

SUPPLEMENTARY INFORMATION TEXT:

METHODS

1. Quantifying the occurrence of extreme events – modified after Siegmund *et al.* (2016)

a) Calculation of the temperature data:

To compute binary vectors that indicate those years corresponding to extreme temperature events at day i , the 10 % and 90 % quantiles of 30-day time-windows was calculated, for every day of the year (DOY). Thereby, DOY specific temperature threshold values were gathered for the periods of days ($i - 29$) to day i in all studied years (1978–2018). A time window of length 30-days (in line with Siegmund *et al.*, 2016) was chosen considering aspects like (1) the length of a time period, which may influence plant development; and (2) the effect of changes in temperature variations. Extreme temperature events were estimated (extreme hot or extreme cold) on day i , if the arithmetic mean of daily minimum, mean, or maximum temperatures within the time window of the specific year fall below or above the corresponding 10 % or 90 % quantiles of the studied period (1978–2018), respectively. This estimation was done for each DOY between January 31, 1978 and December 31, 2018. The information was stored in a binary vector for each DOY with 1 indicating an extreme temperature event (or 0, when no extreme event was captured).

b) Calculation of phenological data:

All dates of phenological observations given in month and days were converted to DOY values (using the *phenex* R package; Doktor and Lange, 2017). The extreme phenological event (extreme early or extreme late phenophases) identification process differs a bit from (a), as described below. The difference lies in the calculation of the binary vector that determines extreme phenological events. For all 35 phenophases of each six-grapevine variety, the 10 % and 90 % quantiles from all DOY values were calculated separately in all studied years (1978 – 2018). Similarly, to the temperature data, those DOY values were marked to be extremely early or extremely late, which lay below or above the corresponding 10 % or 90 % quantiles; and this information was stored in a binary vector (1: an extreme phenological event; 0: no extreme event was captured).

2. Identifying the coincidence of extreme events – modified after Siegmund *et al.* (2016)

After classifying the extreme events in both time series (daily temperature and timing of the phenophases, see above), the coincidence of these events was identified. Event coincidence analysis (Donges *et al.*, 2011; Donges *et al.*, 2016; Siegmund *et al.*, 2016) is a method which explicitly specifies the coincidence interval, the possible lag (τ) and the directionality of these interrelationships. An extreme phenological event on day i is identified as coincidence with an extreme temperature if it occurred within 30 days of an extreme temperature event (defined as a temperature in the upper- or lower-most 10 % quantile) ending on day j , *i.e.* if $i \leq j + 30$. Coincidence interval of 15 days was also applied, as by Siegmund *et al.* (2016), but results from both studies concluded that 30 days coincidence interval is a better choice. Siegmund *et al.* (2016) define a lag parameter to relax the 30-day requirement so that a phenological event may be classified as extreme if it occurred within $30 + \tau$ days of the extreme temperature event ending. No information could be found about the optimum lag for grape varieties so far. However, our experiments have showed that $\tau = 3$ (maximum shift of 3 days) leads to the most coincidences. This is a strong indication that $\tau = 3$ is a good choice, because it not only gives the highest coincidences, but a lag of three days is also a good choice from the biological point of view. If τ is too small, *e.g.* 0, then it is assumed that the extremely low/high temperatures events have no delayed effect on the phenology of the plant; while when τ is too high, it may have captured random, unrelated effects. Thus, coincidence of extreme events was identified, when a phenological event occurs with maximum 33 days ($30 + \tau$ days) of an extreme temperature event. In iterative steps, all binarized vectors were analysed by the CoinCalc package (Siegmund *et al.*, 2017) in R (R Core Team, 2019).

3. Outline of the general idea of the method of Siegmund *et al.* (2016)

The following graph (Fig. S0) highlights, why the modified method of Siegmund *et al.* (2016) is more sophisticated than the “Quantile method” (see the Manuscript) which calculates only quantiles of the arithmetic means of all the mean temperatures.

As a reference year, 2017 (red dots) was selected when the day of the leaf unfolding of the Syrah variety was 96. The y axes represent the mean temperature within the time window before the phenological event occurred (from 33 days before until 3 days after the occurrence of the phenological event). Quantiles (0.1 and 0.9) are

indicated by black vertical lines. It can be seen that for 2017 the mean temperature values in the specific temperature time window are often above the 0.9 quantile, thus reported as extreme. Based on these statistics it is determined if a coincidence between temperature and the phenological event is present (details in Siegmund *et al.*, 2016).

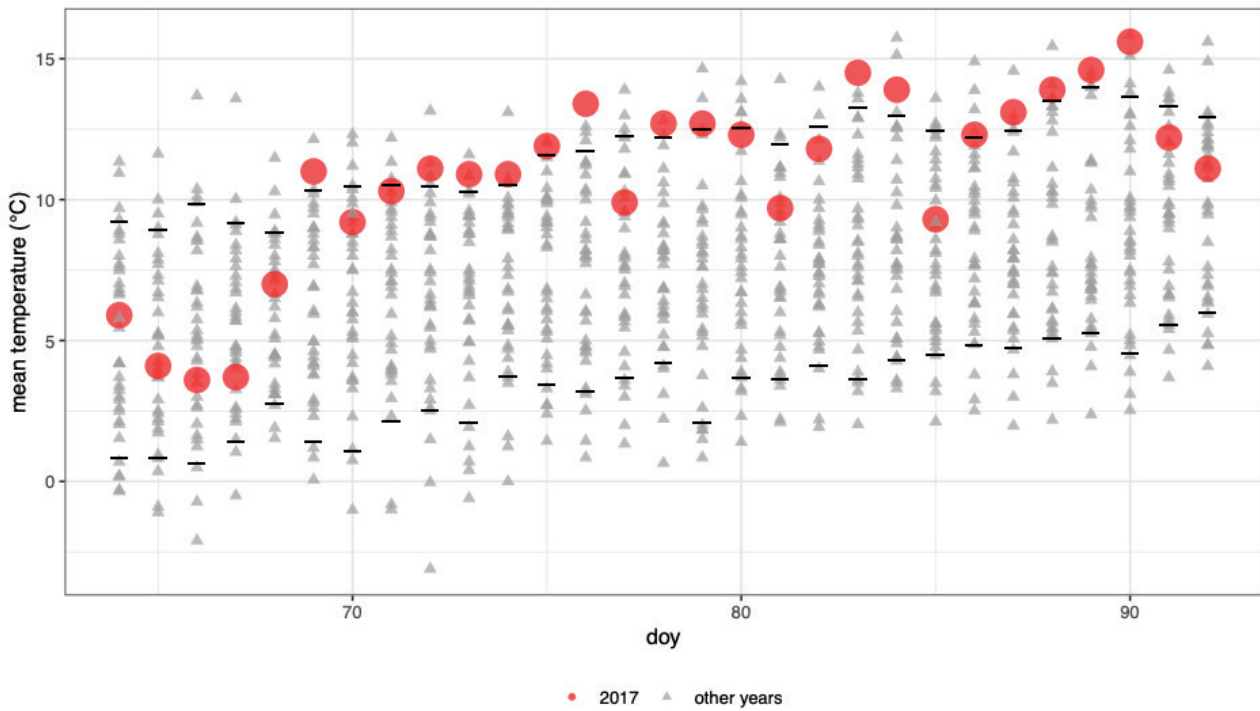


FIGURE S0. Outline of the general idea of the method of Siegmund *et al.* (2016)

SUPPLEMENTARY TABLE:

TABLE S1. Phenological phases of grapevines included in the study.

No.	BBCH-scale	Phenophase	Growth stage
1	0	Dormancy: winter buds pointed to rounded, light or dark brown according to cultivar; bud scales more or less closed according to cultivar	0: Sprouting/Bud development
2	1	Beginning of bud swelling: buds begin to expand inside the bud scales	0: Sprouting/Bud development
3	3	End of bud swelling: buds swollen, but not green	0: Sprouting/Bud development
4	5	“Wool stage”: brown wool clearly visible	0: Sprouting/Bud development
5	7	Beginning of bud burst: green shoot tips just visible	0: Sprouting/Bud development
6	9	Bud burst: green shoot tips clearly visible	0: Sprouting/Bud development
7	10	Leaf unfolding	1: Leaf development
8	11	First leaf unfolded and spread away from shoot	1: Leaf development
9	12	Second leaf unfolded	1: Leaf development
10	13	third leaf unfolded	1: Leaf development
11	14	Fourth leaf is unfolded	1: Leaf development
12	15	Fifth leaf is unfolded	1: Leaf development
13	16	Six leaf is unfolded	1: Leaf development
14	53	Inflorescences clearly visible	5: Inflorescence emergence
15	55	Inflorescences swelling, flowers closely pressed together	5: Inflorescence emergence
16	57	Inflorescences fully developed; flowers separating	5: Inflorescence emergence
17	59	Completely separate flower buds	5: Inflorescence emergence
18	61	Beginning of flowering: 10% of flowerhoods fallen	6: Flowering
19	62	Flowering: 20% of flowerhoods fallen	6: Flowering
20	63	Flowering: 30% of flowerhoods fallen	6: Flowering
21	64	Flowering: 40% of flowerhoods fallen	6: Flowering
22	65	Full flowering: 50% of flowerhoods fallen	6: Flowering
23	66	60% of flowerhoods fallen	6: Flowering
24	67	70% of flowerhoods fallen	6: Flowering
25	68	Late flowering: 80% of flowerhoods fallen	6: Flowering
26	69	End of flowering	6: Flowering
27	71	Fruit set: young fruits begin to swell, remains of flowers lost	7: Development of fruits
28	73	Berries goat-sized, bunches begin to hang	7: Development of fruits
29	75	Berries pea-sized, bunches hang	7: Development of fruits
30	77	Berries beginning to touch	7: Development of fruits
31	79	Majority of berries touching	7: Development of fruits
32	81	Beginning of ripening: berries begin to develop variety-specific colour	8: Ripening of berries
33	83	Berries developing colour	8: Ripening of berries
34	85	Softening of berries	8: Ripening of berries
35	87	Complete end of softening of berries	8: Ripening of berries
36	89	Berries ripe for harvest	8: Ripening of berries

The BBCH-scale for grapes (Lorenz *et al.* 1994) describes the growth stages of grapes during development using the BBCH-scale (Meier 1997).

SUPPLEMENTARY FIGURES:

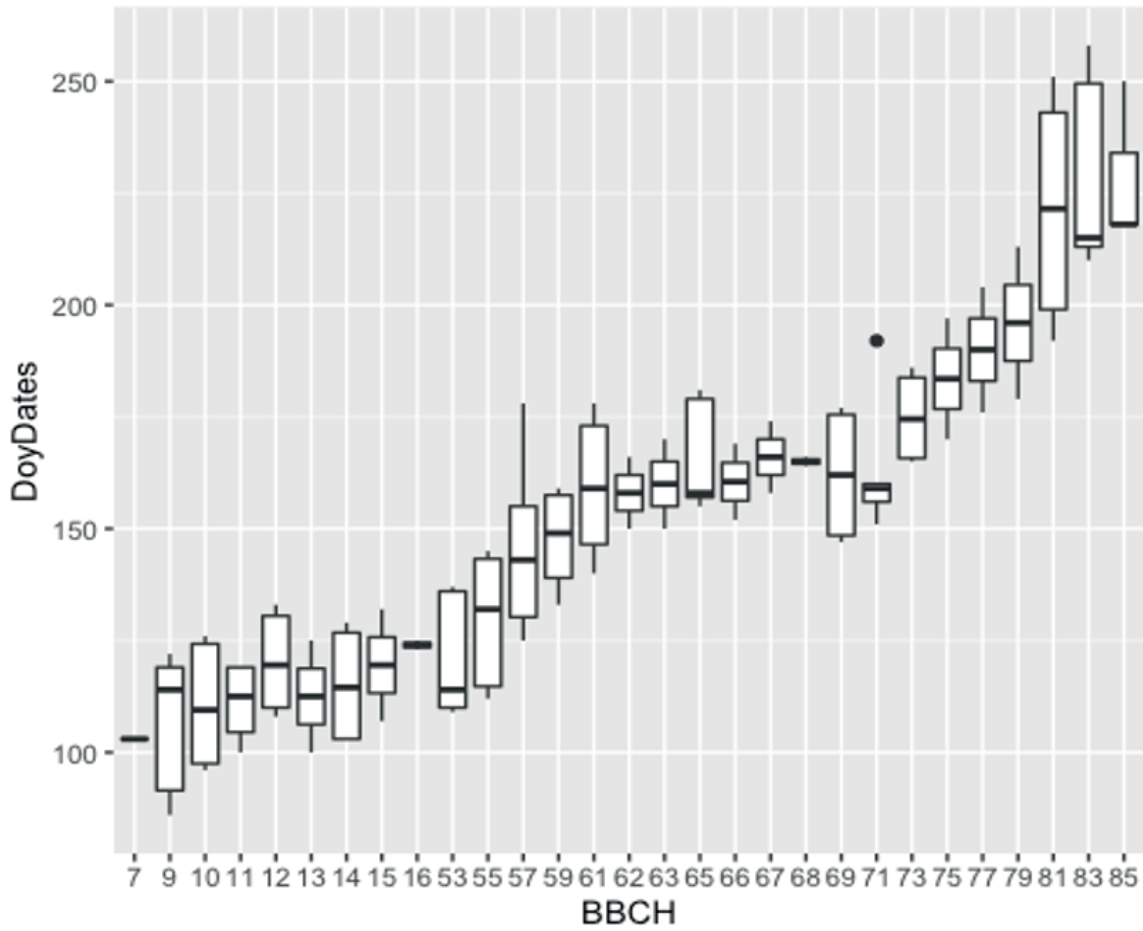


FIGURE S1. The number of observations between years and phenophases.

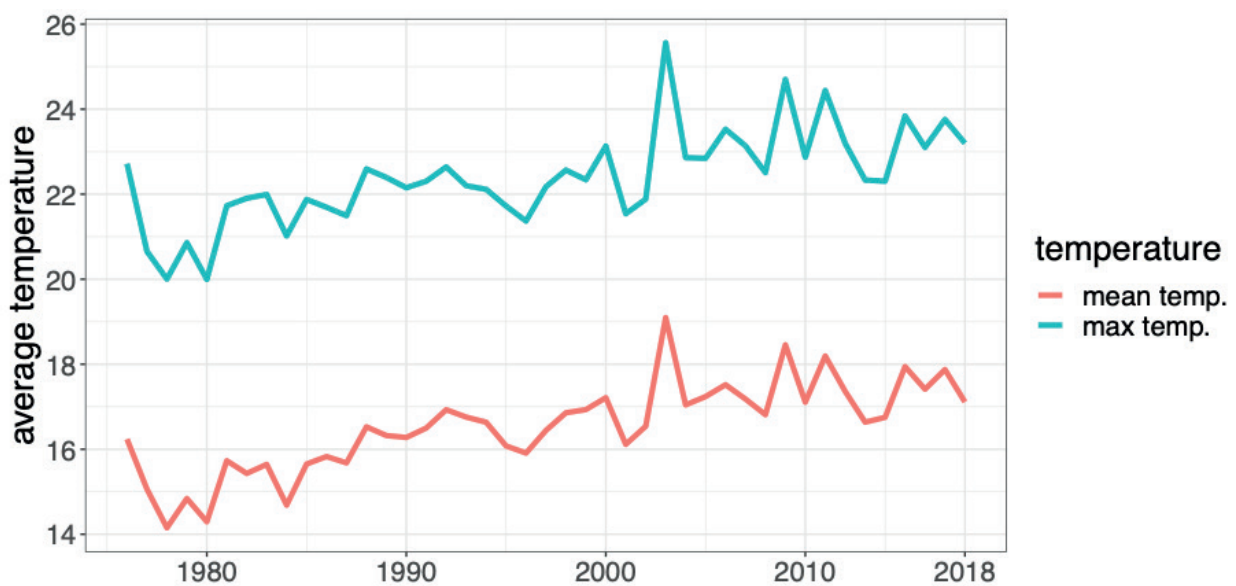


FIGURE S2. Average temperature (mean and max) over time (1978 - 2018) at Leytron, Switzerland.

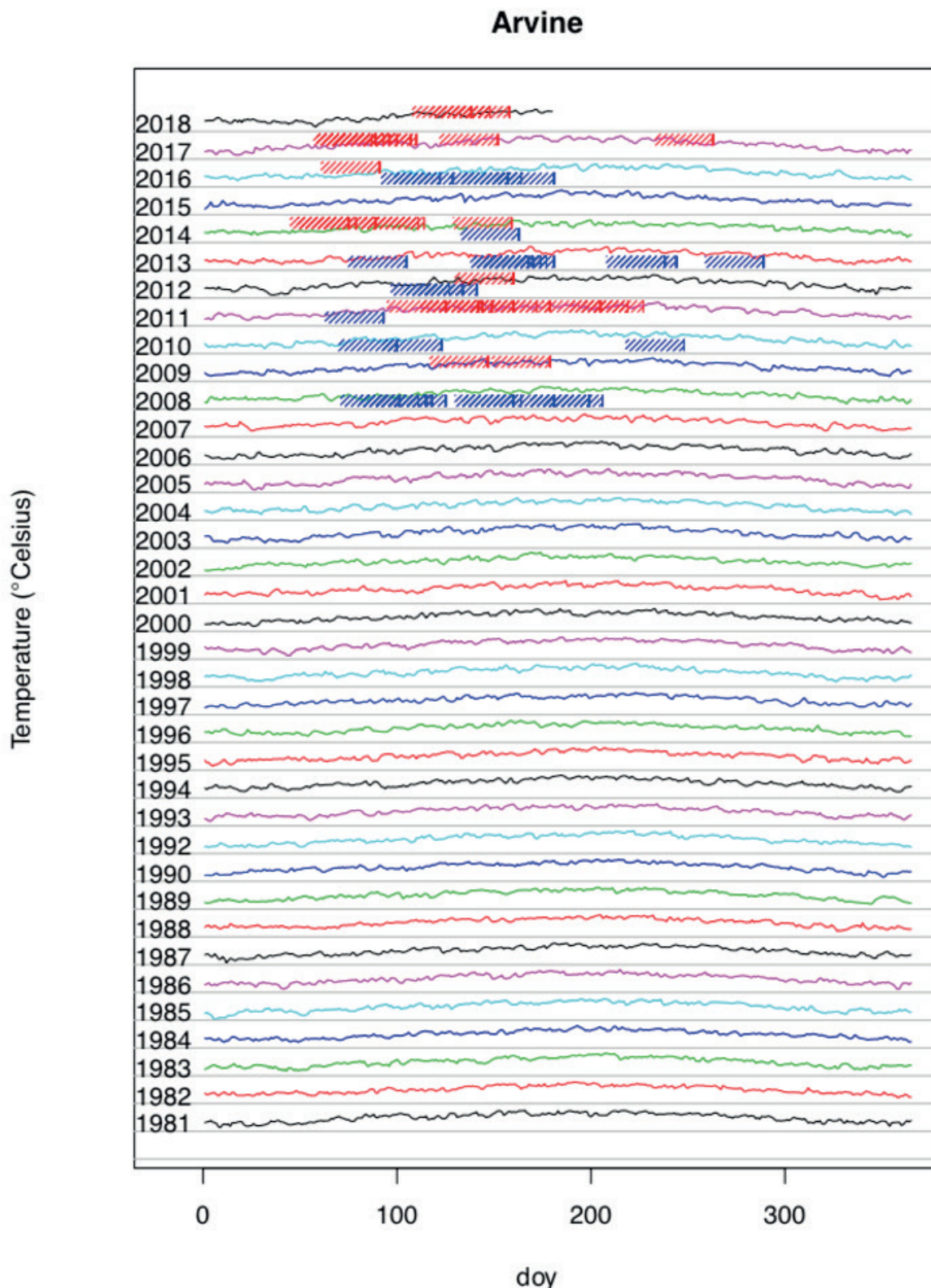


FIGURE S3. Coincidences of extreme phenological and temperature events (1978-2018) of the ‘Arvine’ variety in Leytron, Switzerland.

The polygon lines express the daily mean temperatures of the corresponding years. The coloured areas indicate extreme coincidences (according to Siegmund *et al.*, 2016) within the time window of the year before the timing of the phenological event. The colour of the bars corresponds to the direction of the extreme phenological shift (red bars: earlier doys; blue bars: later doys). The number of bars within the colour shaded area corresponds to the number of extreme coincidence events. All phenological events considered in the analysis are listed in Table S1.

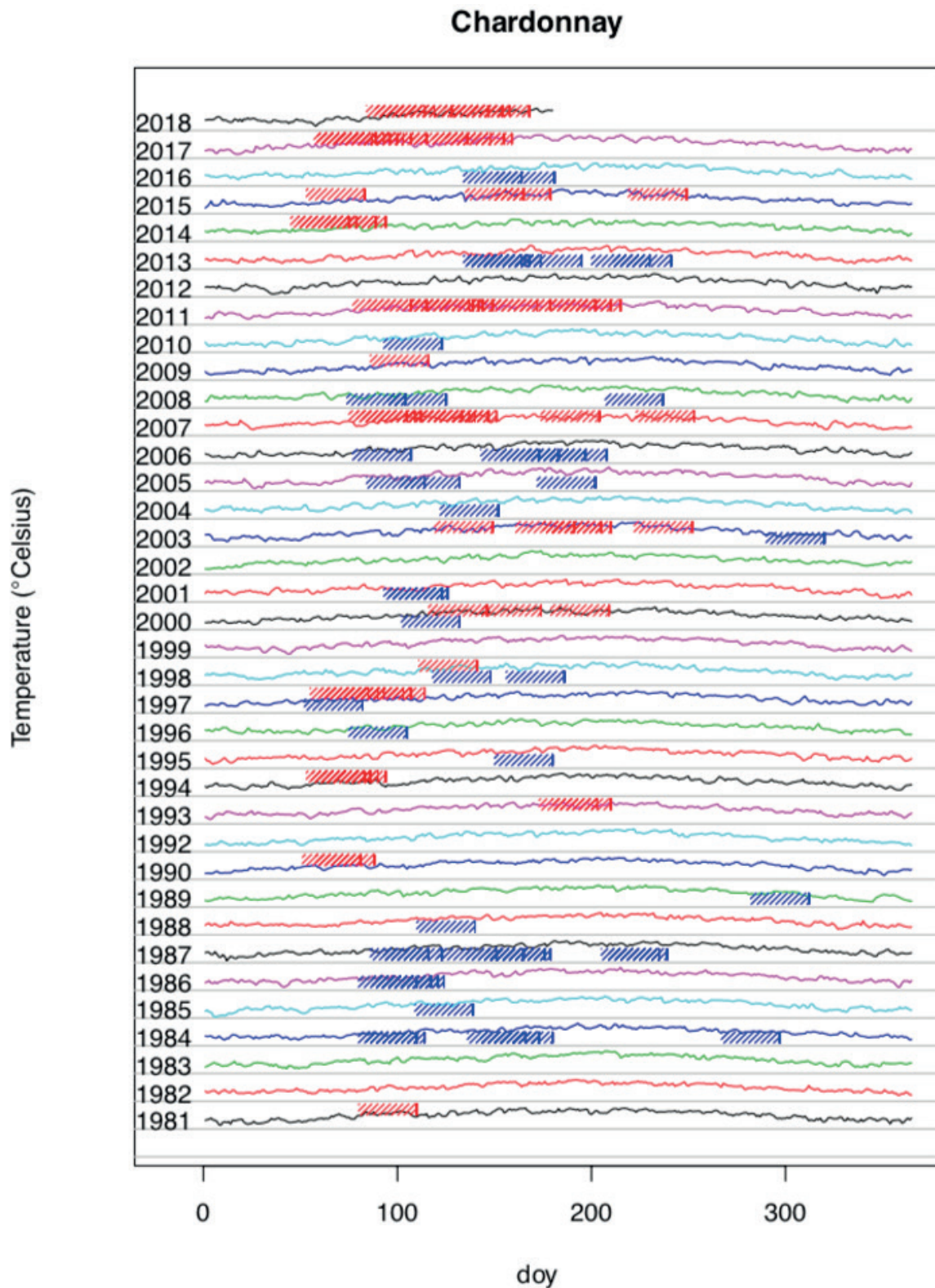


FIGURE S4. Coincidences of extreme phenological and temperature events (1978-2018) of the ‘Chardonnay’ variety in Leytron, Switzerland.

Abbreviations as in Figure S3.

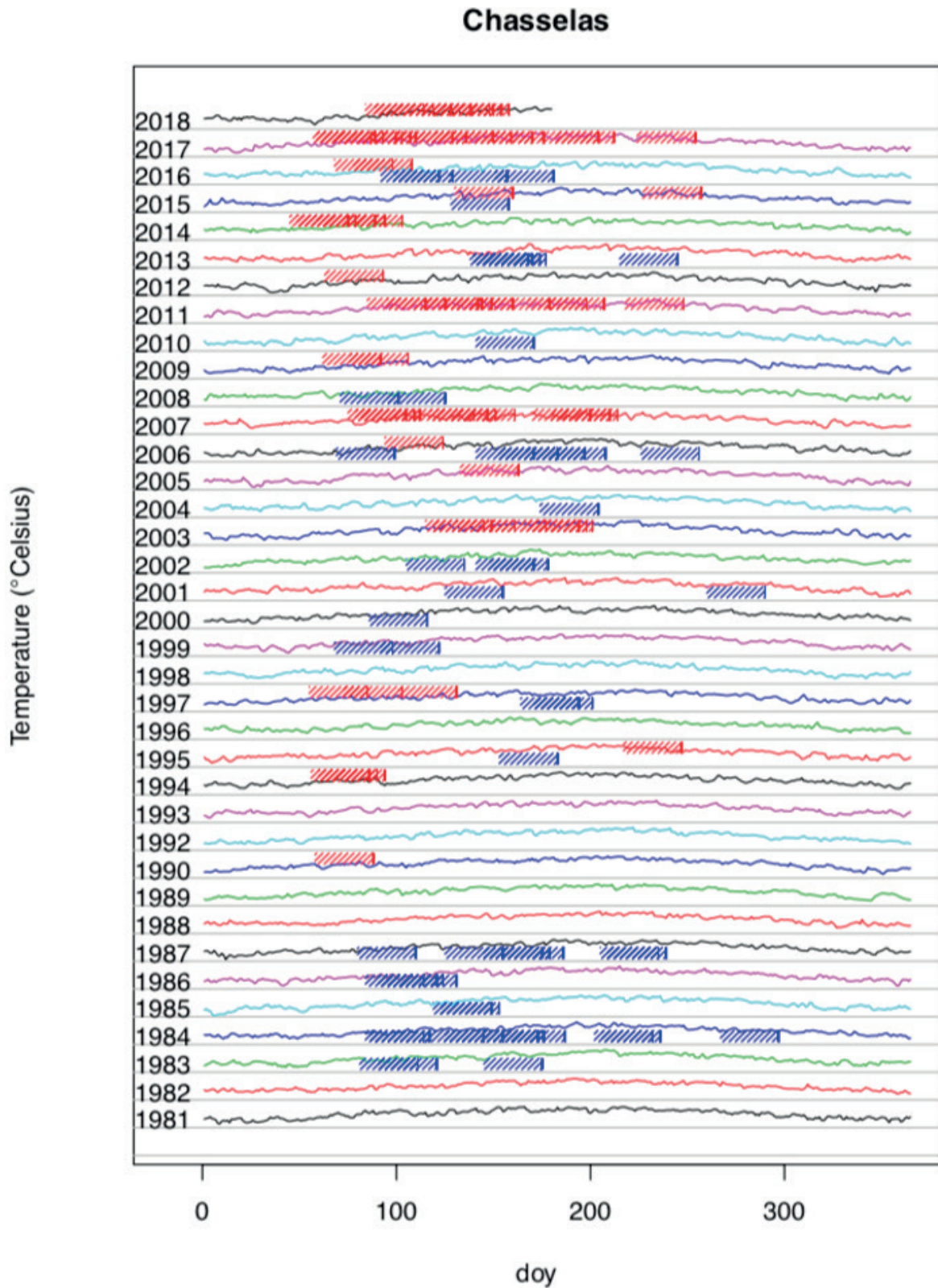


FIGURE S5. Coincidences of extreme phenological and temperature events (1978 - 2018) of the ‘Chasselas’ variety in Leytron, Switzerland.

Abbreviations as in Figure S3.

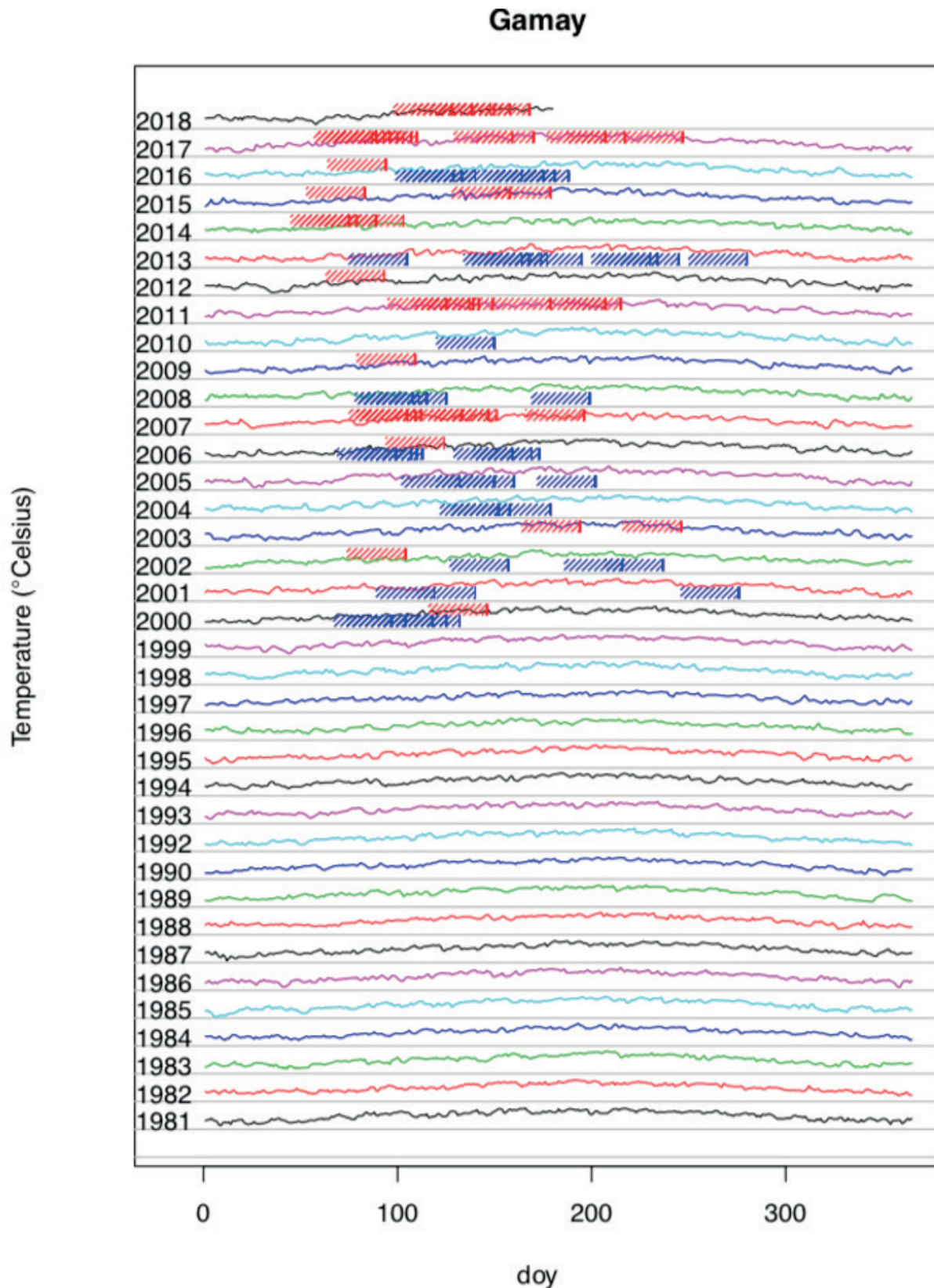


FIGURE S6. Coincidences of extreme phenological and temperature events (1978-2018) of the ‘Gamay’ variety in Leytron, Switzerland.

Abbreviations as in Figure S3.

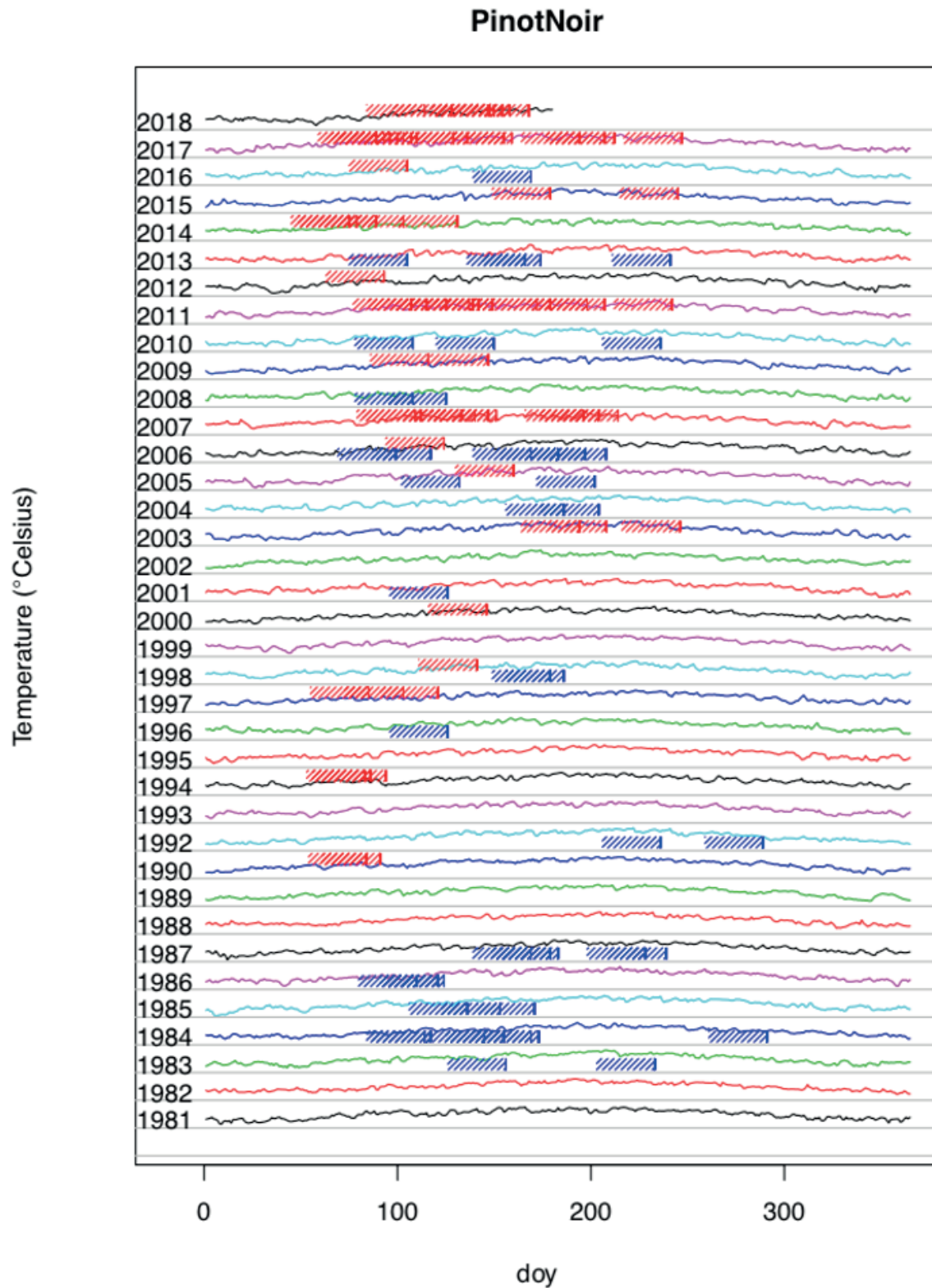


FIGURE S7. Coincidences of extreme phenological and temperature events (1978-2018) of the ‘Pinot noir’ variety in Leytron, Switzerland.

Abbreviations as in Figure S3.

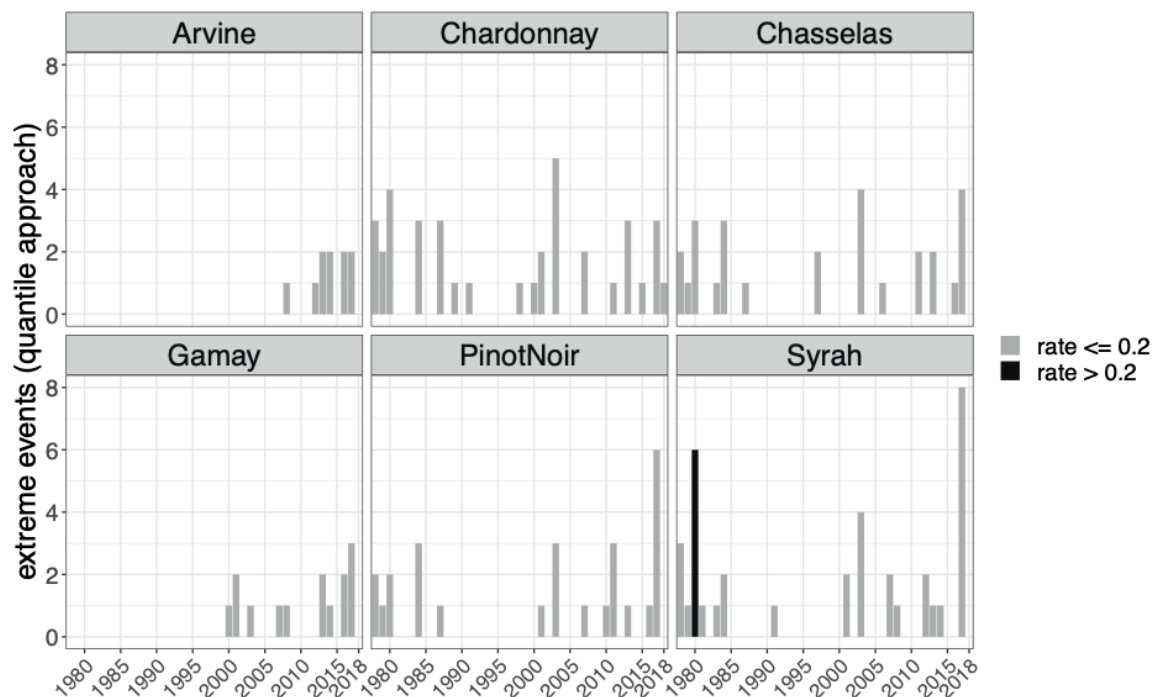


FIGURE S8. Distribution of the number of extreme phenological events (all 36 BBCH phenophases) of the studied grapevine varieties over the study period (1978-2018) observed in Leytron « Quantile method ».

The height of the bars shows the number of extreme coincidence events. Bars in black demonstrate when the rate of extreme events is above 20 % (p-level 0.05), while grey bars indicate non-significant years. Higher rates correspond to larger number of phenophases that coincided with extreme temperature events in the given year per grape variety. Note: there is missing data at the beginning of the studied period for the Arvine (1978-2007) and Gamay (1978-1999) varieties.

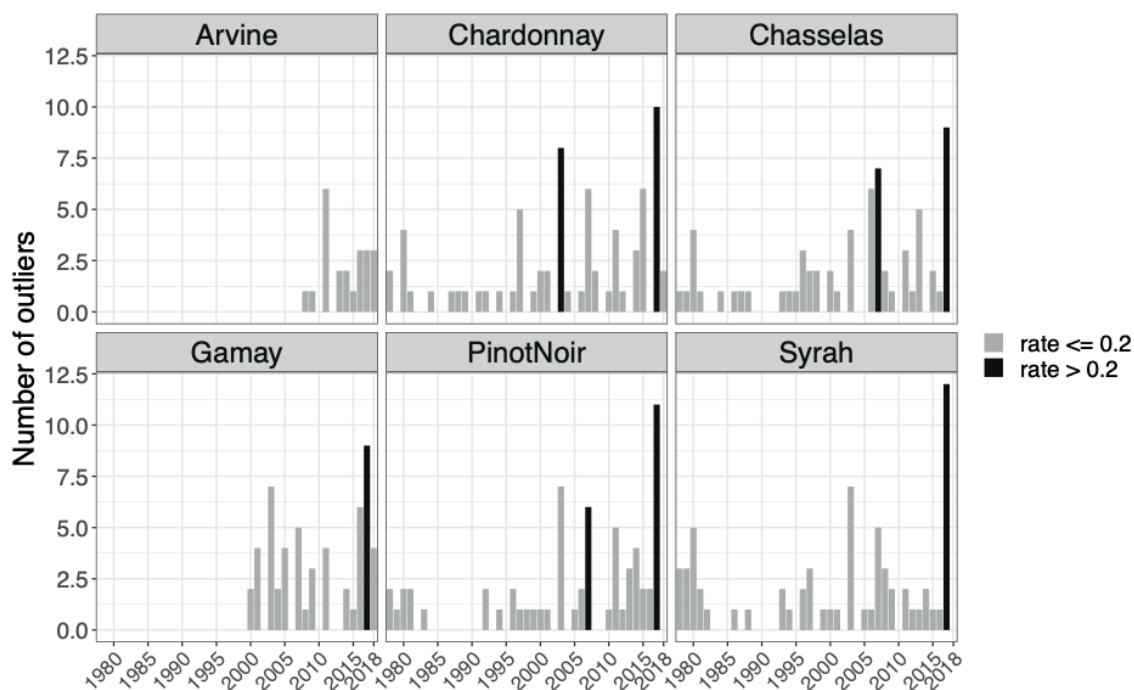


FIGURE S9. Distribution of the number of extreme phenological events (all 36 BBCH phenophases) of the studied grapevine varieties over the study period (1978-2018) observed in Leytron based on the « Robust-covariance estimation ».

Abbreviation as in Figure S8.

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