Newest version, updates

SWATdoctR

`SWATdoctR` is a collection of functions and routines for SWAT model calibation and model diagnostics. The R package includes routines for a guided model calibration, functions for the evaluation of the model performance, as well as functions for the visualization and diagnosis of simulation outputs. The aim of the `SWATdoctR` is to identify potential issues in the model setup early in the calibration process and to support the SWAT modeler to focus on a plausible process representation in the model calibration process.

First ToDos for model verification

- Write SWAT run function to extract simulation outputs for model verification
- Step 1 in verification: Simulation of climate variables
  - read basin water balance file
  - overview figure precip (snow, rain), yearly, monthly, allocation to water balance components
- Step 2: check triggered management
  - read mgt_out
  - function to extract triggered management schedules

Plunge, S., Schürz, C., Čerkasova, N., Strauch, M. & Piniewski, M. SWAT+ model setup verification tool: SWATdoctR. Environ. Model. Softw. 171, 105878 (2024).

https://doi.org/10.1016/j.envsoft.2023.105878

ELSEVIER

Environmental Modelling & Software

Volume 171, January 2024, 105878

SWAT+ model setup verification tool: SWATdoctR

Svajunas Plunge [a b], Christoph Schürz [c], Natalja Čerkasova [e f], Michael Strauch [c], Mikołaj Piniewski [a]

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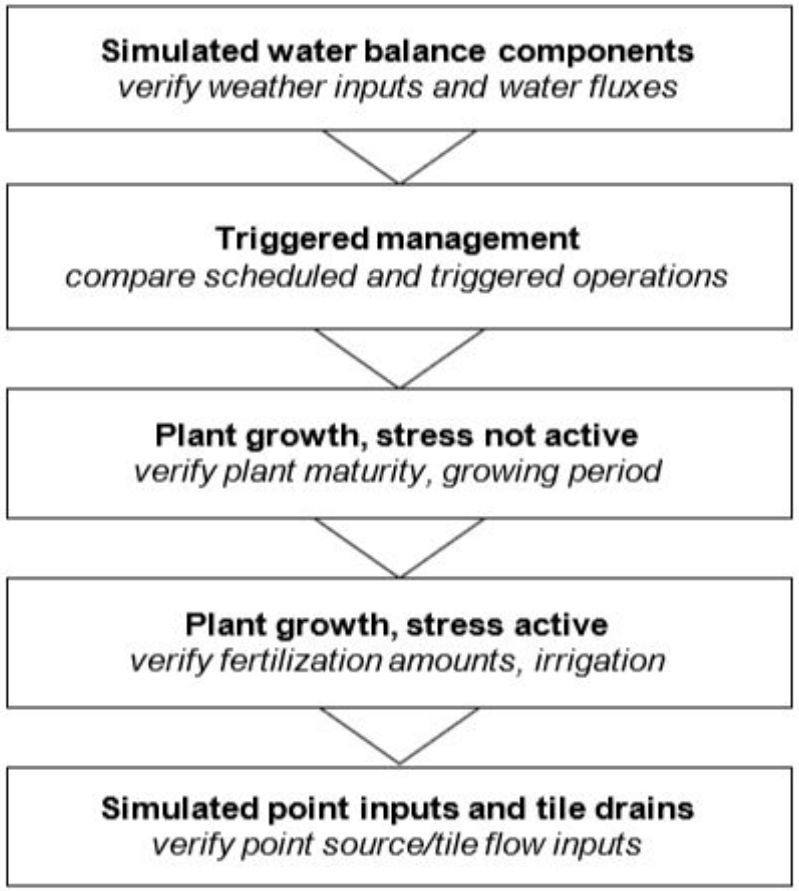
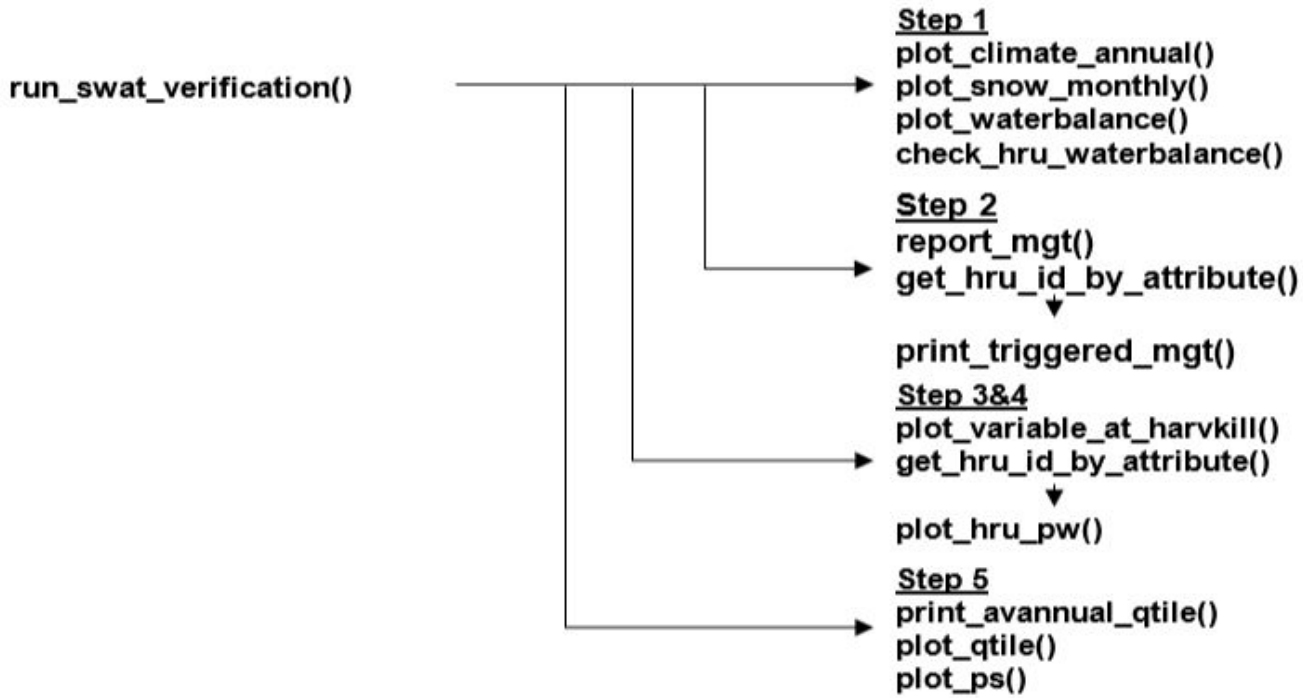
Proposed workflow 5 steps

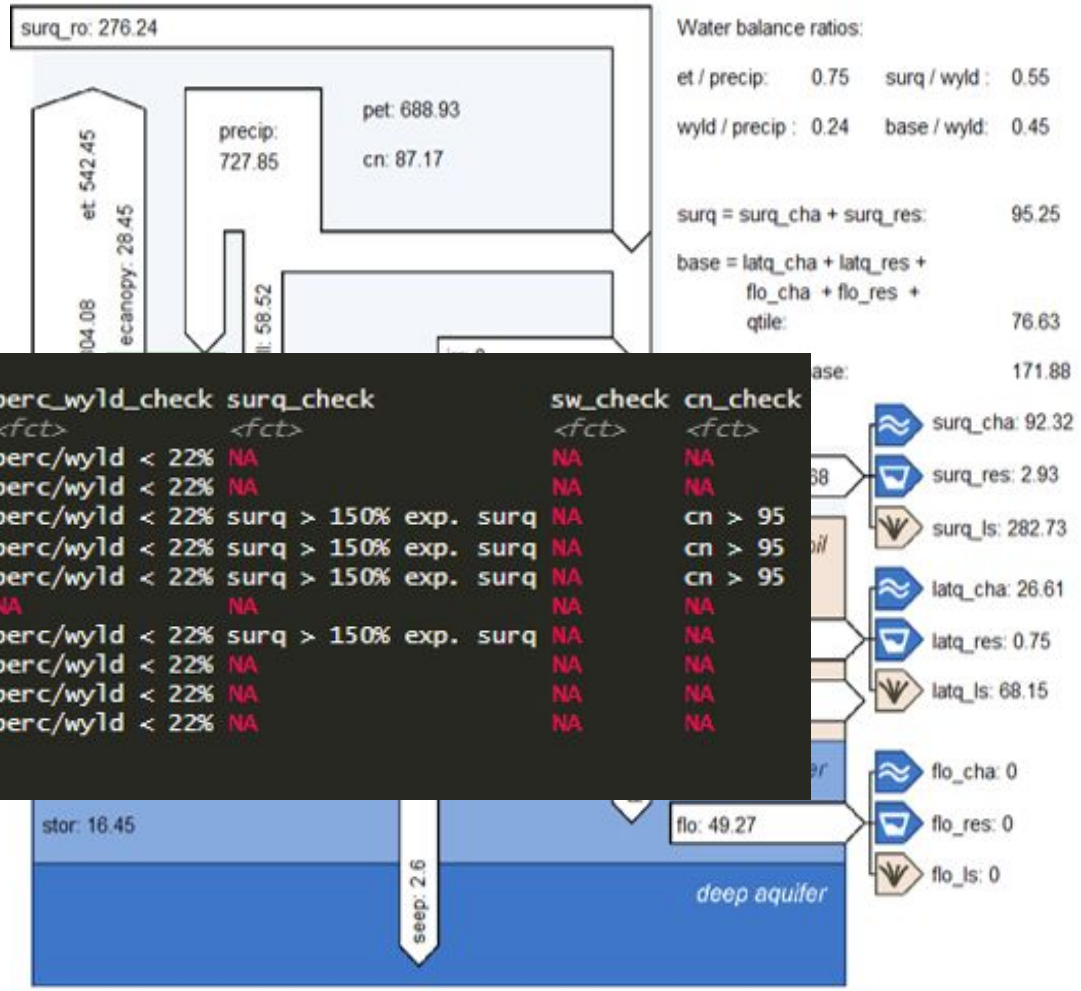


SWATdoctR



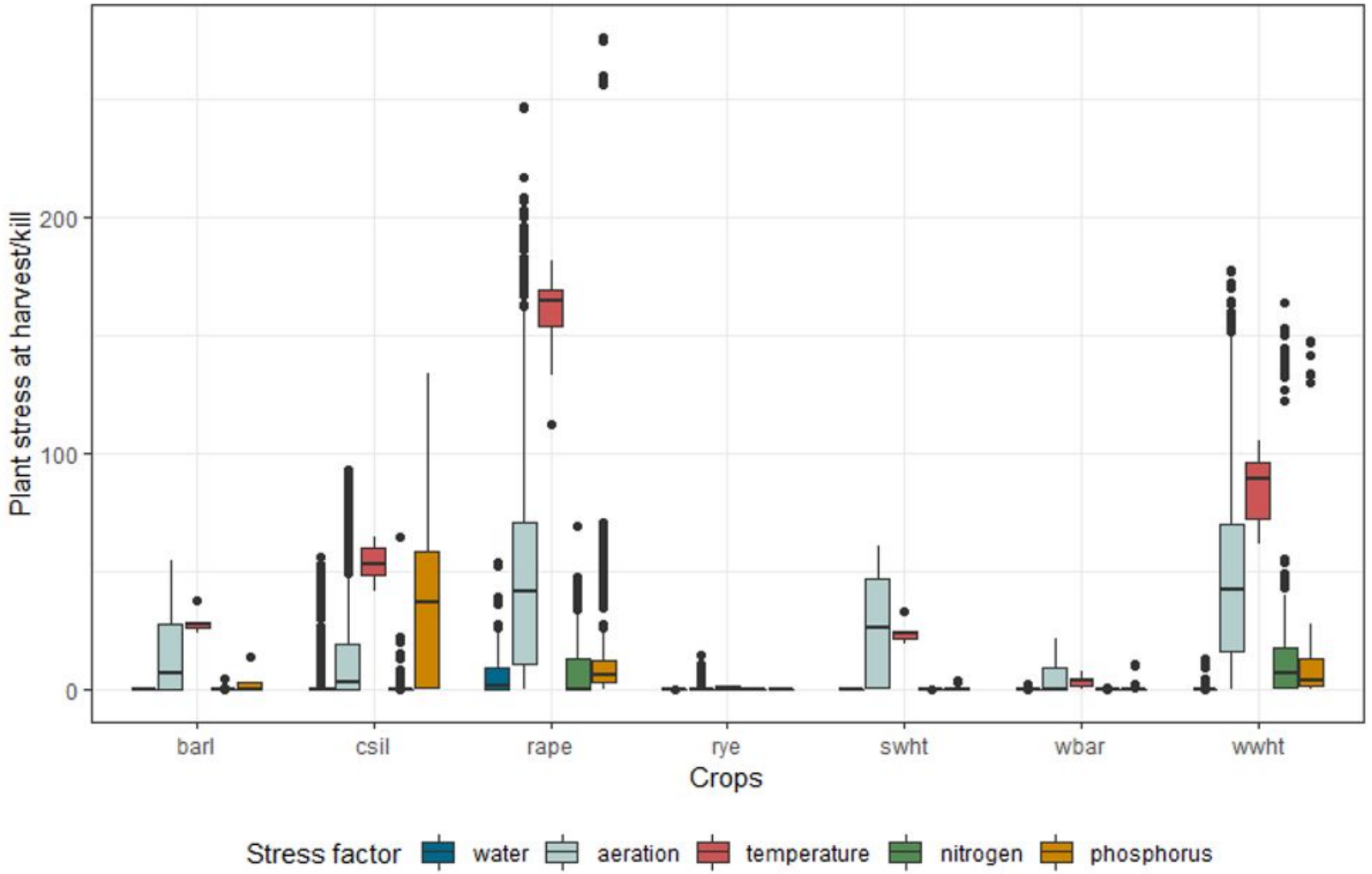
Example 1. Analysis of simulated climate variables and water balance component

```
# A tibble: 1,426 × 10
      id lu_mgt          precip_check et_check eplant_check   surq_wyld_check perc_wyld_check surq_check           sw_check cn_check
   <int> <chr>           <fct>        <fct>    <fct>           <fct>           <fct>           <fct>               <fct>    <fct>
 1     2 field_392_1_lum NA           NA       eplant < esoil  NA              perc/wyld < 22% NA                  NA       NA
 2     4 rngb_lum        NA           NA       NA              surq/wyld < 31% perc/wyld < 22% NA                  NA       NA
 3     5 rngb_lum        NA           NA       NA              surq/wyld > 78% perc/wyld < 22% surq > 150% exp. surq NA     cn > 95
 4     6 field_394_lum   NA           NA       eplant < esoil  surq/wyld > 78% perc/wyld < 22% surq > 150% exp. surq NA     cn > 95
 5     7 field_396_lum   NA           NA       eplant < esoil  surq/wyld > 78% perc/wyld < 22% surq > 150% exp. surq NA     cn > 95
 6     8 field_167_1_lum NA           NA       NA              surq/wyld > 78% NA              NA                  NA       NA
 7     9 field_167_2_lum NA           NA       NA              surq/wyld > 78% perc/wyld < 22% surq > 150% exp. surq NA     NA
 8    10 frst_lum        NA           NA       NA              NA              perc/wyld < 22% NA                  NA       NA
 9    11 frst_lum        NA           NA       NA              NA              perc/wyld < 22% NA                  NA       NA
10    12 frst_lum        NA           NA       NA              NA              perc/wyld < 22% NA                  NA       NA
# … with 1,416 more rows
# ℹ Use `print(n = ...)` to see more rows
```

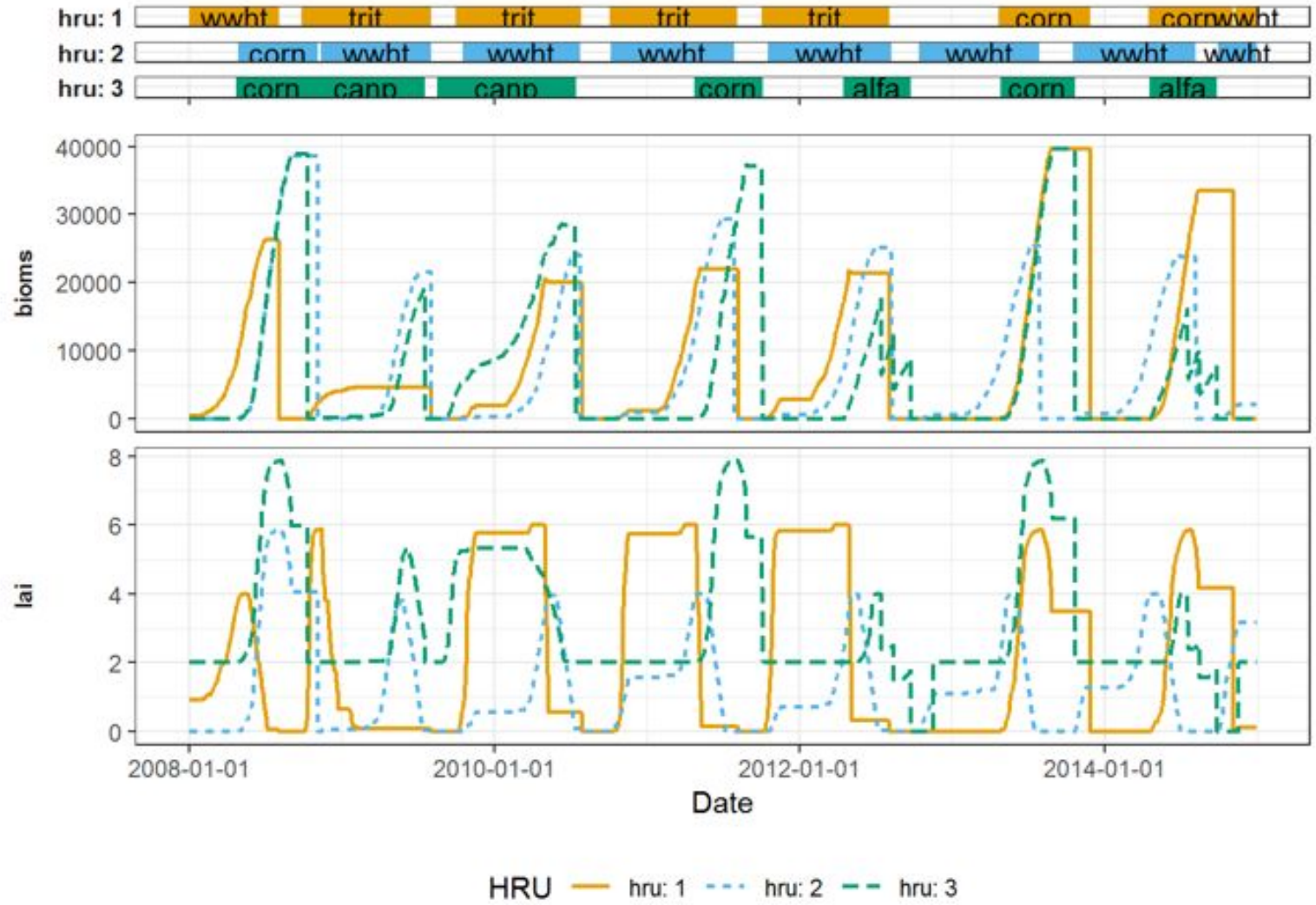


Example 2. Analysis of plant stress

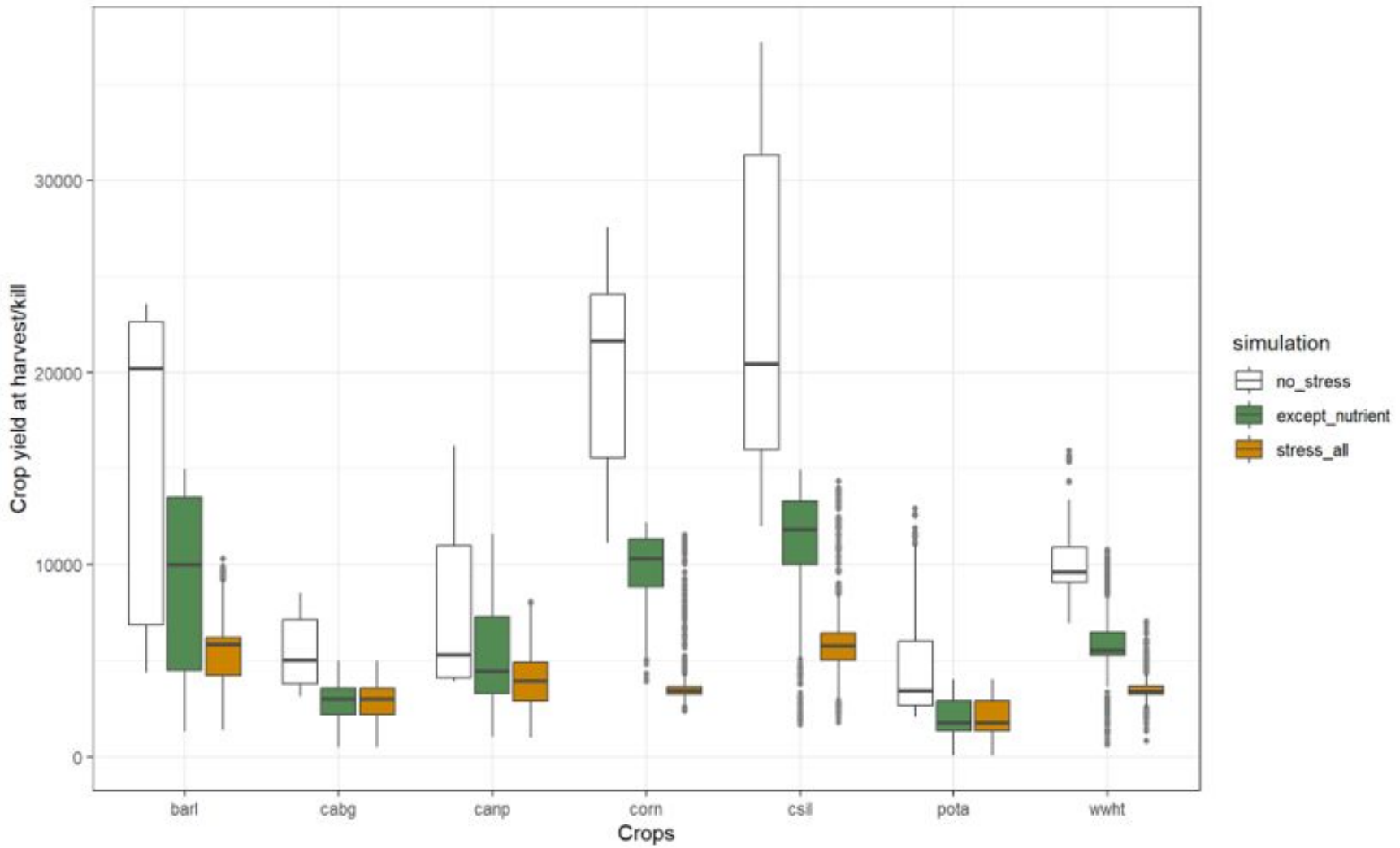
- 5 plant stress factors



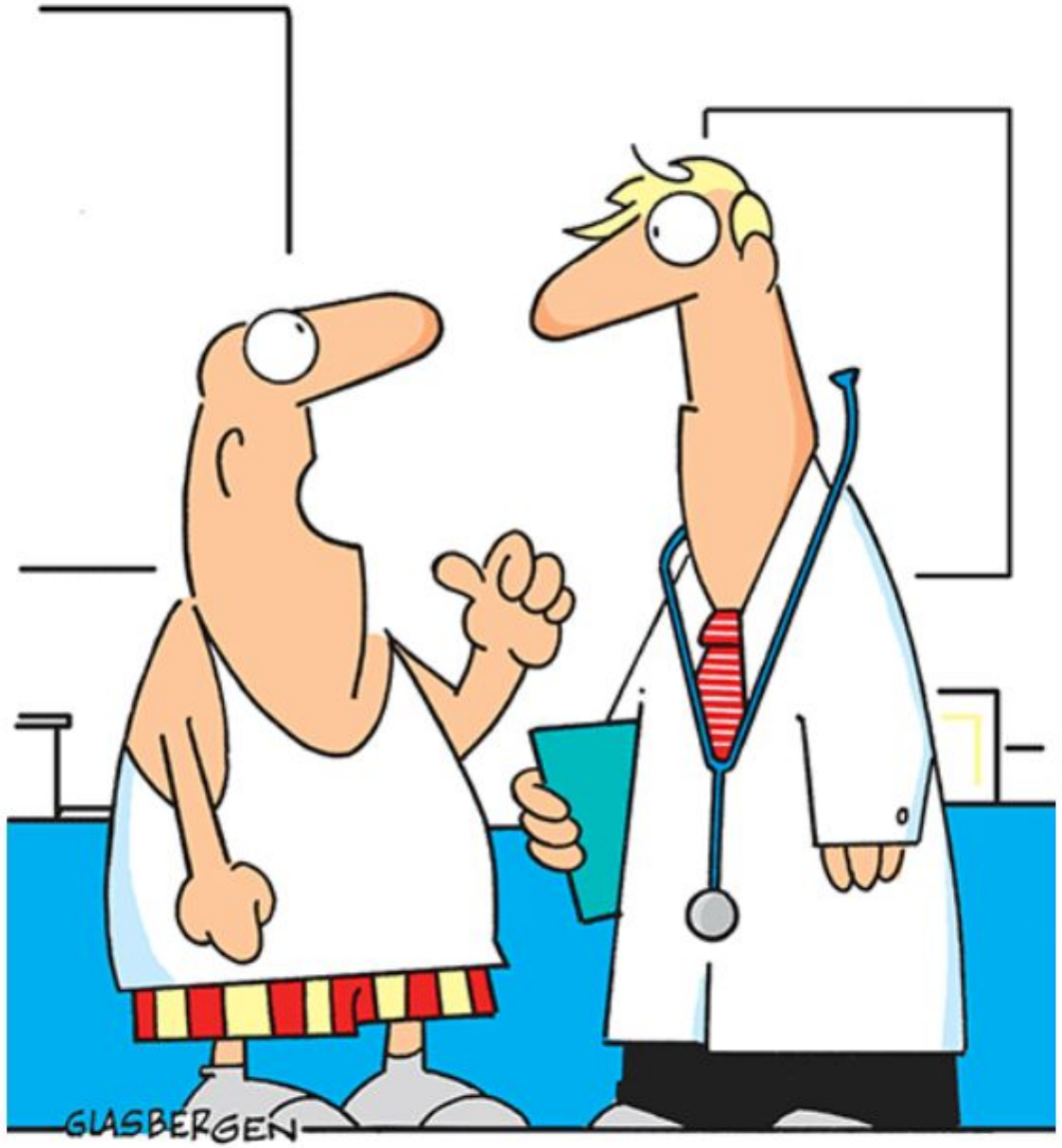
Example 3. HRU plant growth dynamics



Example 4. Model simulations with plant stress active

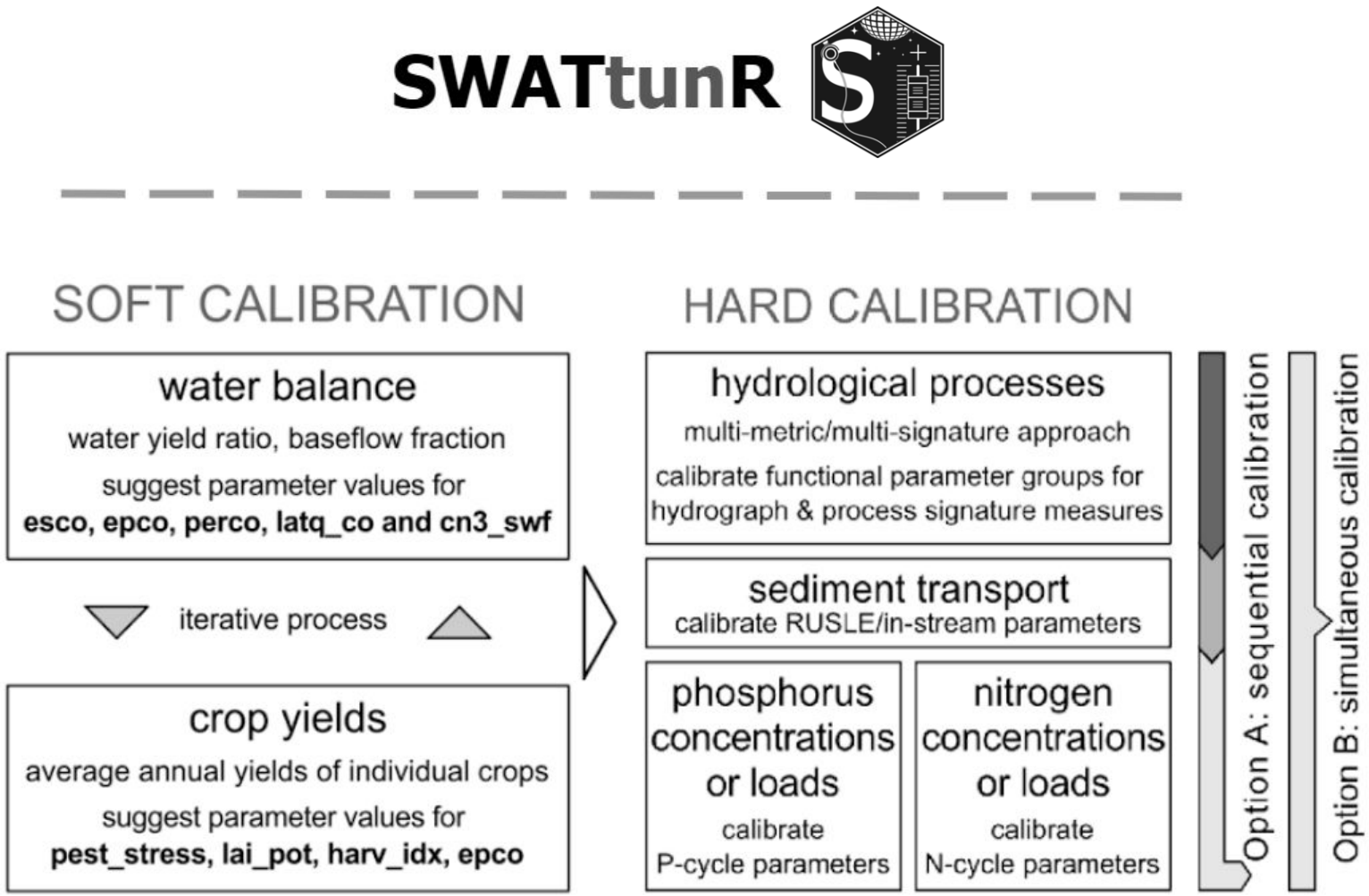


- Model setup verification procedure helps to identify and eliminate input or structural errors in early stages
- Saving time and efforts in later stages (calibration, validation, scenario runs)
- Important for building confidence, especially for stakeholders
- Easy to integrate into templates (as markdown) and provide automatized reports
- Helps to investigate issues, find problems with model



"I could be a healthy person if you'd stop finding things wrong with me!"

SWAT+ soft & hard cal/val is fully scriptable in R



SWATtunR 0.0.1.9015 Reference Articles Changelog Search for

Introduction to SWATtunR

SWATtunR

devel version 0.0.1.9015 | last commit today | lifecycle stable | repo status Active | code size 104 kB | license MIT

The goal of `SWATtunR` is to help with the SWAT+ model calibration and validation. These functions were developed and tested for the implementation of modeling tasks in the OPTAIN project, Nordbalt-Ecosafe and LIFE SIP Vanduo. Functions are initially developed by Christoph Schuerz, which added important capability on top of other R tools designed for the SWAT/SWAT+ models. Therefore, we highly recommend trying and using these tools:

- SWATbuildR[1] - R tool for building SWAT+ setups;
- SWATprepR - SWAT+ model input data preparation helper. The package is presented in the article Plunge, Szabó, et al. (2024);
- SWATfarmR - R tool for preparing management schedules for SWAT model;
- SWATdoctR - A collection of functions in R and routines for SWAT model calibration and model diagnostics. The package is presented in the article Plunge, Schürz, et al. (2024);
- SWATrunR - R tool for running SWAT models for different parameters and scenarios. Please install branch names *remove_legacy*. It could be done using line like this `remotes::install_github("chrisschuerz/SWATrunR@remove_legacy")`
- SWATmeasR[2] - R tool for implementing Natural/Small Water Retention Measures (NSWRMs) in the SWAT+ models and running scenarios.

Links

Browse source code

Report a bug

License

MIT + file LICENSE

Citation

Citing SWATtunR

Developers

Svajunas Plunge
Author, maintainer

Christoph Schuerz
Author

Michel Strauch
Author

Mikołaj Piniewski
Author

Articles

Soft calibration

Crop Yields

Water Yield

Hard calibration

Run calibration

Plot results

Extend calibration

Validation

Website for the package

https://biopsichas.github.io/SWATtunR/

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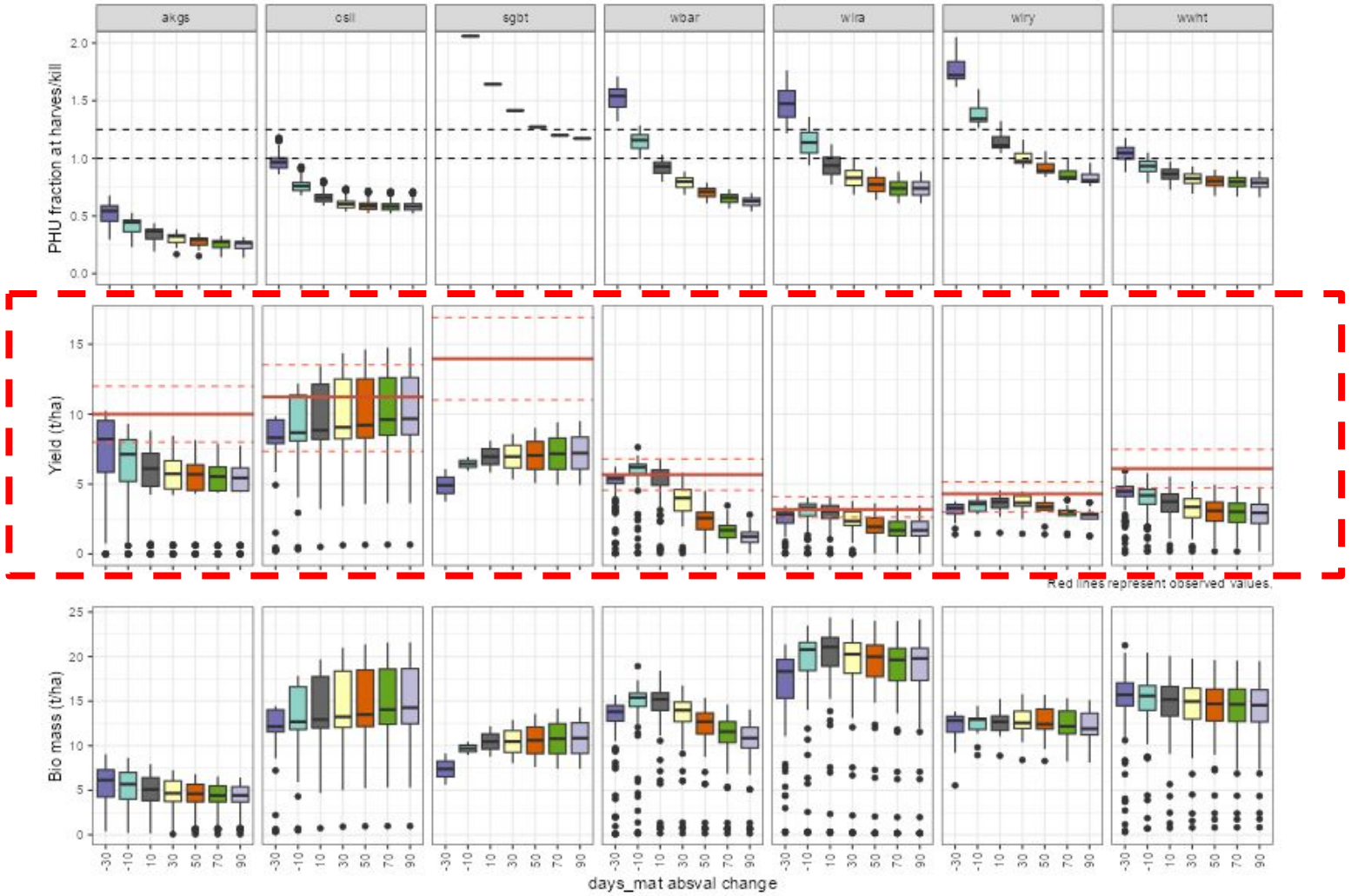
What do you get with it?

- Definition of parameters and model runs done with SWATrunR (former SWATplusR), but there is **a workflow and guidance** on SWATtunR website
- New functions to calculate model performance metrics on one or multiple variables
- Result visualisation options:
  - Dotty plots with multiple customization options
  - Interactive time series plots
  - Parameter identifiability plots
  - OAT analysis plots
  - Cal/Val comparison plots
- 'calibration.cal' file export function
- QA workflow with SWATdoctR (in process)

Example 1. Soft-cal for crop yields (days_mat)



SWAT2012

Plant heat units (PHU)

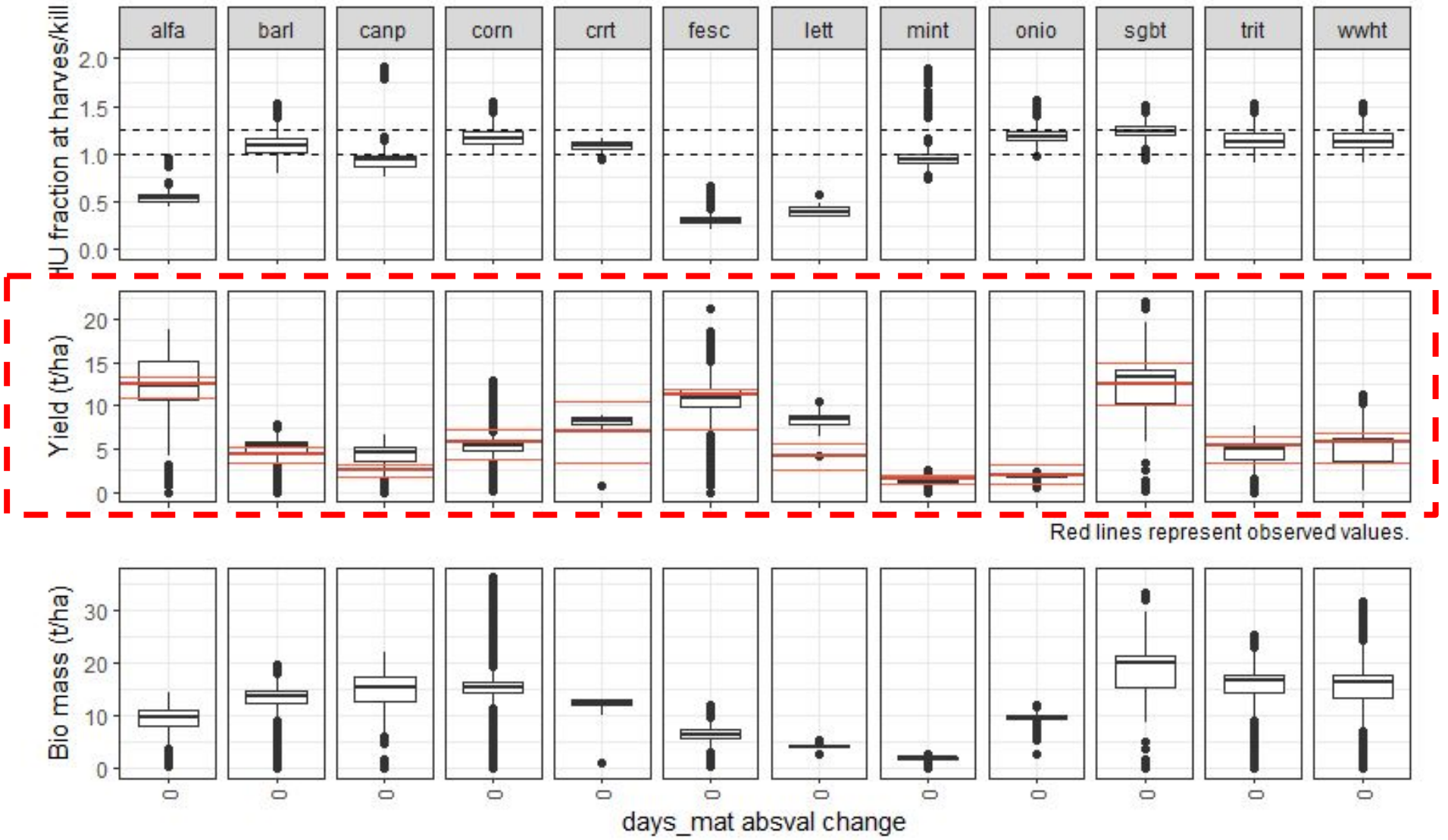
|

V

SWAT+

Days to maturity (days_mat)

Red lines are observed yields


alfa
barl
canp
corn
crrt
fesc
lett
mint
onio
sgbt
trit
wwht
HU fraction at harves/kill
Yield (t/ha)
Red lines represent observed values.
Bio mass (t/ha)
days_mat absval change

Hard calibration workflows

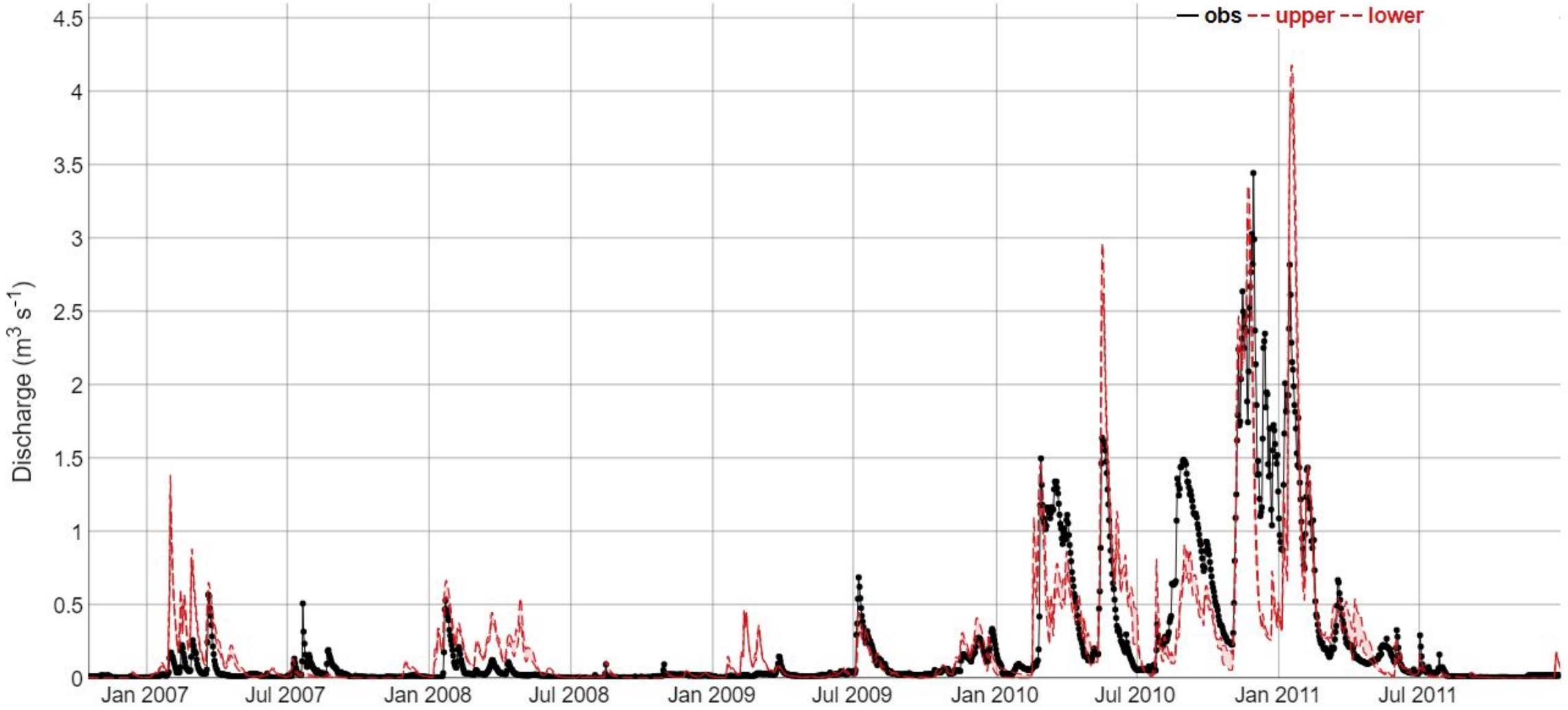
Option A: Sequential calibration

- Define **flow** parameters
- Run model
- Calculate performance metrics
- Select parameter set/s
- Add N, P, sediment parameters
- Run model
- Calculate performance metrics
- Select best parameter set/s
- Prepare 'calibration.cal'

Option B: Simultaneous calibration

- Define **all** parameters
- Run model
- Calculate performance metrics
- Select parameters set/s
- Prepare 'calibration.cal'

Example 2. Time series plot



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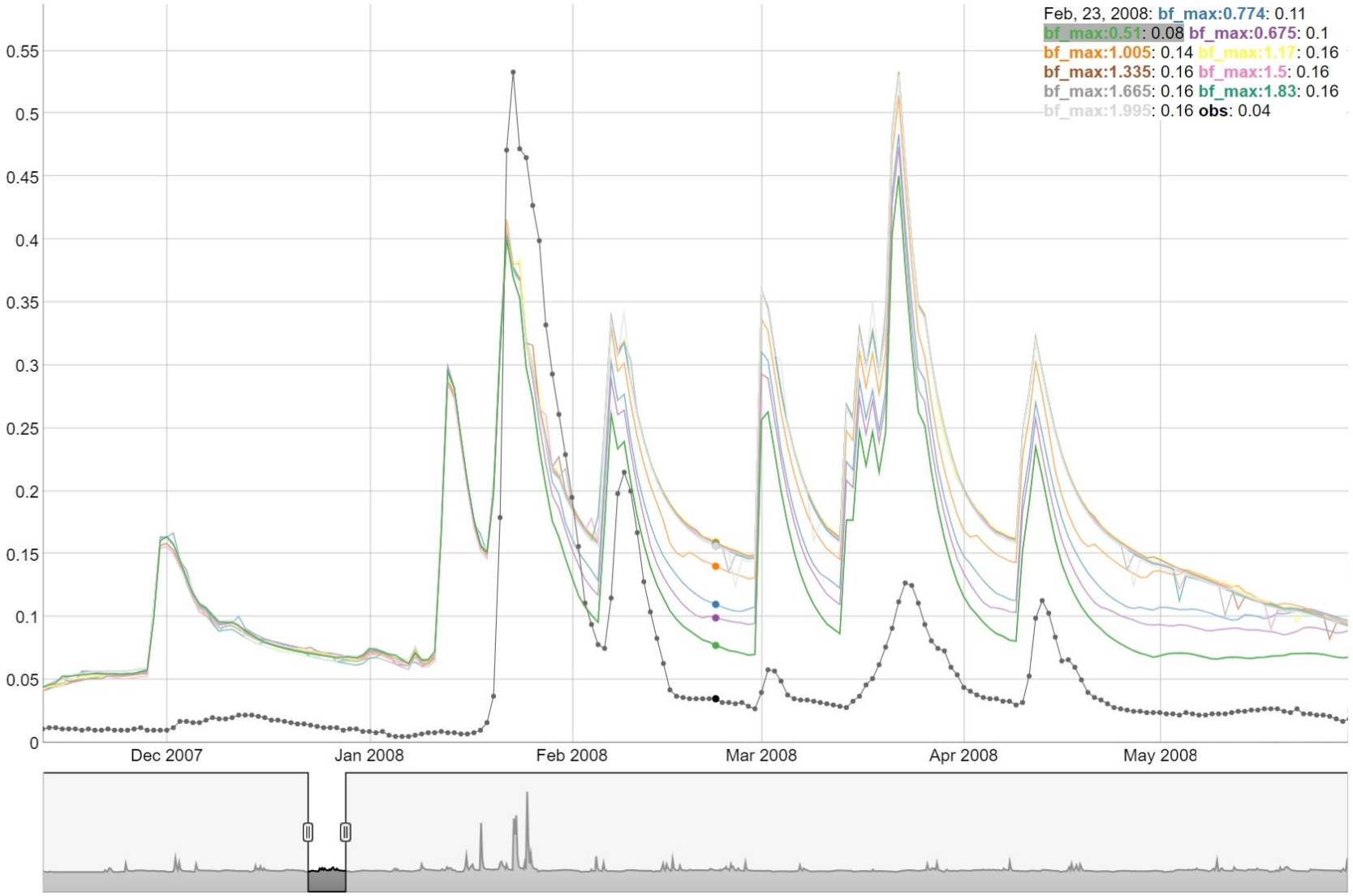
Example 3. OAT plot



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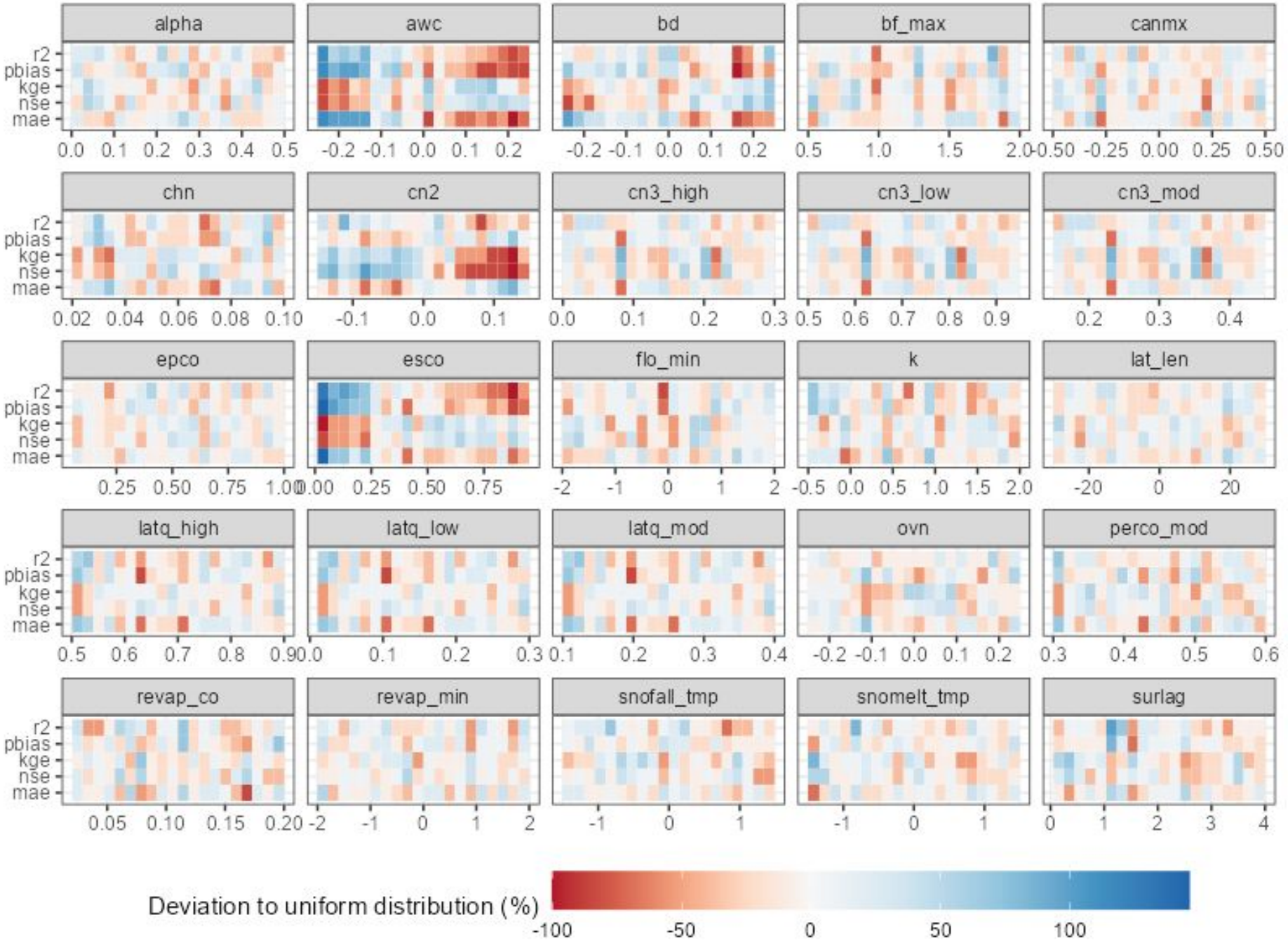
Example 4.
Identifiability plot



Adapted from Guse, Björn, Jens Kiesel, Matthias Pfannerstill, and Nicola Fohrer. 2020. “Assessing parameter identifiability for multiple performance criteria to constrain model parameters.” Hydrological Sciences Journal 65 (7): 1158–72. https://doi.org/10.1080/02626667.2020.1734204

End thoughts

- SWAT+ cal/val fully scriptable in R.
- Unified across multiple studies.
- Saving time, documenting and correcting.
- Easily extended for multiple objectives, fully parallelized.
- Website + package provide easily applied tools and guidance.
- Already tested in two projects. Others are in line.
- Coming soon… additional capabilities and article.