Land surface parameter optimisation through data assimilation: the adJULES system

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1 adJULES in brief

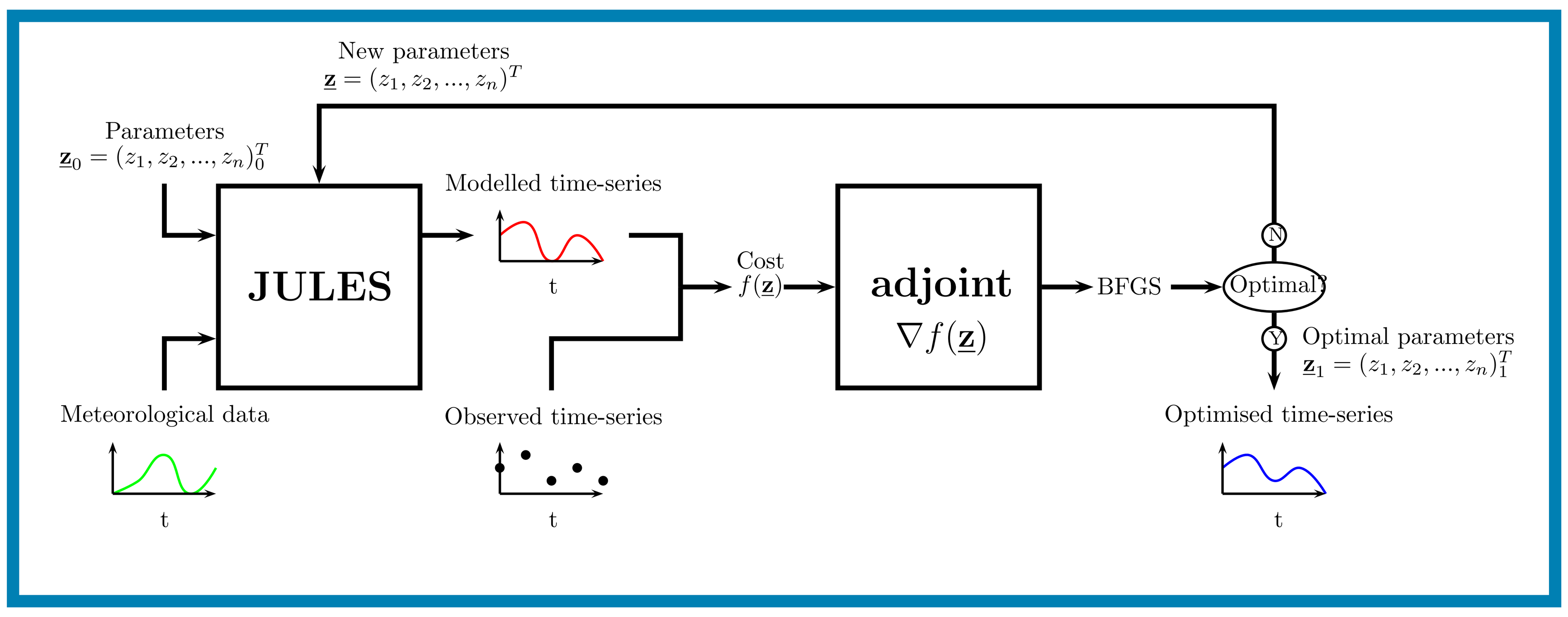
The Joint UK Land Environment Simulator (JULES) land-surface model is a mathematical representation of the flows of energy, carbon and water between soil, vegetation and atmosphere. JULES groups vegetation into 5 plant functional types (PFTs). adJULES improves the output of this model through parameter optimisation.

- JULES generates modelled time-series for a given parameter set **z** at a chosen FLUXNET measurement site.
- The **cost** is a measure of the mean squared difference between modelled and observed time-series, and includes a background term with tuning parameter λ.

$$f(\mathbf{z}) = \frac{1}{2}\left[\underbrace{\sum_t (\mathbf{m}_t - \mathbf{o}_t)^T \mathbf{R}^{-1} (\mathbf{m}_t - \mathbf{o}_t)}_{RMSE\ term} + \underbrace{\lambda^2 (\mathbf{z} - \mathbf{z_0})^T \mathbf{B}^{-1} (\mathbf{z} - \mathbf{z_0})}_{background\ term}\right]$$

- The **adjoint** helps to search efficiently for better parameters.
- adJULES returns an optimised time-series and best set of parameters with their **uncertainties**.

Optimisation procedure



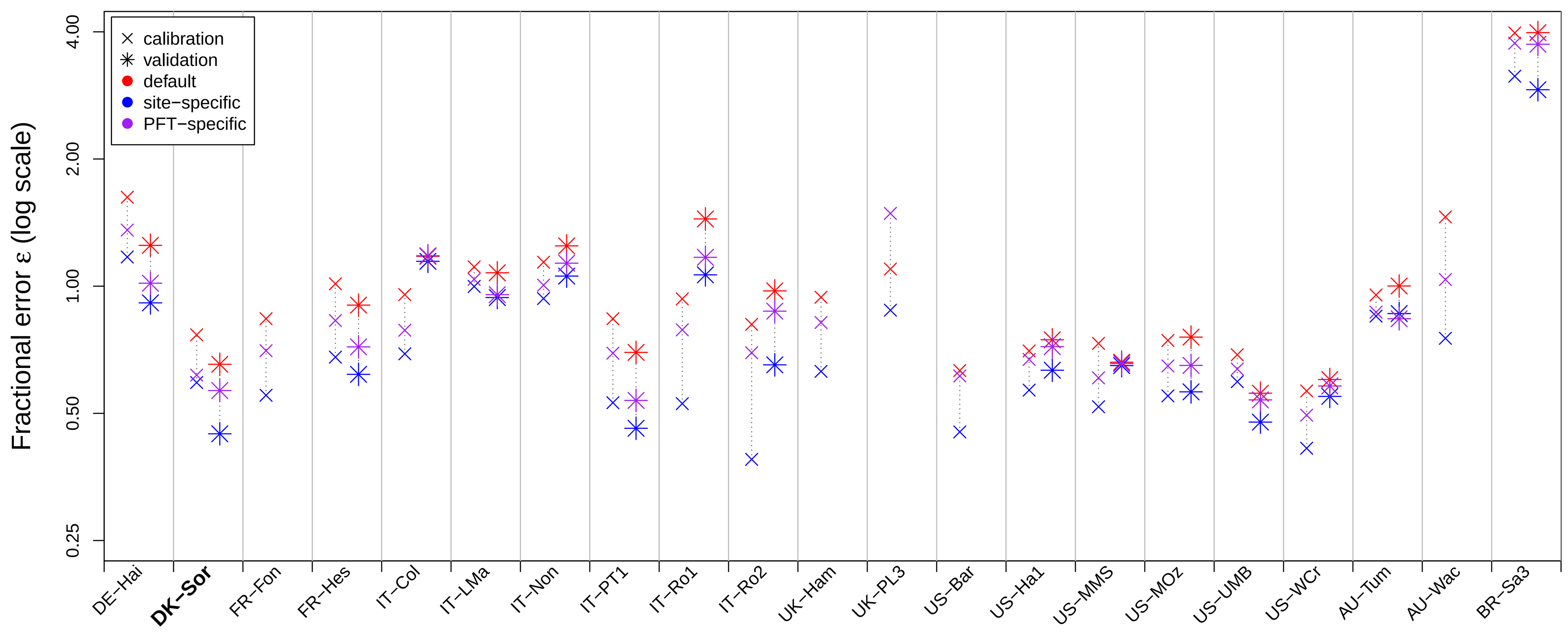
Multisite version takes data from multiple FLUXNET sites to find a **common set of optimal parameters**.

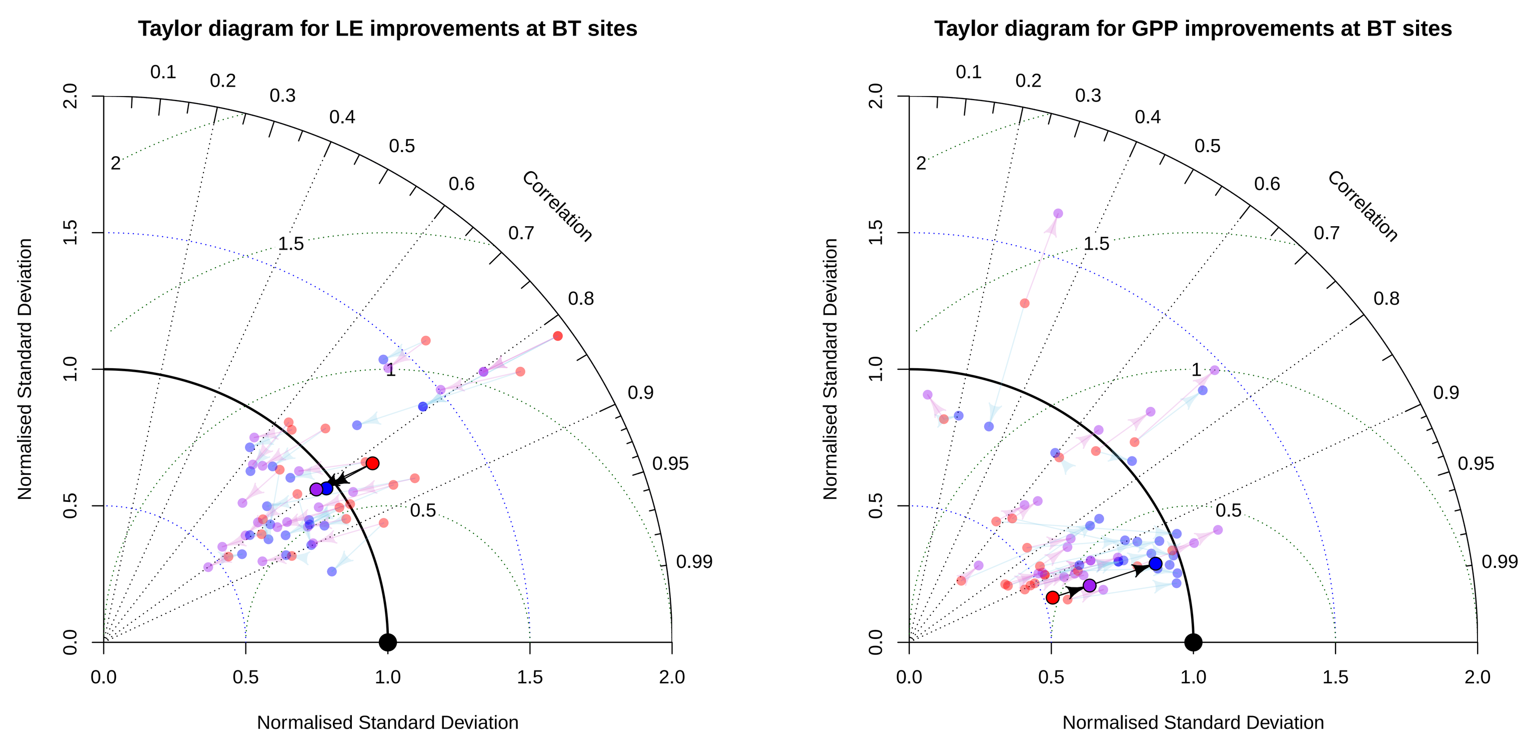
Aim: Find a set of parameters for each PFT that significantly improves the model-observation fit

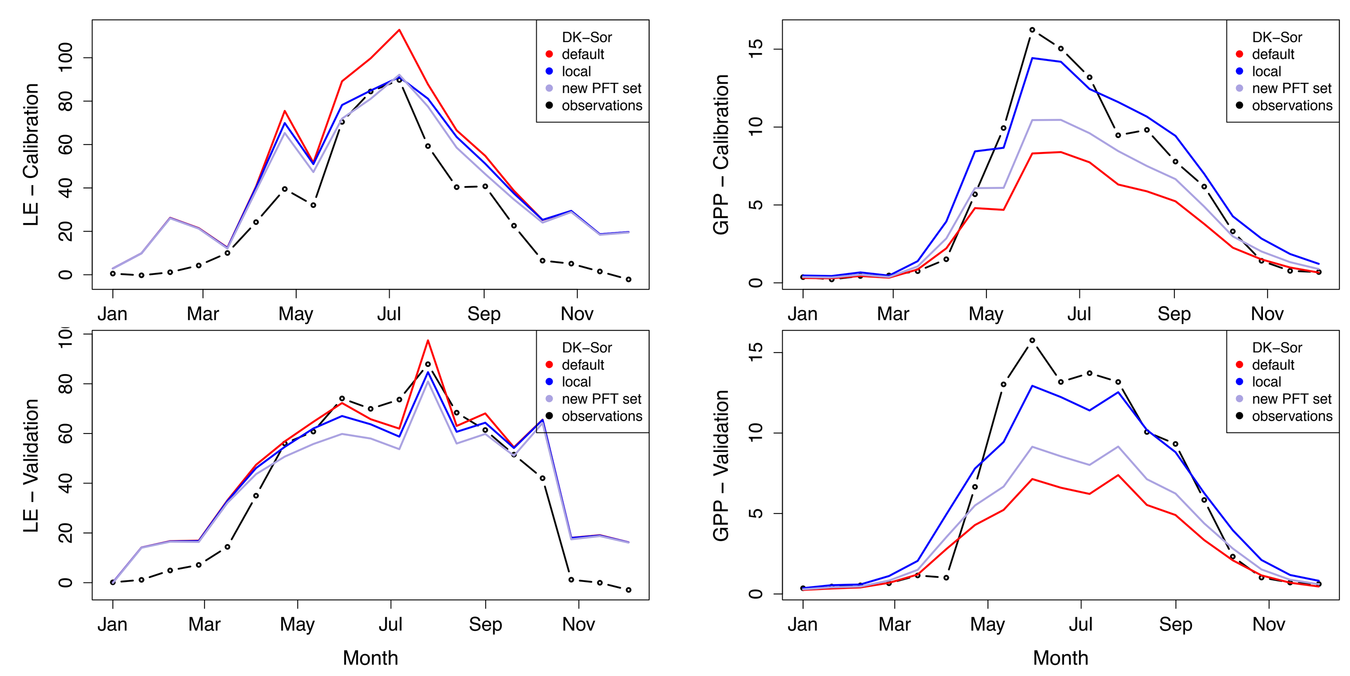
Experiment: One year runs at different sites are optimised against monthly averaged latent heat (LE) and gross primary production (GPP), by allowing a subset of 8 parameters in the adJULES set to vary. All sites in a given PFT are optimised simultaneously to find a generic set of parameters appropriate to the PFT.

2 Assessing the new parameter set found by optimising over the JULES Broadleaf PFT

Focusing on the DK-Sor site in particular, we consider the total error between the modelled and observed time-series for JULES runs using different **z**: default set (•), locally optimised set (•), PFT optimised set (•). Taylor diagrams are used to decompose misfit in terms of correlation and standard deviation. Time-series of the data streams are displayed for both the calibration and validation years.







- **100%** of sites improve when optimised individually.
- **92%** of the sites improve when optimised by PFT.
- **40%** of the sites perform as well for the PFT-grouping set as they do when individually optimised.
- The GPP flux improves the most.
- The LE flux improves to a lesser extent. Since the parameters varied in this experiment were mainly photosynthetic, different parameters may need to be incorporated for this flux to improve.

- adJULES allows for multiple data streams and multiple sites to be assimilated.
- adJULES essentially produces the best possible fit to observations, given the existing model physics and the prescribed driving data. For sites where the fit is still inadequate, the problems will lie with the model and data, rather than parameter values.

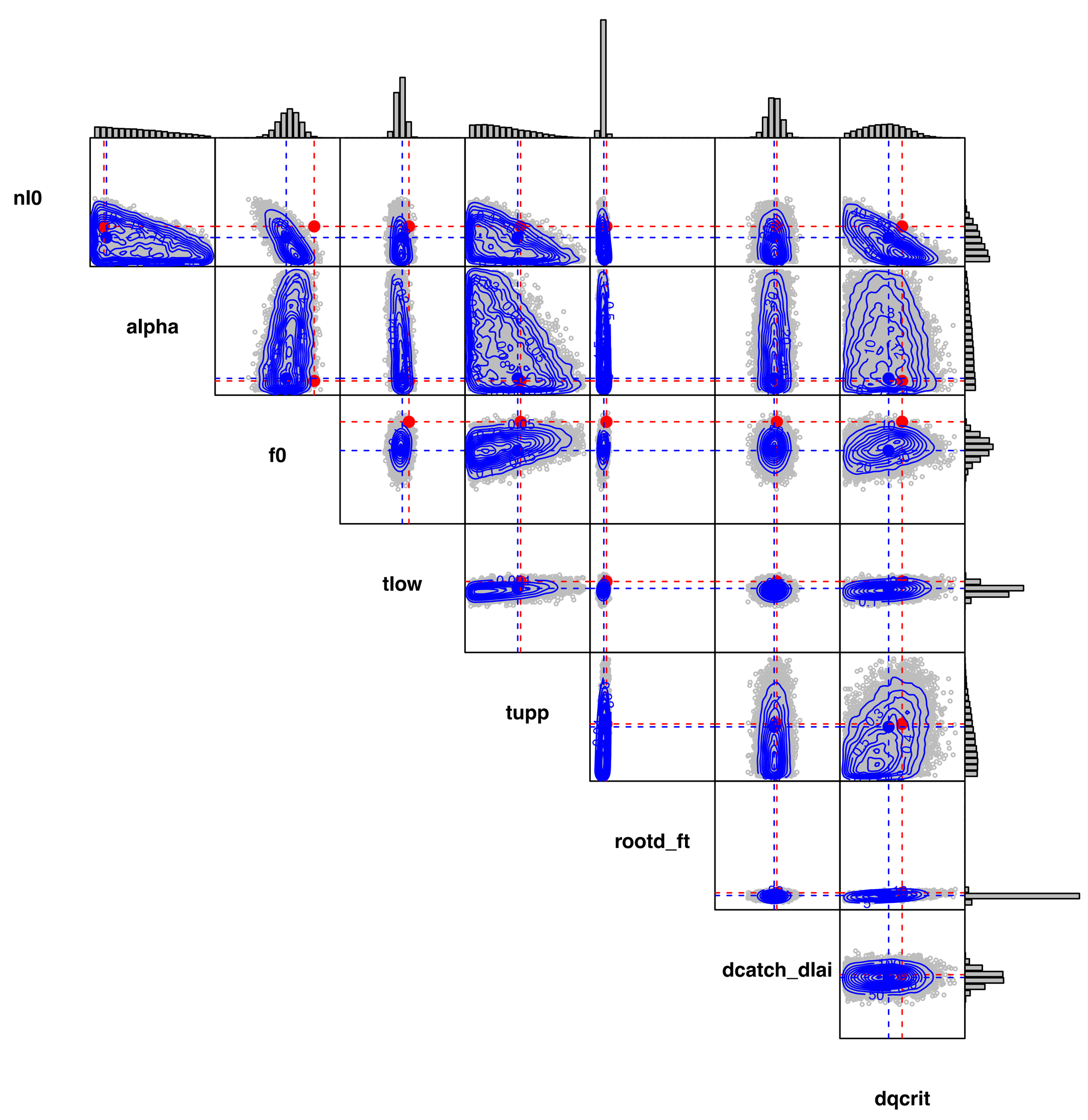
3 Representing parameter uncertainty

The second derivative of the cost function (Hessian) is used to generate a truncated multivariate normal distribution in parameter space.

Gibbs sampling is used to generate an ensemble of plausible parameter vectors from this distribution. This gives each optimised parameter an associated uncertainty.

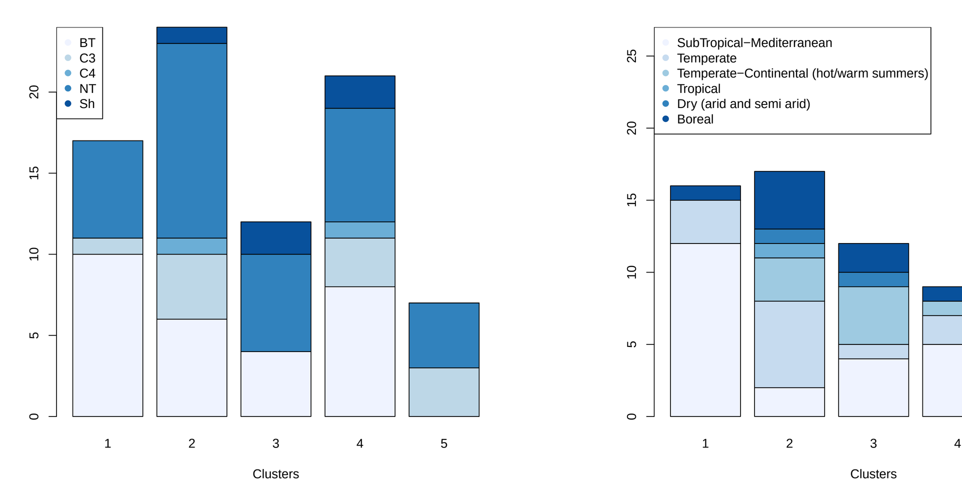
- • : original value
- • : new value
- • : cloud of plausible points
- ◡ : contours of constant cost

The optimised Shrub parameter set is shown on the right. Figure shows two-dimensional slices in a multi-dimensional space.



4 Cluster Analysis

k-means clustering was performed on the single-site parameter sets. The clusters were then compared to another methods of partitioning the sites: PFT definitions and types of climate.



Future of adJULES: adJULES presents an opportunity to confront the JULES model with many different observations, and make real improvements to model parameterisation. Future work includes improvements to the cost function and consideration of errors; multisite optimisations of different site groupings; the use of satellite products as observables for calibration; development of the code to allow the direct assimilation of satellite radiance data.

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