Automated change detection in satellite image time series using BFAST Lite

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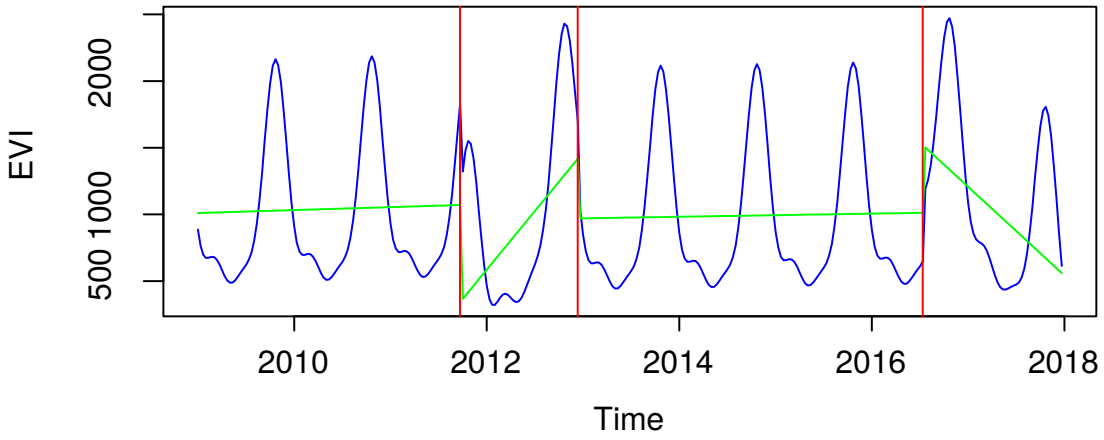
About me

- Lecturer in the Laboratory of Geo-information Science and Remote Sensing, Wageningen University, Geoscripting course
- PhD in global land cover mapping and updating using time series analysis
- Maintainer of the `bfast` pacakge in R
    - All started by Jan Verbesselt



Land cover change detection for map updating

- Reusing the same land cover classification model for the next year leads to too many spurious changes
- Use time series break detection to constrain changed pixels
- Or: detect changes in land cover fractions directly
- Many options for time series break detection algorithms!

Unlikely land cover change: from urban to water

Components of a SITS

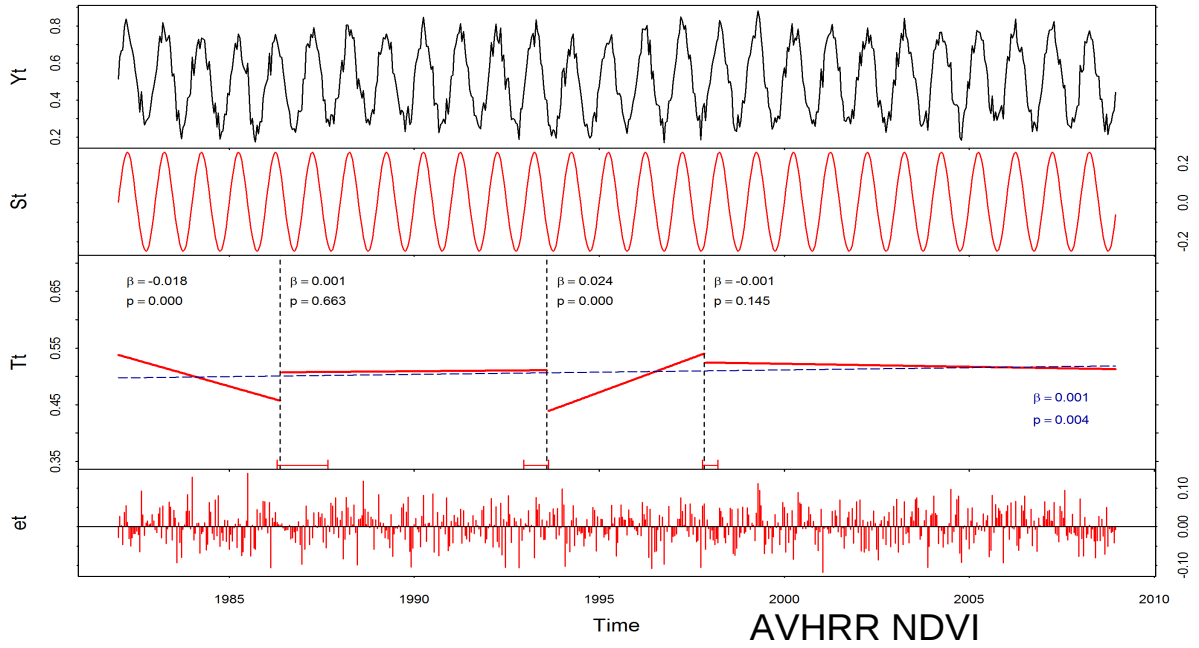
- The components of a time series (of a **vegetation index**):

1)Seasonality

2)Trend

3)Noise

$$Y_t = T_t + S_t + e_t$$



J. Verbesselt, R. Hyndman, G. Newnham, and D. Culvenor, Detecting trend and seasonal changes in satellite image time series, Remote Sensing of Environment, vol. 114, no. 1, pp. 106-115. (2010).

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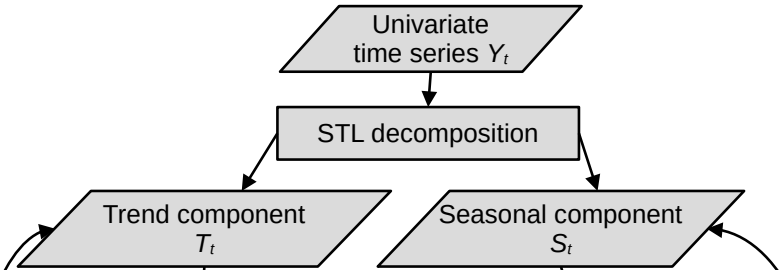
BFAST: Breaks For Additive Season and Trend

- Decomposition of time series into seasonal, trend and remainder components using stl()



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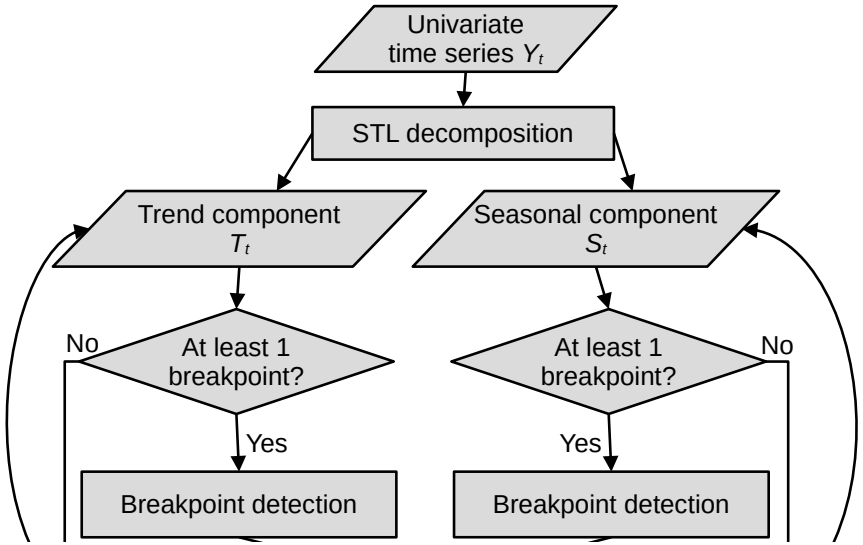

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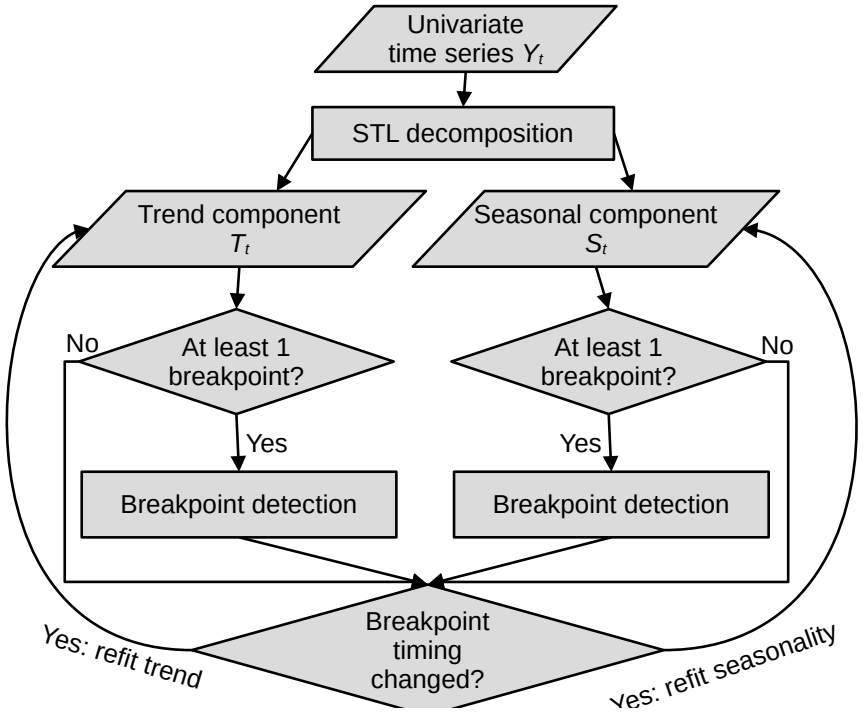

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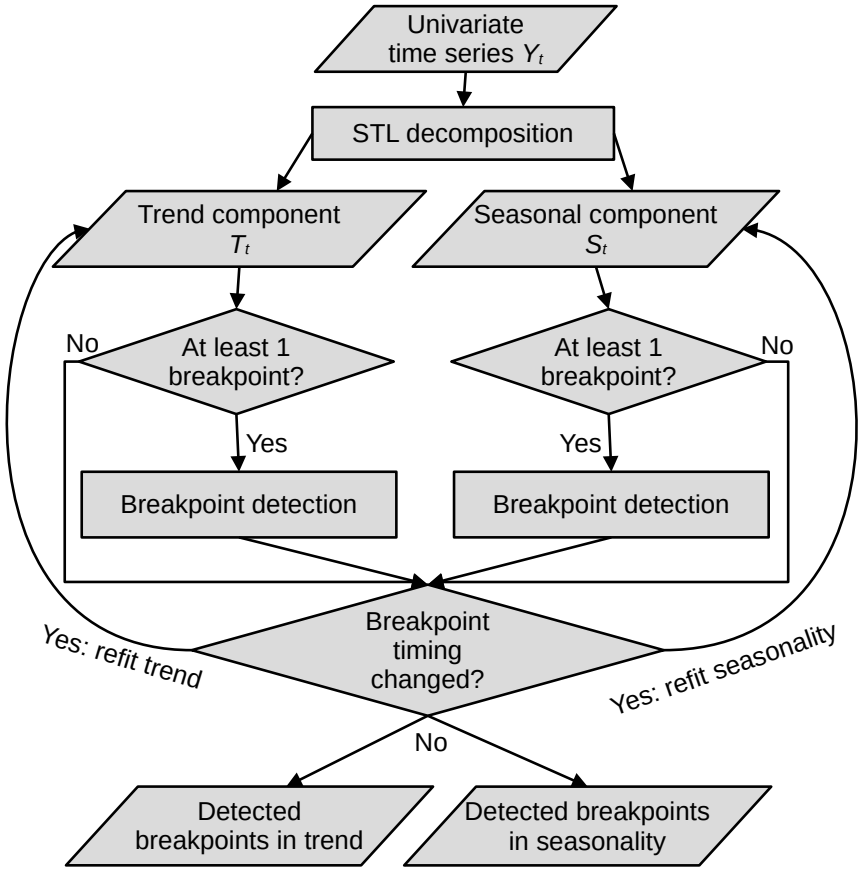

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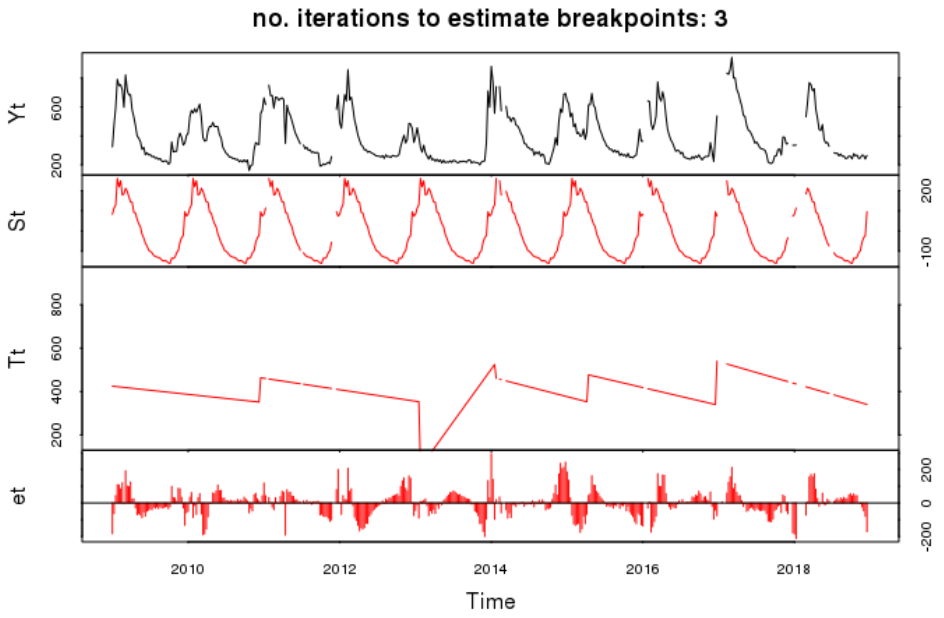

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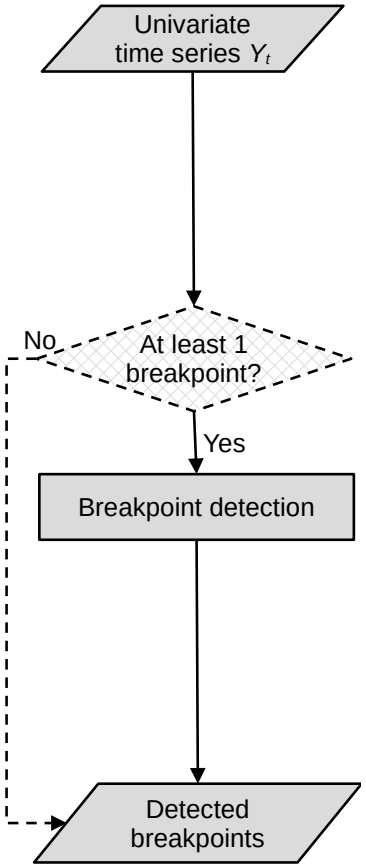
BFAST Lite

- Detecting breaks in all components at once in a single pass
- Can handle missing values
- More tunable parameters: can use harmonics (sin/cos) or seasonal dummies (multiple fitted intercepts per year) or external regressors to fit the data
- Is an order of magnitude faster than BFAST (in addition to speed improvements due to C++ code integration)



Masiliūnas, D., Tsendbazar, N.-E., Herold, M., & Verbesselt, J. (2021). BFAST Lite: A Lightweight Break Detection Method for Time Series Analysis. Remote Sensing, 13(16). https://doi.org/10.3390/rs13163308

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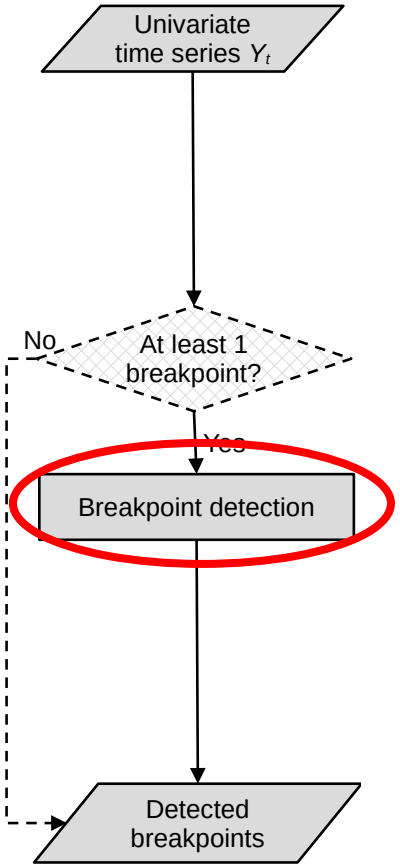

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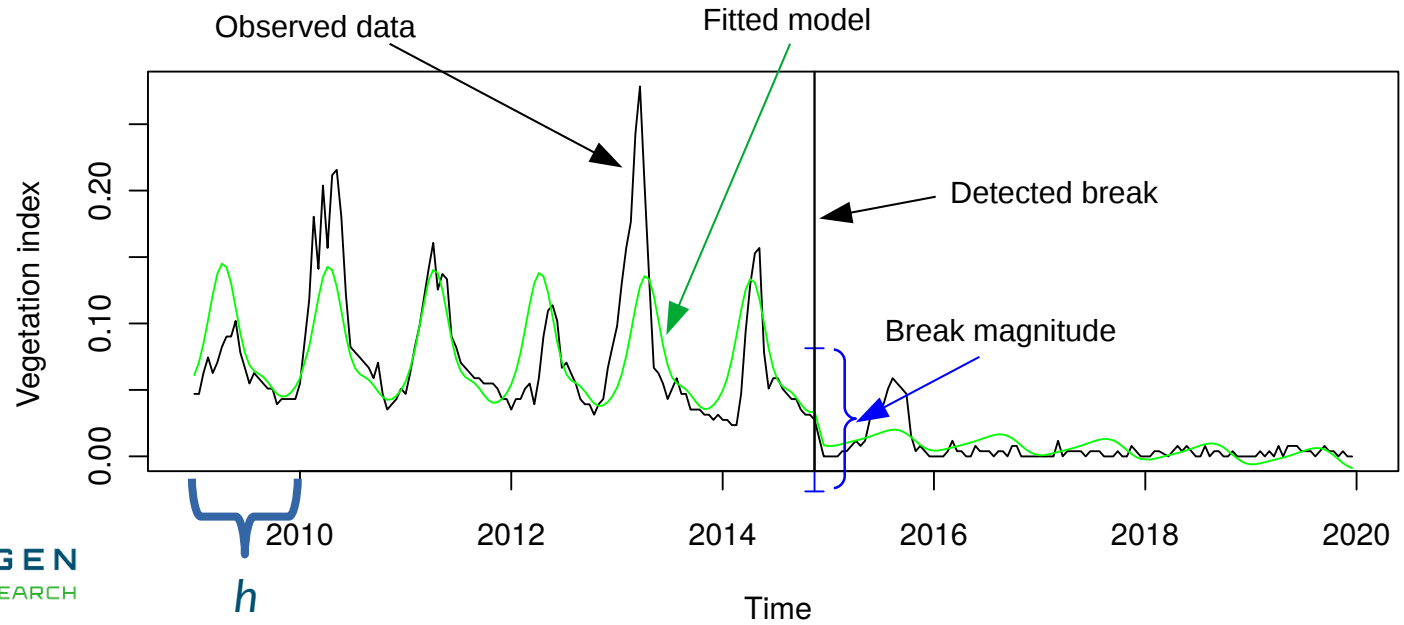
Principle of breakpoints()

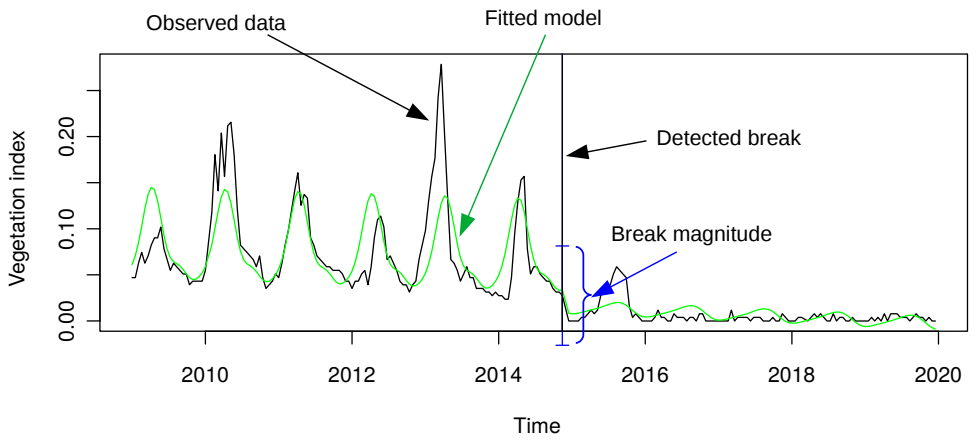
- Piece-wise linear regression:
  - Given that we want one break, and the minimum segment size *h*, what's the optimal location to put it so that the RSS of two segments is minimised?
  - What if we want two breaks?
  - Repeat to get a triangular matrix of all possible breaks and model RSS



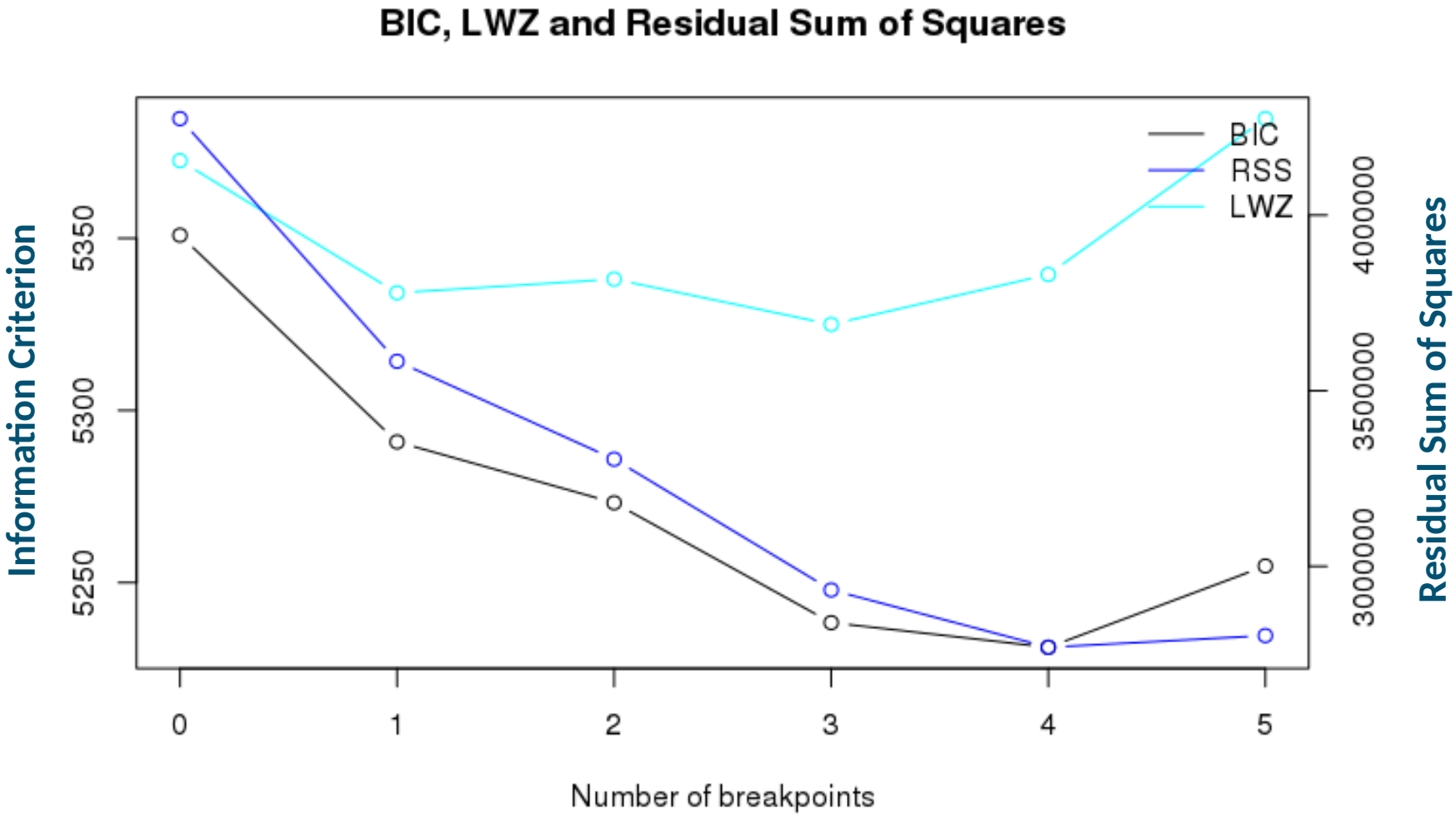
Principle of breakpoints()

- Recursive residuals by Bai and Perron (2003) to solve faster than a grid search: $O(T^2)$ vs $O(T^n)$
- But how many breaks does the time series have?
  - An Information Criterion: if we increase degrees of freedom by adding breaks, data will fit better, so penalise for each degree of freedom added
  - AIC (k=2) is too weak, BIC (k=log(n)) is used by BFAST
  - LWZ ($k=0.299 \times \log(n)^{2.1}$) seems to do better and is default in BFAST Lite

Bai, J., & Perron, P. (2003). Computation and analysis of multiple structural change models. Journal of Applied Econometrics, 18(1), 1–22. https://doi.org/10.1002/jae.659



Breakpoints using LWZ vs BIC



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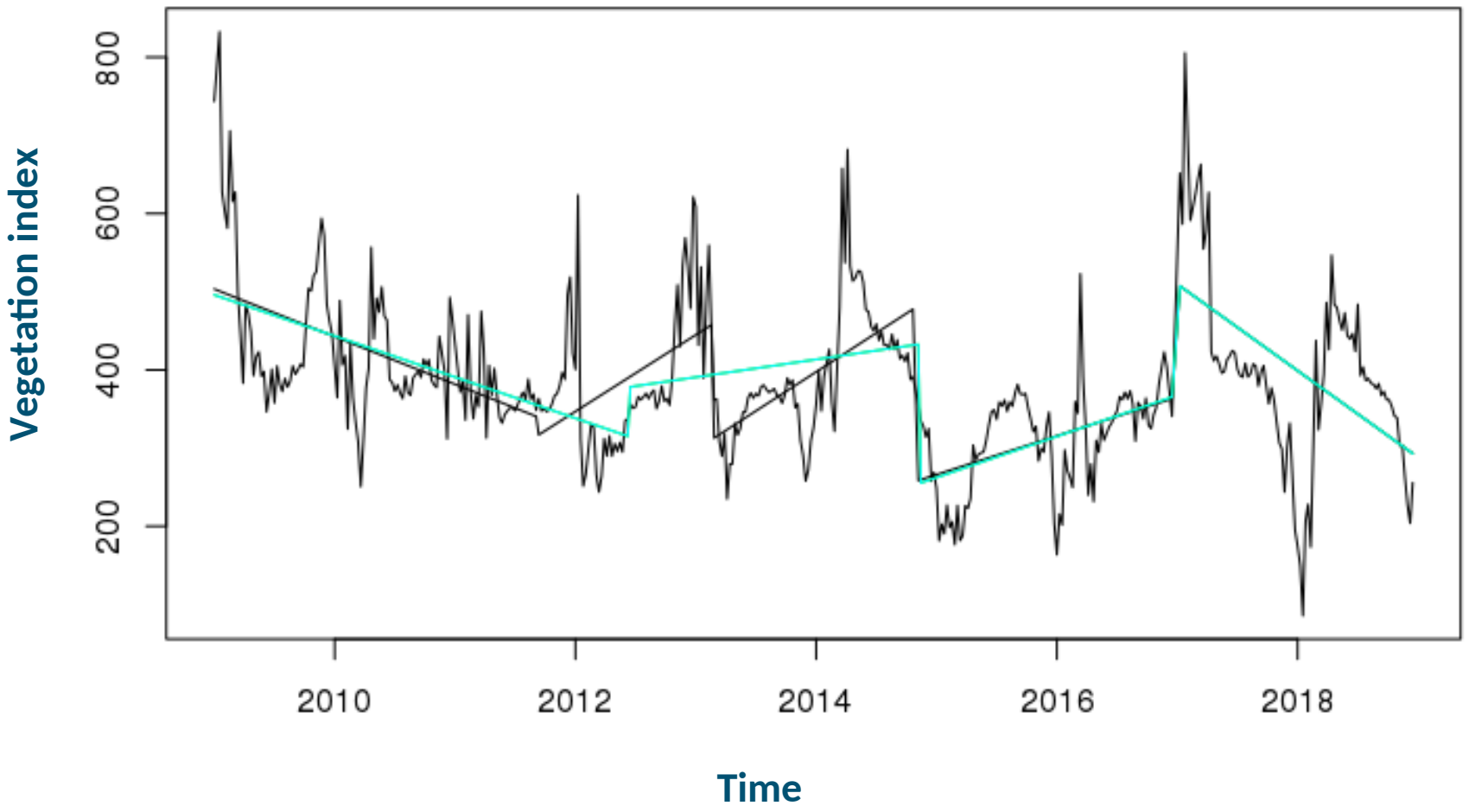

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New in bfast 1.6

- Ability to use LWZ for selecting breaks
- Extra information when printing the results:
    - LWZ statistics
    - R^2
    - Break magnitude, using difference between segment models and the difference in last/first predicted value
- Parameter for customisable seasonal dummy number

Potential features in bfast 1.7

- Structural change test to quickly screen large areas for no break pixels
- Automatic determination of a harmonic order (and number of seasonal dummies)
- Classification of time series typology: abrupt drop, gradual increase, interrupted increase etc. for all breaks in a SITS
- ...and more! Tell us your favourite feature at https://github.com/bfast2/bfast/issues/!

Try BFAST Lite yourself!

- In the practical session, you will try it hands-on on Google Colab (hint: run the first block about package installation over the break, as it takes over 15 minutes!)
- Full tutorial about BFAST Lite and BFAST Monitor:

  https://janverbesselt.github.io/BFASTforAEO/
- Paper with more details about the algorithm:
  Masiliūnas, D.; Tsendbazar, N.-E.; Herold, M.; Verbesselt, J. BFAST Lite: A Lightweight Break Detection Method for Time Series Analysis. Remote Sens. 2021, 13, 3308. https://doi.org/10.3390/rs13163308

Thank you for your attention!

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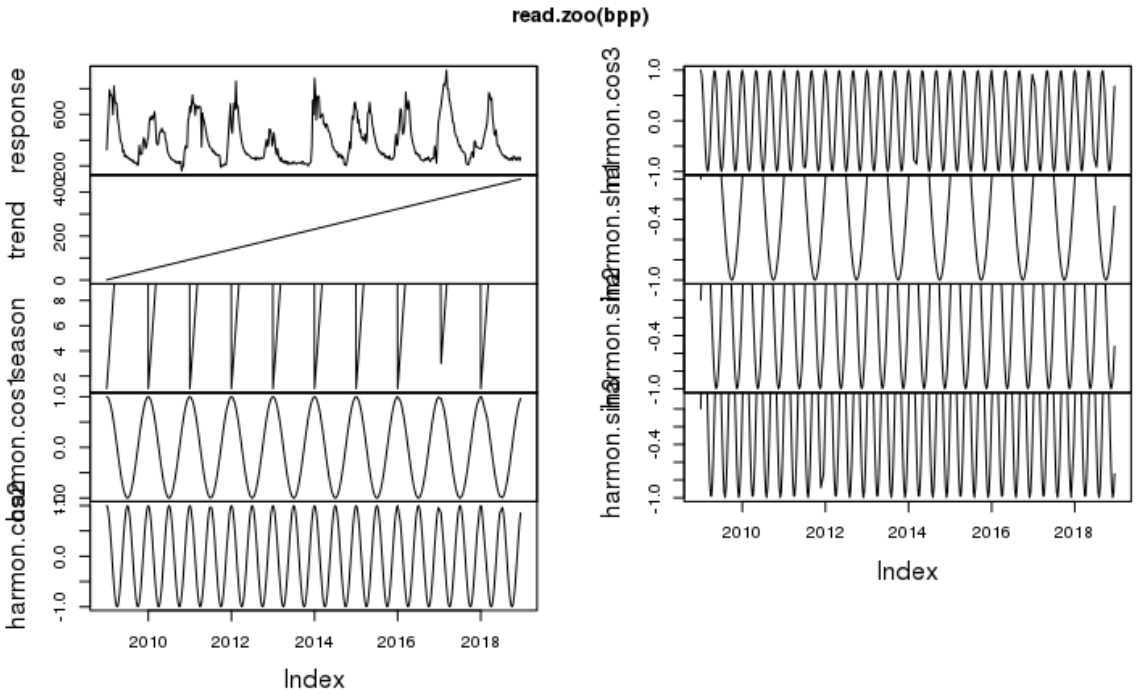
bfastpp()

- How to get data with response ~ trend + harmon?
- bfastpp(ts, order): preprocessing of time series
    - ts must be a `ts` with frequency > 1
    - order is the harmonic order
- Output is a data.frame with:



bfastlite()

- In the bfast pacakge: install.pacakges("bfast")
- bfast::bfastlite(data, formula, h, ...)
    - bfast::bfastpp() + strucchangeRcpp::breakpoints()
    - data: a `ts` object (see bfastts() if you don't have one)
    - formula: e.g. response ~ trend + harmon
    - h: minimum segment size, either fraction of the time series length or integer defining the number of samples
- Output: a list containing a `breakpoints` object that indicates breakpoint timing and confidence interval, in sample numbers (mapping to `data`); you can use plot() and summary() for more info