Supporting Information

Article title: Processing and extraction of seasonal tree physiological parameters from stem radius time series
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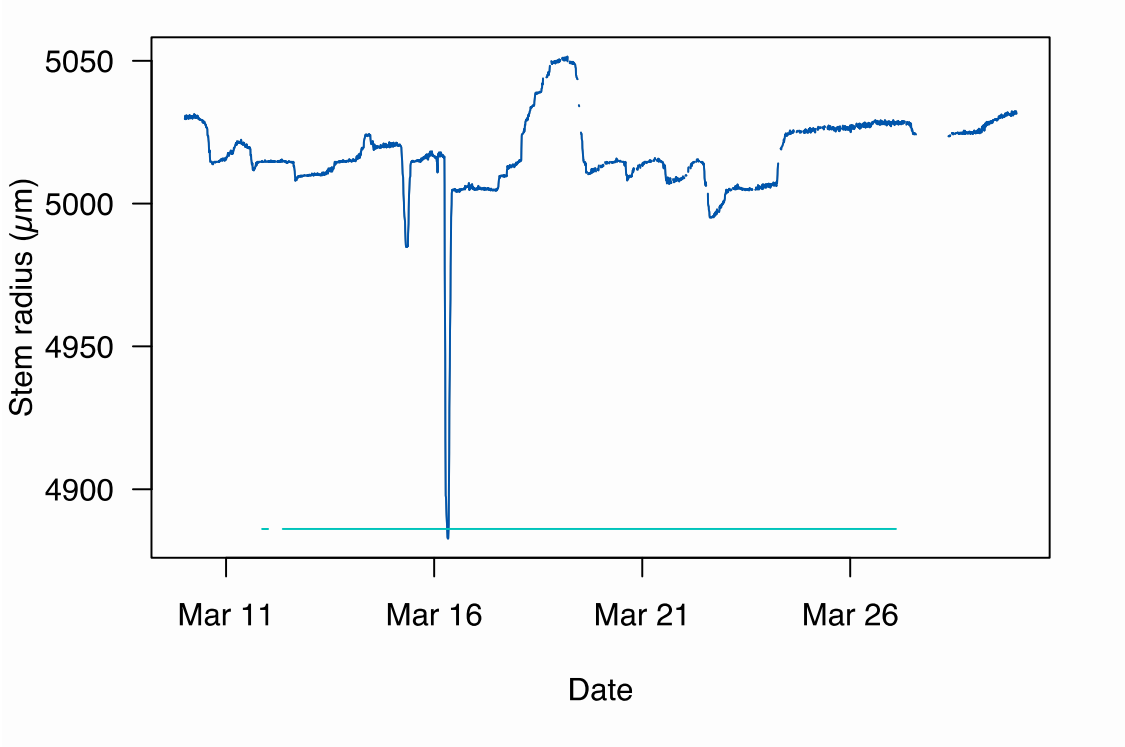

Figure S1. Frost shrinkage. The horizontal cyan line indicates the potential frost period, i.e. temperatures fall below 5 °C (defined with `frost_thr`). The peak on March 16 was induced by a freezing stem for a couple of hours only. The thawing process returned the stem size to its original size. The rest of the potential frost period showed no such event, most likely because the temperature dropped not low enough.

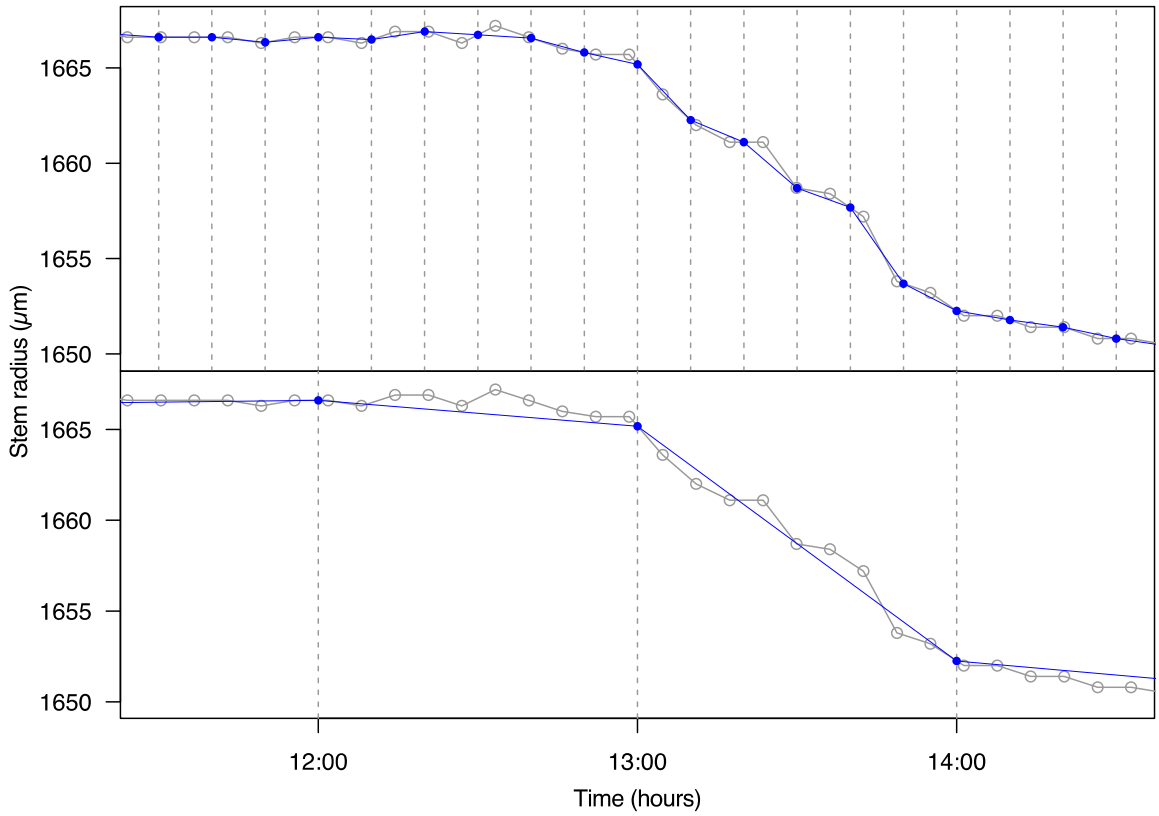

Figure S2. Time-alignment of raw data. Time-alignments to a resolution of 10 (top: `reso = 10`) and 60 minutes (bottom: `reso = 60`). Grey lines and circles indicate the raw data, blue lines and points show the time-aligned data.

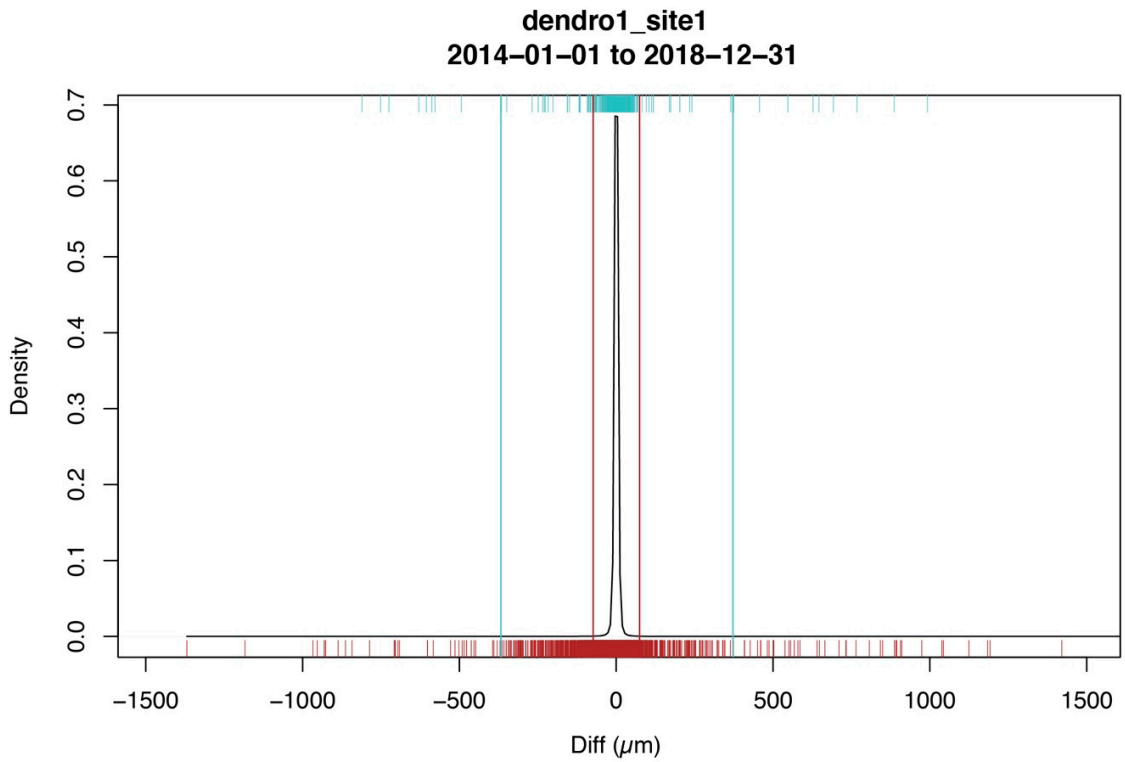

Figure S3. Density distribution for detecting outliers. Density distribution of first order differences (*diff*) of dendrometer L1-data. Red and blue vertical lines represent the thresholds for outlier detection in periods without, respectively with potential frost events.

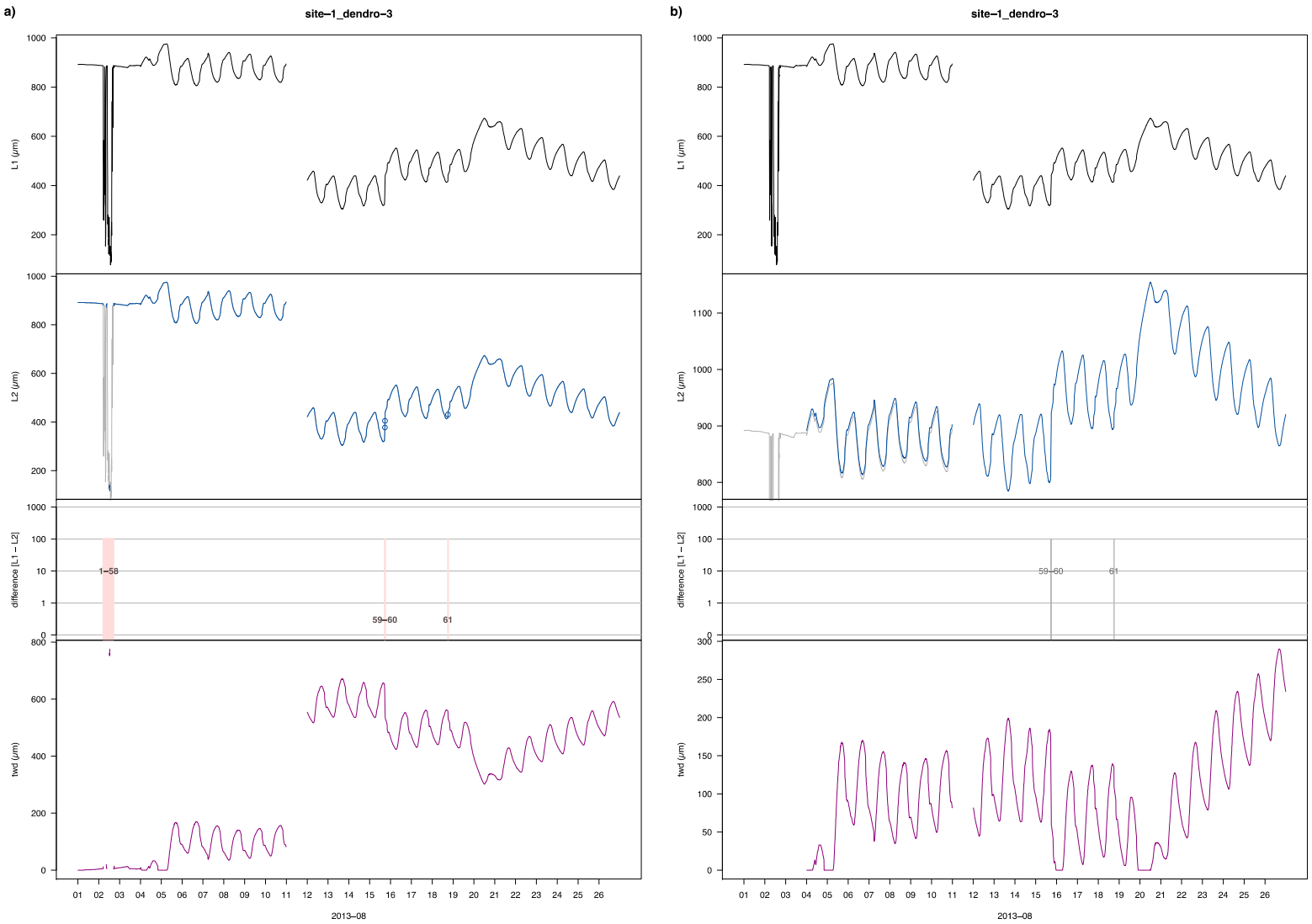
a)
site−1_dendro−3
L1 (µm)
L2 (µm)
difference [L1 − L2]
1−58
59−60
61
twd (µm)
2013−08
b)
site−1_dendro−3
L1 (µm)
L2 (µm)
difference [L1 − L2]
59−60
61
twd (µm)
2013−08

Figure S4. Data corrections with the function `corr_dendro_L2`. Example of remaining errors after data cleaning (a) and the manual correction of these errors (b) done with the function `corr_dendro_L2`. The first panel in (a) and (b) shows the stem radius changes of the time-aligned dendrometer data (L1). The second panel shows the stem radius changes of the cleaned dendrometer data (L2) with remaining errors (a, pink) and corrected errors (b, grey). The third panel shows the changes that occurred during data cleaning (a) or the changes that were reversed (b). The last panel shows the tree water deficit (twd). The following remaining errors were corrected in (b): The deleted values 59, 60 and 61 were restored with the argument reverse = 59:61 since the raw data seems to be correct (reversed changes are indicated in grey in the third panel). The remaining jump in the data occurring on August 12 has been removed with the argument force = “2013-08-12”. The period of erroneous data between August 1-4 has been deleted with the argument delete = c("2013-08-01", "2013-08-04"). See the vignette Introduction to `treenetproc` for sample code to this example. The x-axis in (a) and (b) shows the date.

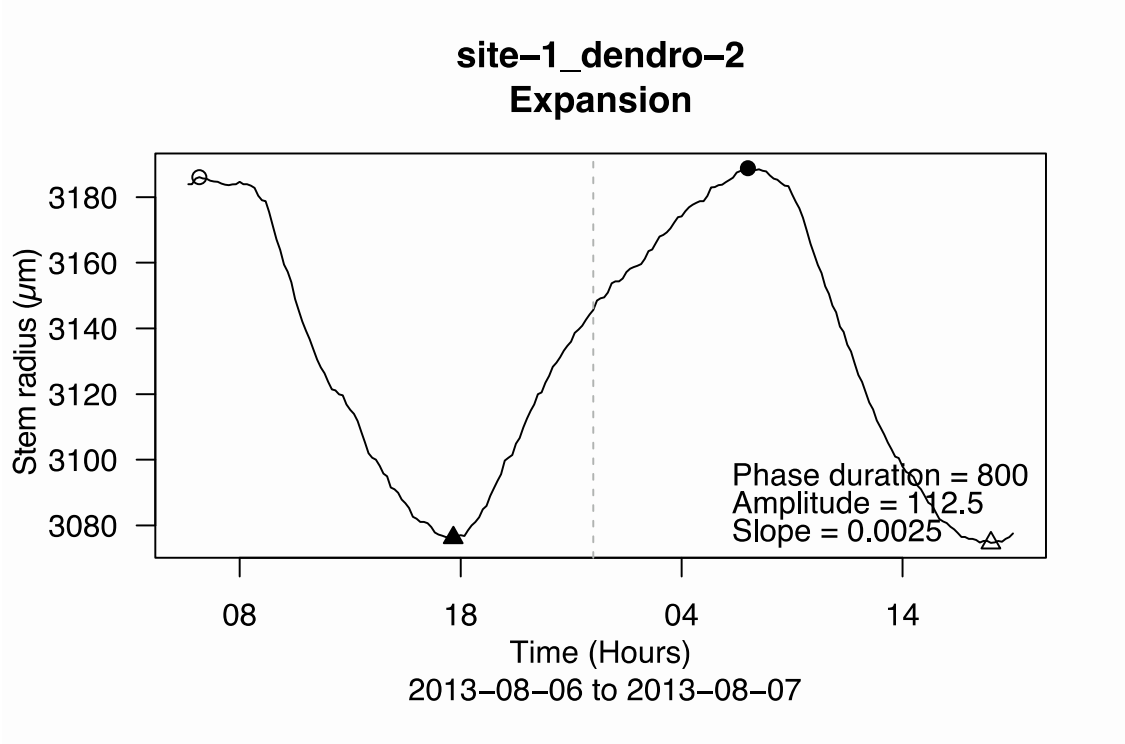

Figure S5. Calculation of shrinkage and expansion phases with `phase_stats`. The filled triangle (minimum) and circle (maximum) denotes the start respectively the end of the expansion phase for which the duration (minutes), amplitude (µm) and slope (µm * 10min-1) is printed in the plot. Dashed grey lines indicate midnight. Empty circles and triangles show maxima and minima of previous or subsequent shrinkage or expansion phases.

Table S1. Input data format (long). The dendrometer raw data in long format with the requested column names. The timestamp column (ts) needs to be in a standard date format (e.g., %Y-%m-%d %H:%M:%S). The value column should contain the dendrometer measurements in µm.

series	ts	value
site-1_dendro-1	2013-05-01 00:04:37	3677.9
site-1_dendro-1	2013-05-01 00:10:55	3677.6
site-1_dendro-1	2013-05-01 00:17:12	3676.1
site-1_dendro-1	2013-05-01 00:23:30	3676.1
site-1_dendro-1	2013-05-01 00:29:47	3674.9

Table S2. Input data format (wide). The input raw data in wide format with a column timestamp (`ts`), three columns with dendrometer time series and one column with temperature data. The column names of the dendrometer and temperature measurements should contain the series name (e.g. site-1_dendro-1) and the name of the temperature series has to contain the string 'temp' to be correctly identified. Dendrometer measurements have to be provided in µm.

ts	site-1_dendro-1	site-1_dendro-2	site-1_dendro-3	site-1_temperature
2013-08-01 01:00:52	NA	NA	NA	18.0
2013-08-01 01:01:05	NA	NA	891.8	NA
2013-08-01 01:02:48	1143.1	NA	NA	NA
2013-08-01 01:03:29	NA	3269.7	NA	NA
2013-08-01 01:07:40	NA	NA	891.9	NA

Table S3. Output data format of the function `proc_dendro_L2`. The following columns are returned. Series, name of the dendrometer series; `ts`, timestamp in the format %Y-%m-%d %H:%M:%S; `value` (µm), cleaned dendrometer measurements; `max` (µm), highest measured dendrometer value up to this timestamp; `twd` (µm), tree water deficit calculated according to Zweifel et al. (2016); `gro_yr` (µm), cumulative sum of growth since the beginning of the year (calculated according to Zweifel et al. 2016); `frost`, indicates potential frost periods (i.e. periods in which the temperature is below `frost_thr`); `flags`, documentation of all changes that occurred during data cleaning; `version`, package version number.

series	ts	value	max	twd	gro_yr	frost	flags	version
site-1_dendro-1	2013-05-01 00:10:00	3678.6	3677.6	0.0	0.0	FALSE	NA	0.1.4
site-1_dendro-1	2013-05-01 00:20:00	3676.1	3677.6	1.5	0.0	FALSE	NA	0.1.4
site-1_dendro-1	2013-05-01 00:30:00	3675.9	3677.6	2.8	0.0	FALSE	NA	0.1.4
site-1_dendro-1	2013-05-01 00:40:00	3673.3	3677.6	4.3	0.0	FALSE	NA	0.1.4
site-1_dendro-1	2013-05-01 00:50:00	3671.4	3677.6	6.3	0.0	FALSE	NA	0.1.4

Table S4. List of flags. Flags document changes of the original data and are returned with the processed data (Table S3).

function	flags	description
`proc_dendro_L2`	`out`	Detection and removal of an outlier
	`jump`	Detection and correction of a shift (jump) in the time series
	`fill`	Linearly interpolated value
`corr_dendro_L2`	`rev`	Manually forced reversion of an automated correction
	`fjump`	Manually forced correction of a data shift (jump)
	`del`	Manually deleted value

Method S1. The function phase_stats.

Parameters of shrinkage and expansion phases are calculated with the function `phase_stats` according to the following processing steps. First, maxima and minima are identified in time-windows with a length of 8 hours (default value of `phase_wnd`, can be adjusted by the user). Second, the windows are offset by half the window length and the maxima and minima are again identified. A comparison between the identified extreme points in these two time-windows allows for the identification of appropriate local maxima and minima. Based on the identified extreme points, shrinkage and expansion phases are defined. Phases that are shorter than 0.5 * `phase_wnd` and phases with more than 50% of missing data are not considered. For all remaining shrinkage and expansion phases the timing, duration, amplitude and slope are calculated and returned (Table 2). In addition, the parameter `phase_class` identifies days on which radial change is likely driven by transpiration (`phase_class = 1`, days with a single shrinkage phase with a duration < 12 hours) or by temperature and other still unknown drivers (`phase_class = -1`, days with a single expansion phase with a duration < 12 hours). The output parameters can either be aggregated by day (`agg_daily = TRUE`) or appended to the L2 output data (`agg_daily = FALSE`). If the parameters are aggregated daily, the shrinkage and expansion phases are assigned to the day on which the phase ends (`shrink_end/exp_end`). If multiple shrinkage or expansion phases occur on the same day, multiple rows are used for a single day. Furthermore, the identified phases can be visually checked by setting the argument `plot_phase = TRUE` (Figure S3).

The commonly reported parameter **maximum daily shrinkage** (referred to as *mds*) can be extracted from the output data generated by `phase_stats`. *mds* is equal to the amplitude of shrinkages (`shrink_amp`) in case the duration of the shrinkage is shorter than 24 hours

(`shrink_dur < 1440 min`). A code example on how to extract *mds* can be found in the vignette *Introduction to treenetproc*.