Weather generators and phenological models to study climate change impacts on grapevines and apples

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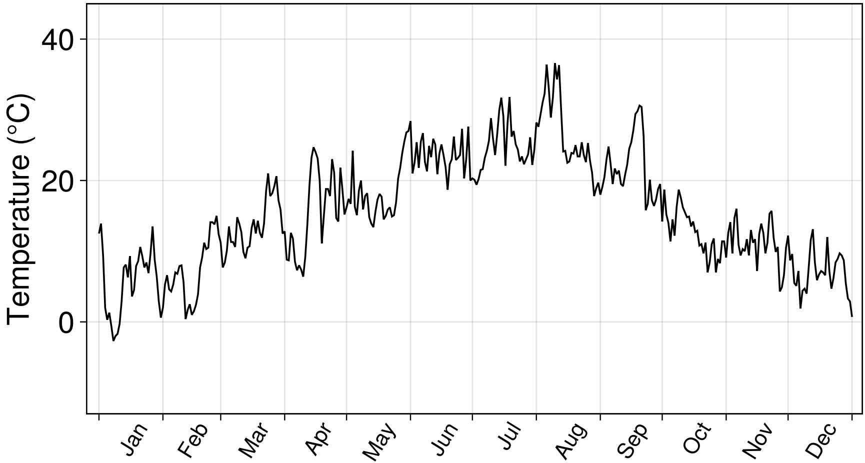
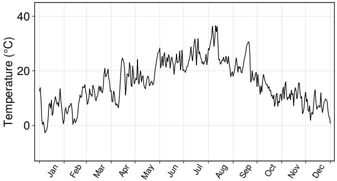
Outline

I. Stochastic weather generators



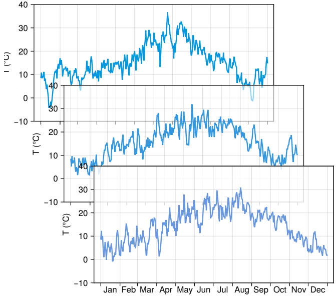
Recorded daily maximum temperature (TX) at Lille from 1^{st} May 2003 to 1^{st} November 2003 (source : ECA&D)

Weather data

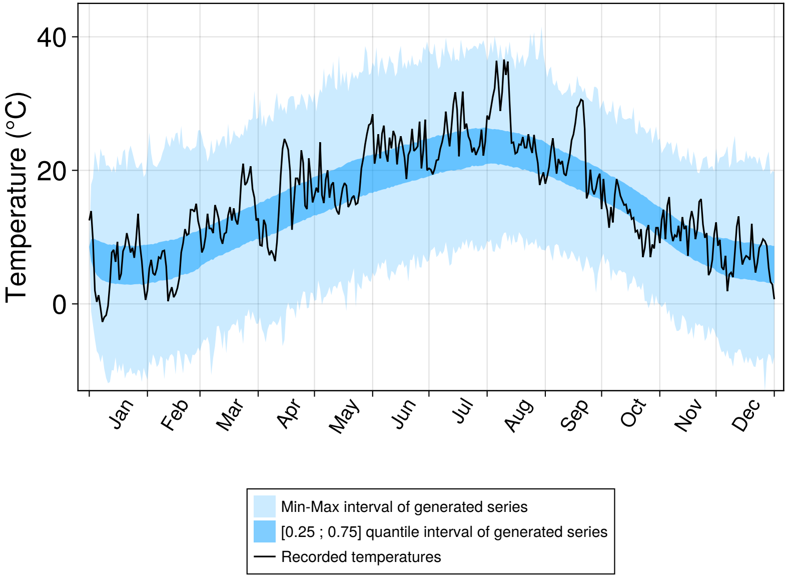


Stochastic Model

Simulations

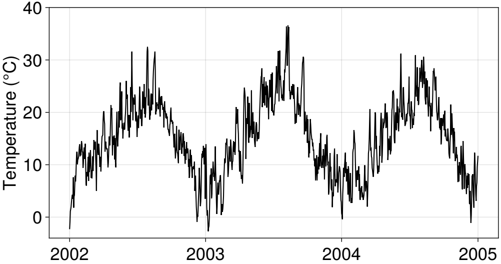


With 5000 simulations :

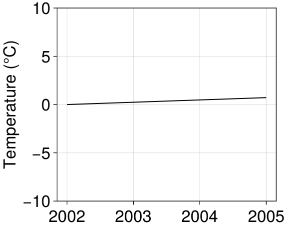


$T_t = M_t + S_t + X_t$ where

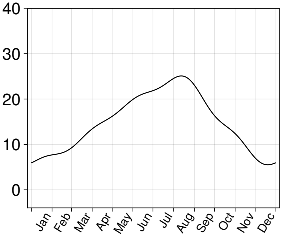
- T_t is the recorded temperature (TN, TG or TX)
- M_t is the trend
- S_t is the seasonality
- X_t is the stochastic part



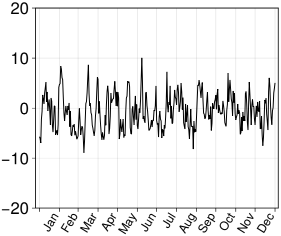
Recorded temperature T_t



Trend M_t



Seasonality S_t



Stochastic part X_t

Model

- Trend : $M_t = 0$ (for now)
- Seasonality : Parametric function with a periodicity of 365.25 days :

$$S_t = \mu + \sum_{k=1}^{K} \alpha_k \cos(\omega k t) + \beta_k \sin(\omega k t)$$

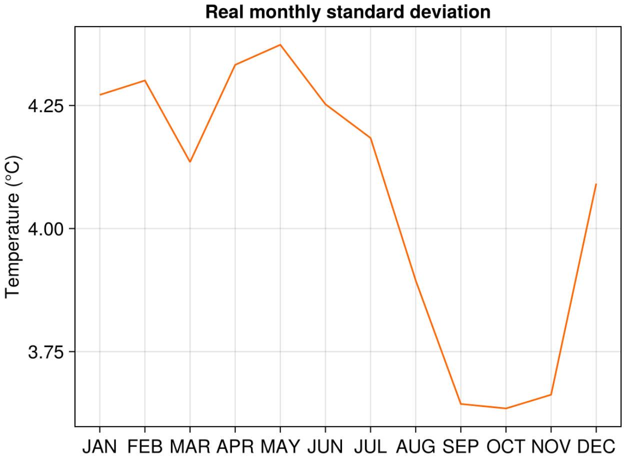
With $\omega = 2\pi/365.25$, α_k and β_k coefficients to estimate and K the order ($K = 5$ in our work).

- Stochastic part $\sim$ AR(p) model i.e :

$$X_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + ... + \phi_p X_{t-p} + \sigma \varepsilon_t$$

With ε_t a noise, ϕ_i and σ coefficients to estimate and p the order (we have chosen $p = 1$).

Problem : Some features change during a year :



Model

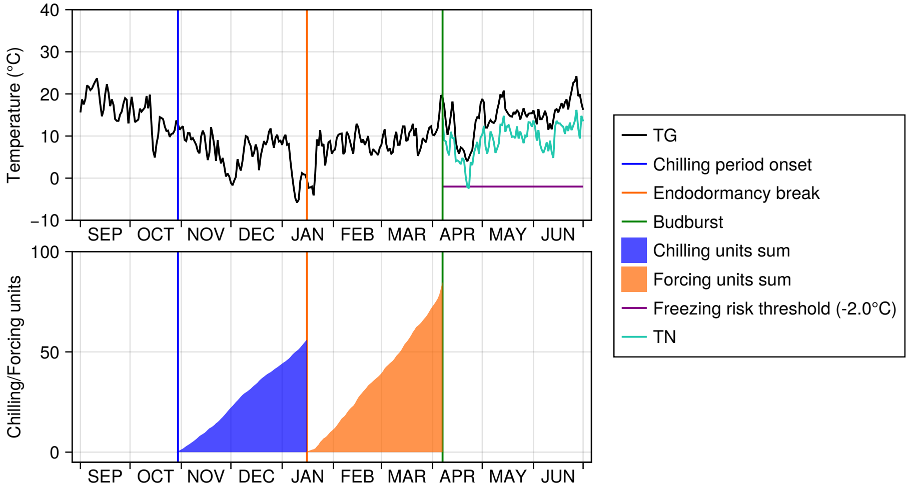
Model with different parameters for each month :

$$X_t = \phi_{1,m(t)} X_{t-1} + \phi_{2,m(t)} X_{t-2} + ... + \phi_{p,m(t)} X_{t-p} + \sigma_{m(t)} \varepsilon_t$$

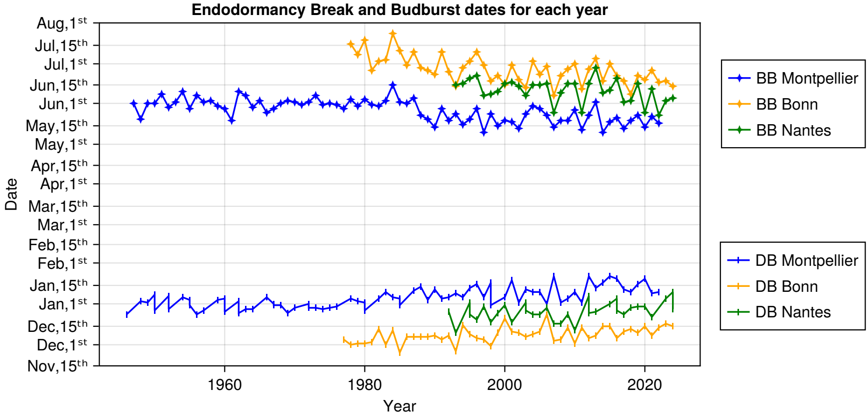
With ε_t a noise and $m(t)$ the month of the date t.
$\rightarrow (p+1) \times 12$ parameters for the stochastic part.

- All parameters (μ, α_k, β_k, $\phi_{i,j}$ and σ_j) estimated with basic statistical methods (Regression and Maximum likelihood estimation).
- To simulate new series :
  1. Initial conditions : $\hat{X}_1 = X_1, \hat{X}_2 = X_2, \ldots, \hat{X}_p = X_p$.
  2. X_t simulated with the equation above. (ε_t is the term which makes it "random")
  3. T_t simulated by adding the periodic function of S_t.

II. Phenological models



Apple phenology dates simulated for the 2023-2024 period in Bonn, according to the parameters estimated in Legave and al. - 2013



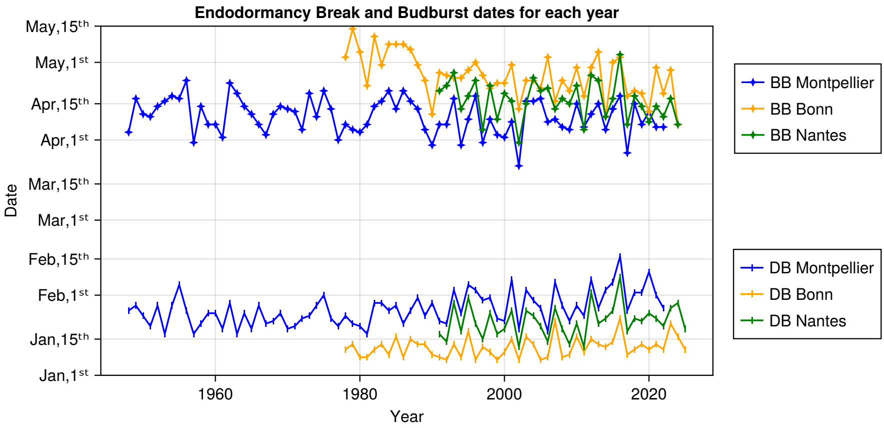
Chilling period onset : 1st of August

Chilling quantity required C_c : 119.0 (chilling units)

Heating quantity required G_{hc} : 13236°C

Q_{10c} : 2.17

T_{0Bc} : 8.19°C

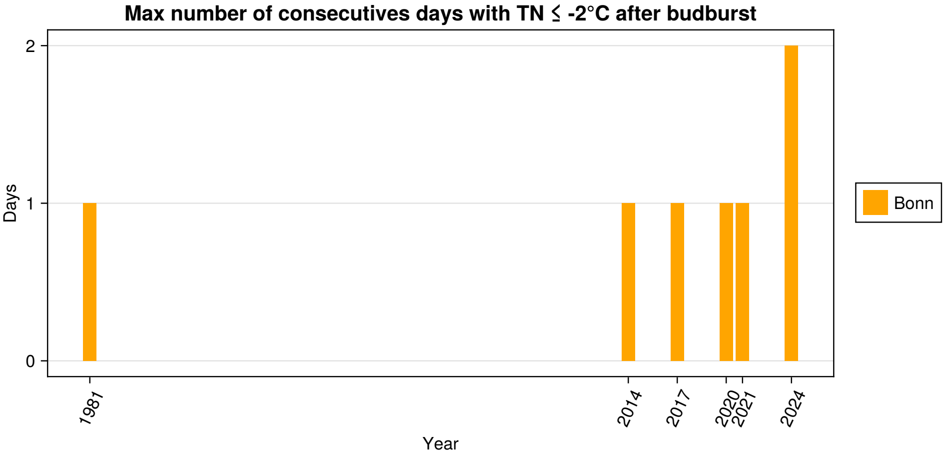


CPO : 30th of October
Chilling quantity required C : 56.0 (chilling units)
Heating quantity required H : 83.58 (forcing units)

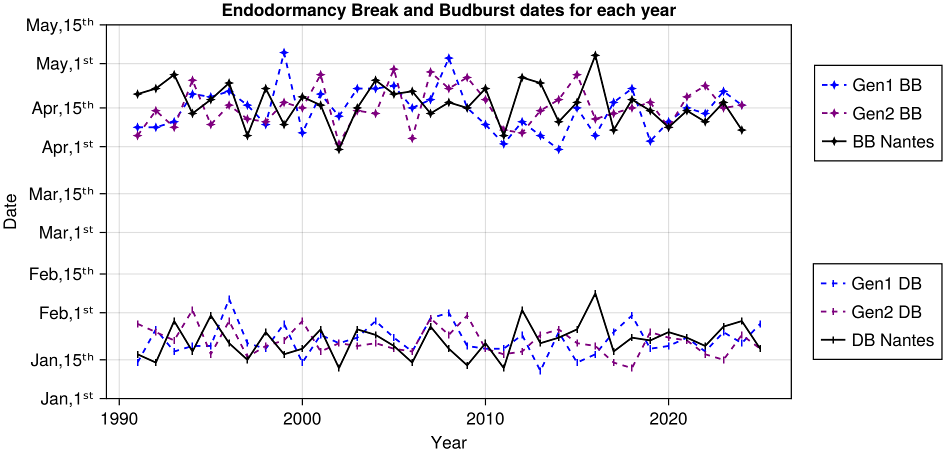
Chilling function F_c : Triangular
T_c : 1.1°C
I_c : 20.°C

Forcing function F_h : Exponential
T_h : 9.0°C

Too early budbirsts make the plant vulnerable to a risk of freezing :



With simulated TG (Apple)



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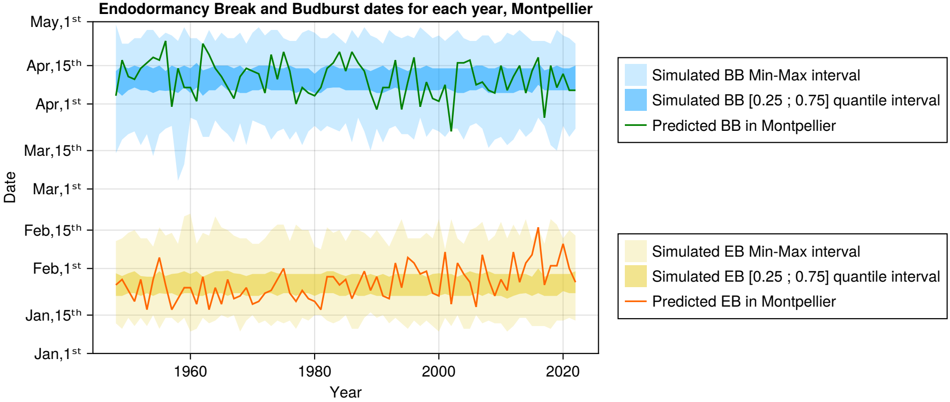

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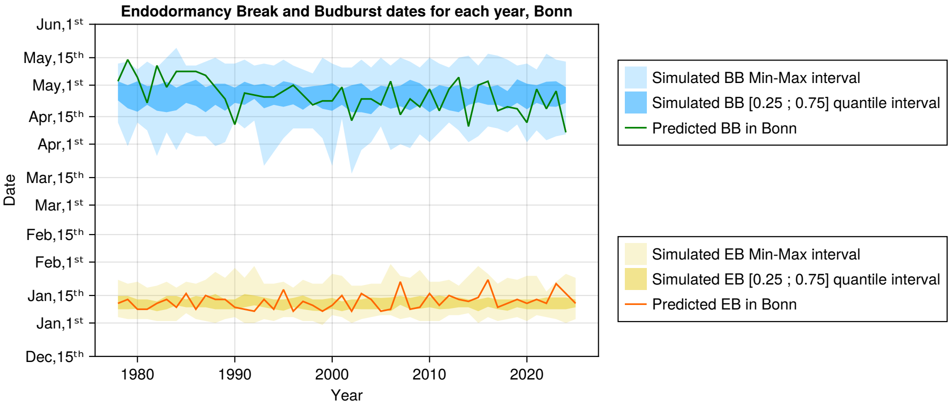
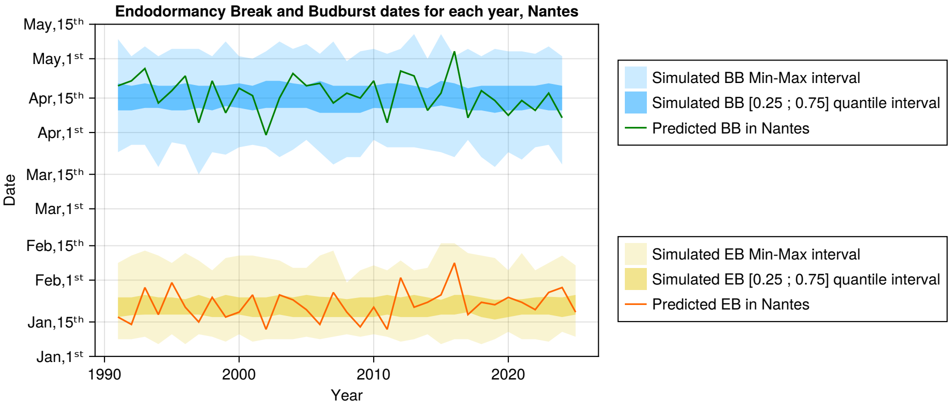


With simulated TG (Apple)



Conclusion

- We have studied and implemented a model that is able to generate temperature series but with a too simple modeling of the trend.
- We have implemented phenological models and applied them on stations from different climates in France, and we noticed that there is an evolution across the years since ≈ 1980.
- Finally, we have applied phenological on simulated series, and the results show that it is required to consider a better model for the trend if we want more realistic temperature series.

Thanks you !