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Identification of flowering patterns specific to strawberry varieties in production condition using longitudinal data analysis

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Introduction:

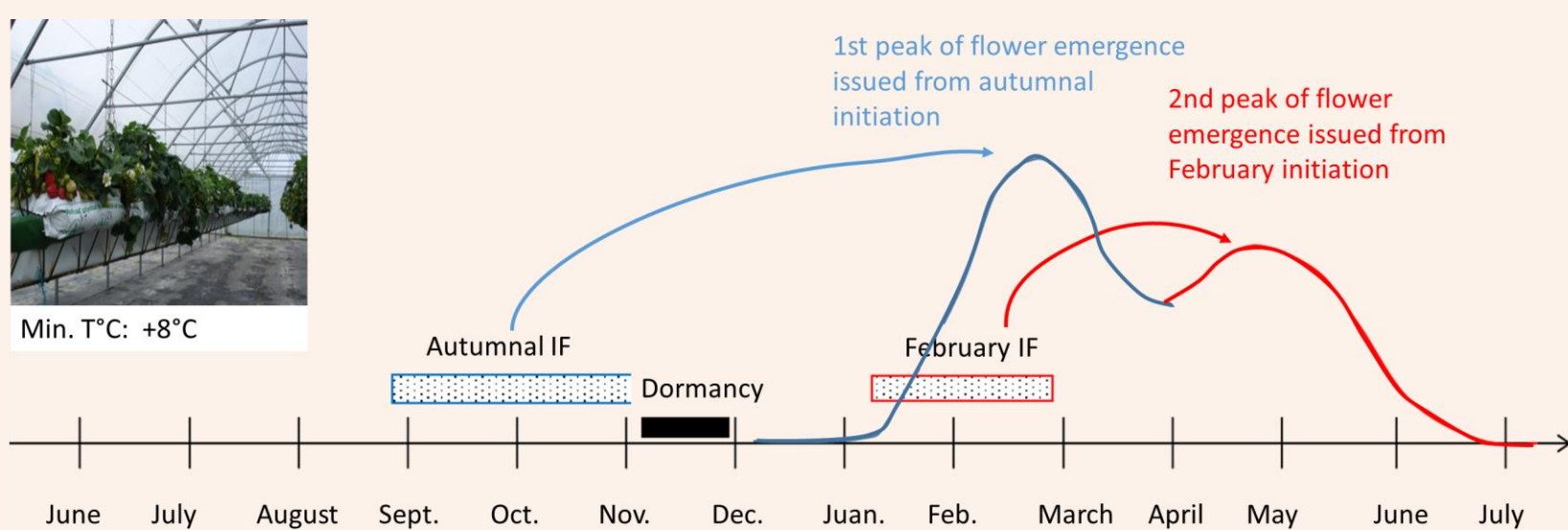
The development of soilless culture for strawberry production is a major socio-economic challenge. This technique improves competitiveness by premature plantation (December) in warmed greenhouse (minimal temperature +8°C) allowing an extension of flowering and, thus, of fruit production. However, this cultural practice is dependent on extension of the flowering period. To this end, a better knowledge of flowering and vegetative growth of varieties is needed.

Plant development is defined as a combination of processes which are subject to environmental, physiological and genetic constraints. Although flowering in strawberry was physiologically and genetically well described, little is known concerning the dynamic of these developmental processes along time.

The **objective** of this study was thus to **identify phenological phases that characterize varieties in production condition.**

Materials and methods:

Thirty two plants per genotype were phenotyped weekly during 28 weeks for their number of newly emerged flowers, leaves, crowns and stolons. We propose a new modelling framework based on multiple change-point models for the identification of phenological phases on the basis of plant follow-up data. Two multiple change-point models were built for each variety, one for flowering and another one for vegetative growth.

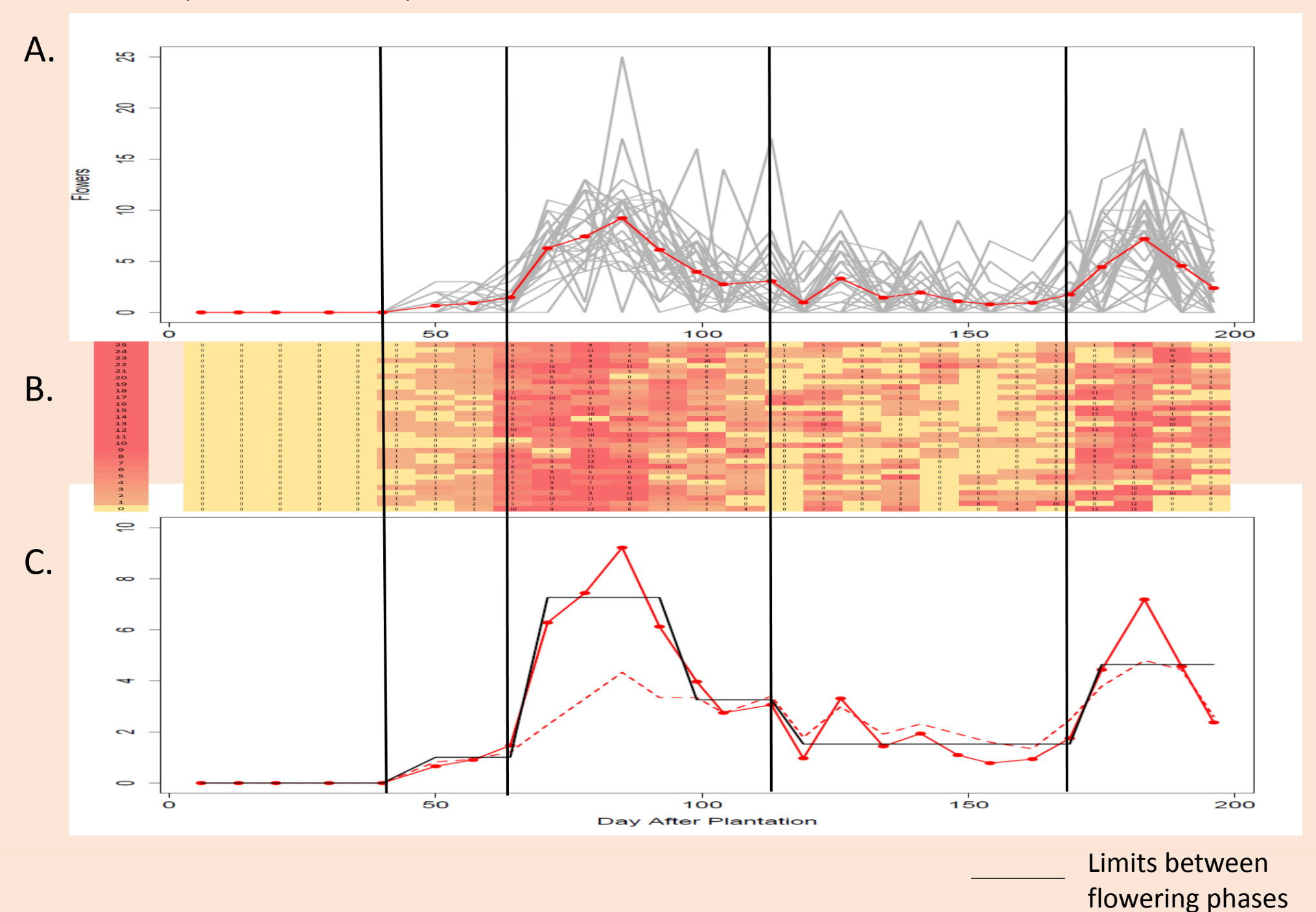


Plant materials: 6 varieties constricted by their number of cold hour, precocity and flowering

Varieties	Number of cold hour	Precocity	Flowering
Gariguette	800	✓	1 st high peak of flowering + 2 nd peak of flowering
Darselect	900	X	No selected for 2 nd peak of flowering
Cir107	300-500	X	High yield, extension of cropping flowering
Capriss	300-500	✓	No peaks of production, Yield ≥ Gariguette
Cléry	900	X	High Yield
Ciflorette	700	X	-

Longitudinal data analysis illustrated with the Gariguette variety

- Weekly number of newly emerged flowers during one cycle of production (Weekly mean in red).
- Flowering data (row: individual; column: date). The number of newly emerged flower is represented by color intensities from 0 (yellow) to 25 (red).
- Piecewise constant function (in black) representing the mean flowering level in each phase. Weekly mean number of newly emerged flowers (red full line) and associated standard deviation (red dashed line).



Statistical model for longitudinal data analysis:

To identify flowering pattern, we hypothesize that:

- flowering pattern for a genotype takes the form of a succession of well-differentiated stationary flowering phases
- the distribution of the number of weekly emerged inflorescences does not change substantially within each phase, but change markedly between phases.

These flowering patterns have been analyzed using segmentation models for each variety. This analysis consists of identifying synchronous phases on the 32 plants measured for a variety.

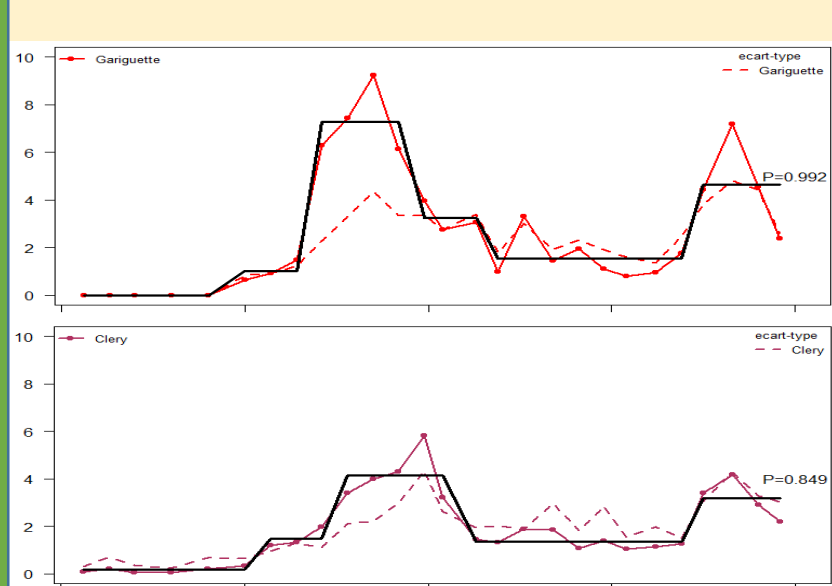
We used the slope heuristic (Guédon, 2015b), a model selection criterion dedicated to the segmentation objective, to determine the number of flowering phases and different diagnostic tools to assess the assumption of the segmentation in stationary flowering phases (Guédon, 2013, 2015a).

Results: Three flowering patterns were identified

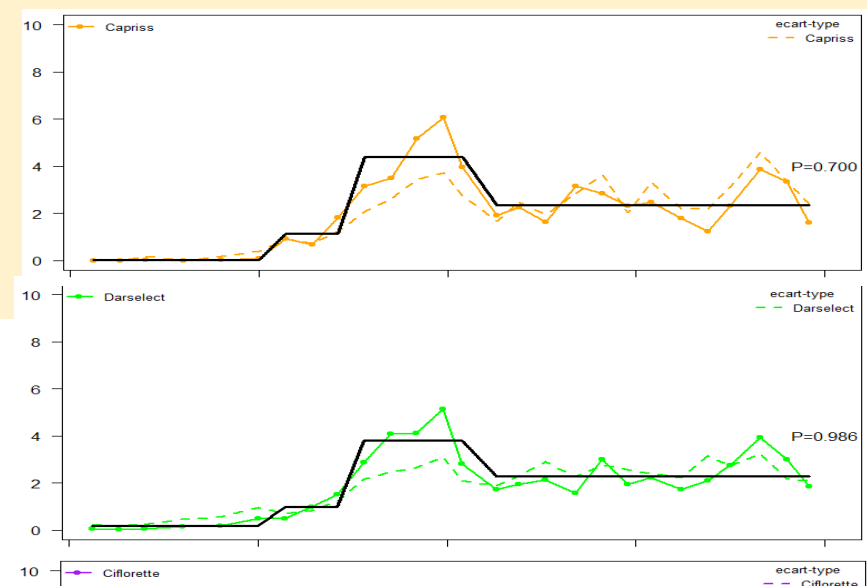
Successive flowering phases were identified using categorical multiple change-point models:

- A first phase of high flowering intensity (64 to 110 days after plantation) common to all the varieties.
- either a second phase of low flowering intensity followed by a third final phase of high flowering intensity (pattern 1; Gariguette and Cléry) or a single second phase of low flowering intensity (pattern 2a; Capriss, Darselect) or intermediate flowering intensity (pattern 2b; Ciflorette and CIR107).

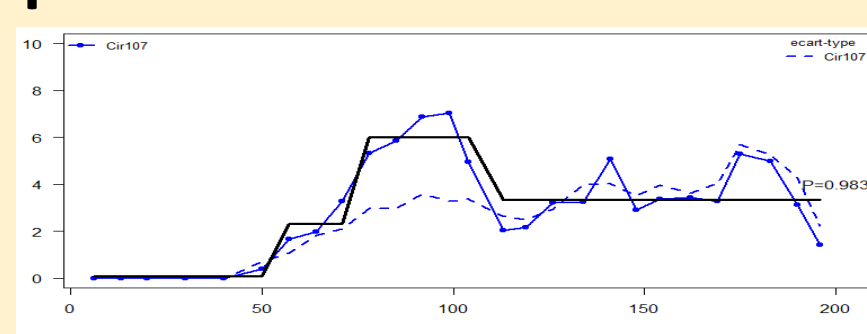
Pattern 1:



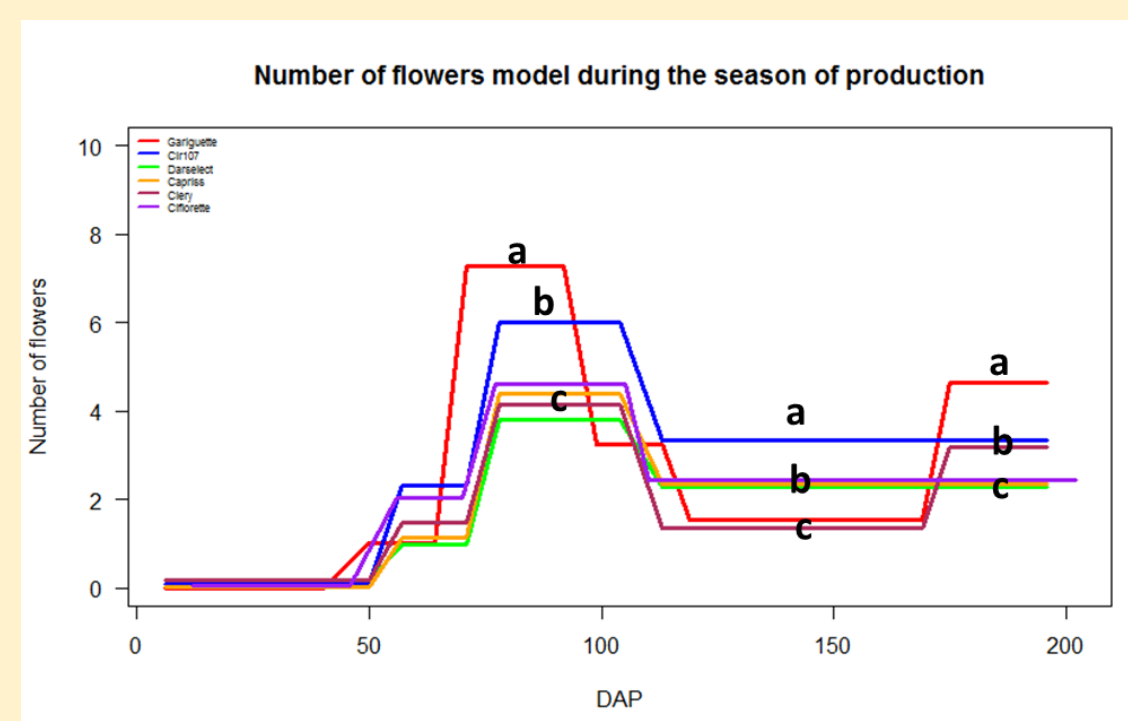
pattern 2a:



pattern 2b:



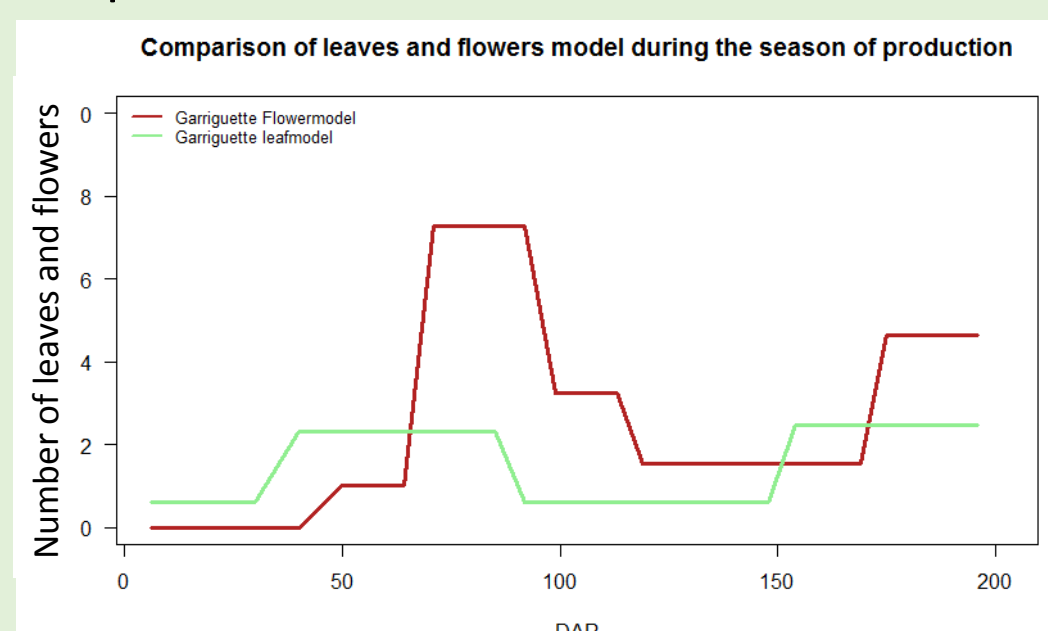
Assessment of the 3 flowering patterns



The variety effect on the distribution of the number of newly emerged flowers in each flowering phase was tested using a one-way ANOVA on ranks (Kruskal-Wallis test and post-hoc analysis). The results are shown for (i) the first phase of high flowering intensity, (ii) the intermediate phase of low flowering intensity and (iii) the final phase of potentially high flowering intensity. When the two last flowering phases were merged (Capriss, Darselect, Ciflorette and CIR107), we use the common limit found for Gariguette and Cléry to split these two last phases.

Perspectives:

A direct extension would be to build multiple change-point models directly on the basis of multivariate plant follow-up data, combining flowering, vegetative growth and runner variables. This would allow to identify global developmental phases relying on the different developmental processes in competition within plants.



Leaves and flowers models during the season of production

Change in the rhythm of leaf emergence:
Can we predict the flowering time using these changes?

References:

- Guédon Y (2013) Exploring the latent segmentation space for the assessment of multiple change-point models. *Comput Stat* 28: 2641–2678
 Guédon, Y. (2015a). Segmentation uncertainty in multiple change-point models. *Statistics and Computing* 25(2), 303-320.
 Guédon, Y. (2015b). Slope heuristics for multiple change-point models. In: *30th International Workshop on Statistical Modelling (IWSM 2015)*. Friedl, H., Wagner H., eds., vol. 2, 103- 106

