A STOCHASTIC WEATHER GENERATOR FOR TEMPERATURE

Examples of use and future developments

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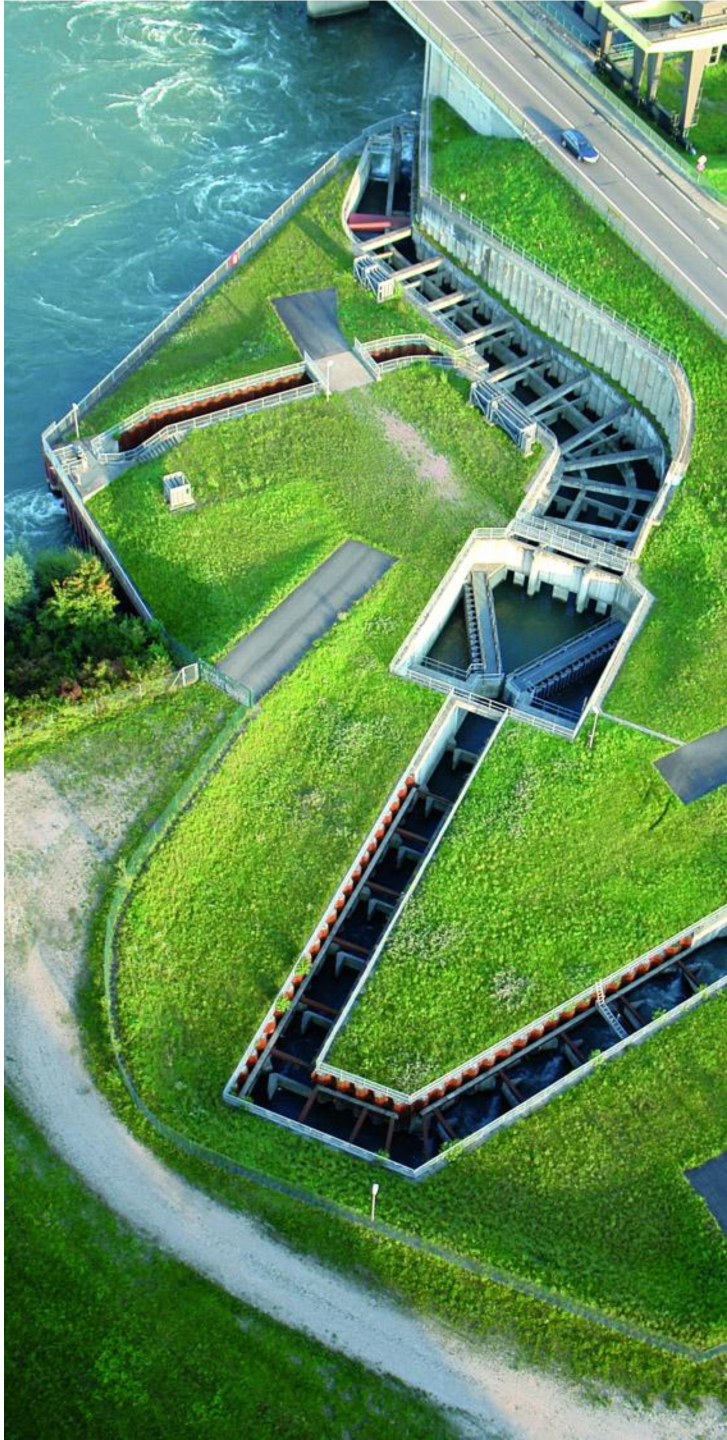
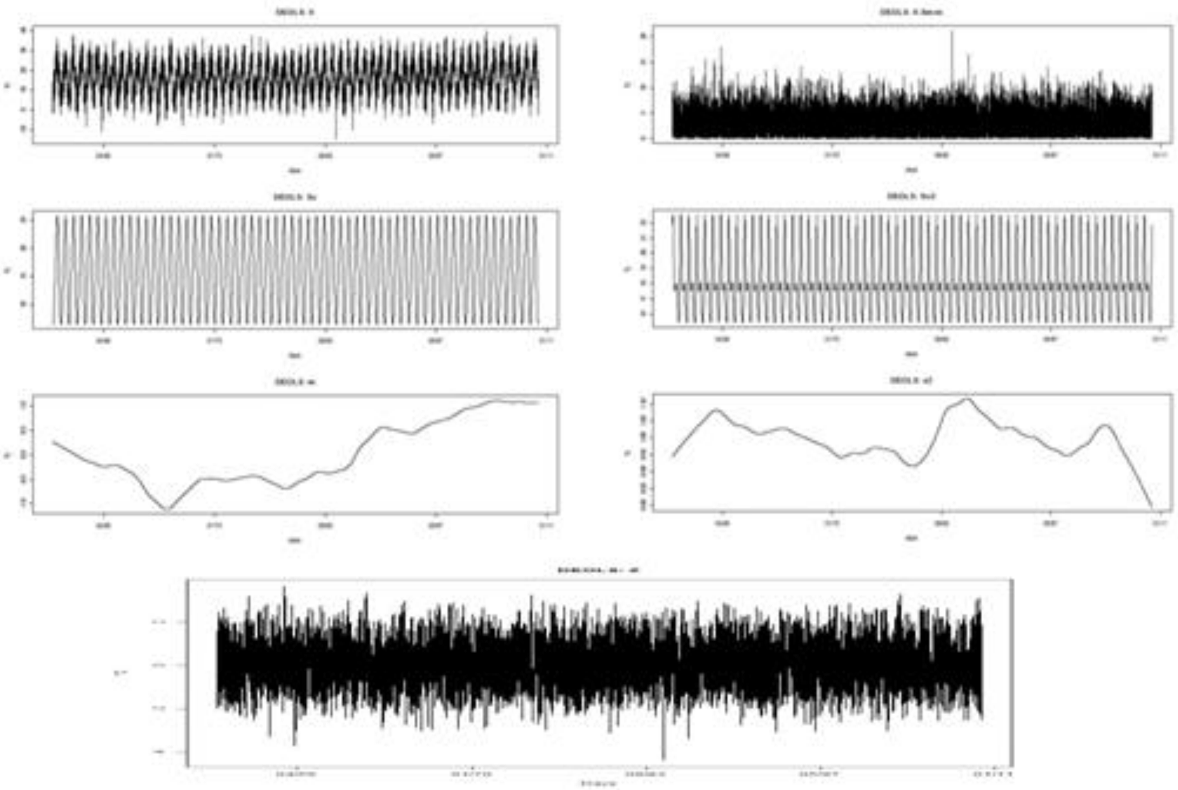


Context

- Collaboration with the mathematics laboratory of Paris 11 Orsay University
- Temperature extremes and non stationarity
- Methodological developments
- Considerations for the development of a stochastic generator
  - Able to simulate extreme values
  - Allowing a (quick) simulation of a large number of equivalent time series

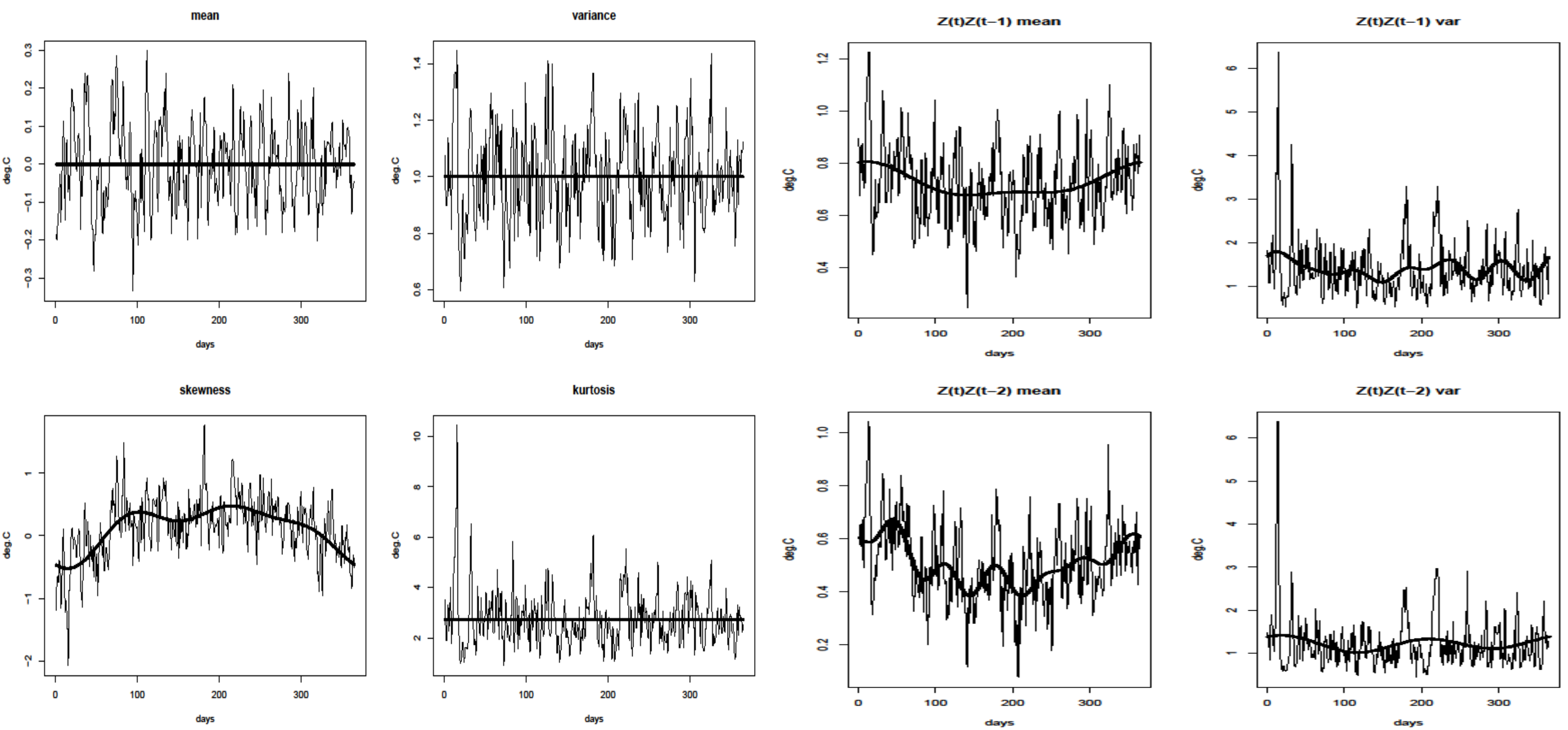
Model principle

- Simulation of Z(t)



$$Z(t) = \frac{X(t) - S_m(t) - m(t)}{S_v(t)s(t)}$$

Characteristics of Z



Remaining seasonalities; no more trends

The SFHAR(seasonal functional heteroscedastic autoregressive) model

- Extension: SFHAR model

$$Z(t) = \left[\theta_{0,k} + \sum_{j=1}^{p_1} \left(\theta_{1,k}^{j} \cos \frac{2j\pi t}{365} + \theta_{2,k}^{j} \sin \frac{2j\pi t}{365} \right) \right] Z(t-1) + a(t, Z_{t-1}) \varepsilon'_t$$

- $a^2(t, Z_{t-1})$
  - Seasonal, depend on the state
  - Zero out of the boundaries
  - positive
  - constraints *C* on the first derivative from the continuous-time diffusion process (see thesis of Hoang, 2010):

$$\left(a^2\right)'(r_1) = \frac{2b(r_1, t)}{1 - 1/\xi_1} \quad et \quad \left(a^2\right)'(r_2) = \frac{2b(r_2, t)}{1 - 1/\xi_2}$$

  - Form of *a*:

$$\begin{cases} \hat{a}^2(t, Z_{t-1}) = (\hat{r}_2 - t)(t - \hat{r}_1) \sum_{k=0}^{5} \sum_{j=1}^{p_2} \left(\alpha_{1,k}^{j} \cos \frac{2j\pi t}{365} + \alpha_{2,k}^{j} \cos \frac{2j\pi t}{365} \right) Z_{t-1}^{k} \\ C(\hat{r}_1, t), C(\hat{r}_2, t) \\ \hat{a}^2(t) > 0 \ \forall t \end{cases}$$

References

- Dacunha-Castelle D., Hoang T.T.H., Parey S.: Modeling of air temperatures: preprocessing and trends, reduced stationary process, extremes, simulation, Journal de la Société Française de Statistique, 2013

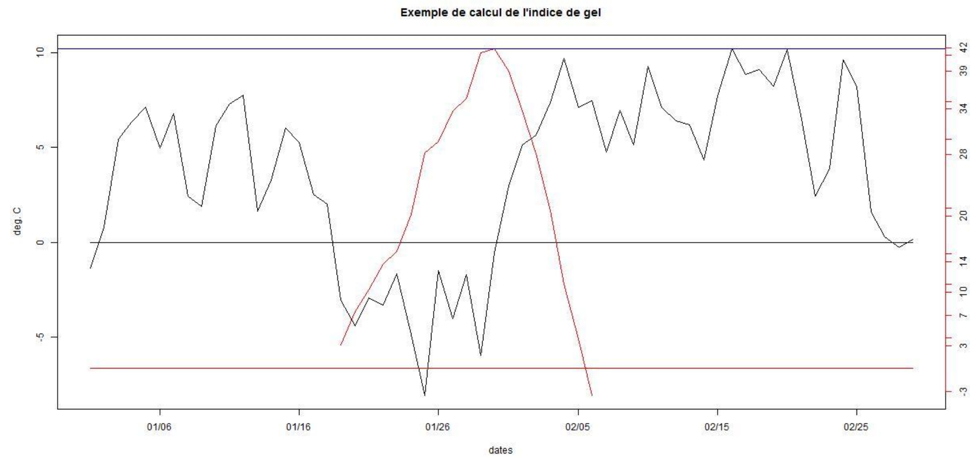
- Parey S., Hoang T.T.H., Dacunha-Castelle D. (2014): Validation of a stochastic temperature generator focusing on extremes and an example of use for climate change, Climate Research, Vol 59, 61-75, doi: 10.3354/cr01201

Examples of use

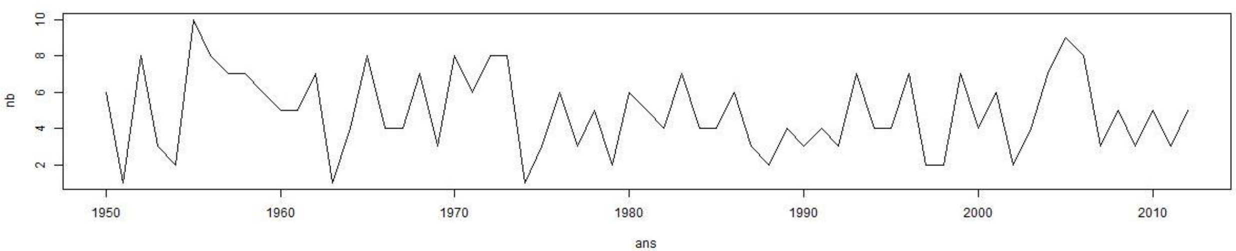
Return levels of frost indices

Frost index

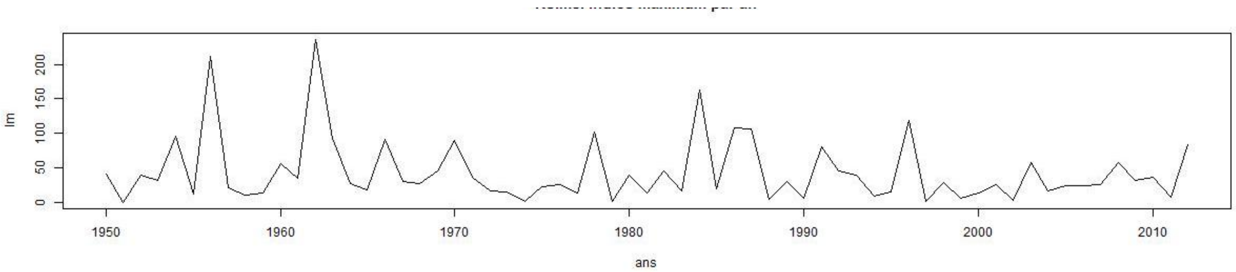
- Sum of negative daily mean temperatures
- Computation:
  - t_0 1^{st} time $T(t_0)<0°C$
  - $N(t_0)=\min\{t>t_0, T(t_0)+T(t_0+1)+ \dots +T(t)>0\}$
  - $Ig(t_0)=\max\{t_0<k<N(t_0), -(T(t_0)+T(t_0+1)+ \dots +T(k))\}$



Nb of events per year

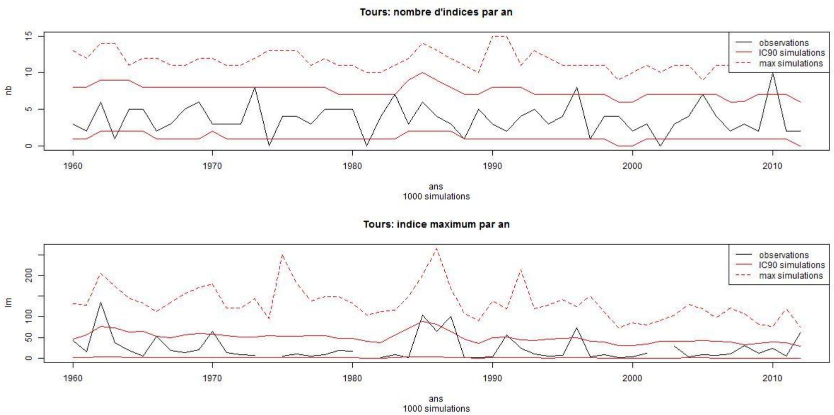


Yearly maximum index



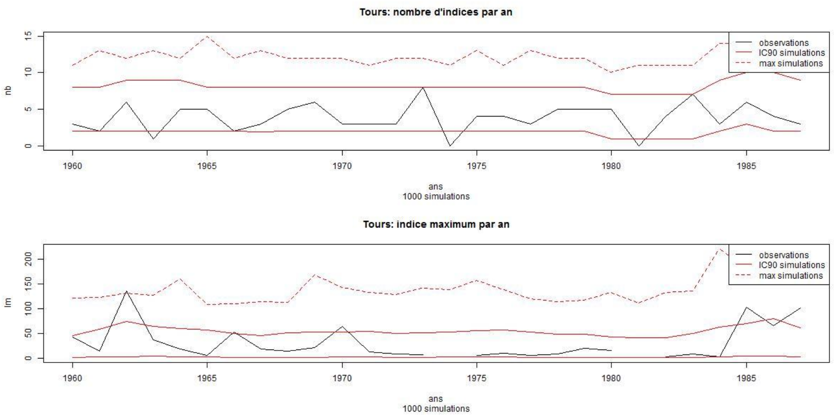
Use of the generator

Tours 1960-2012: 0°C ≅ q3.8%



7 indices > q95 (5% 53 years => 2,65)

Tours 1960-1987: 0°C≅ q4.4%



3 indices > q95 (5% 28 years => 1,4)

The generator tends to under-estimate the frequency of long events when the threshold lies in the far tail of the T distribution

Examples of use

Future cold waves

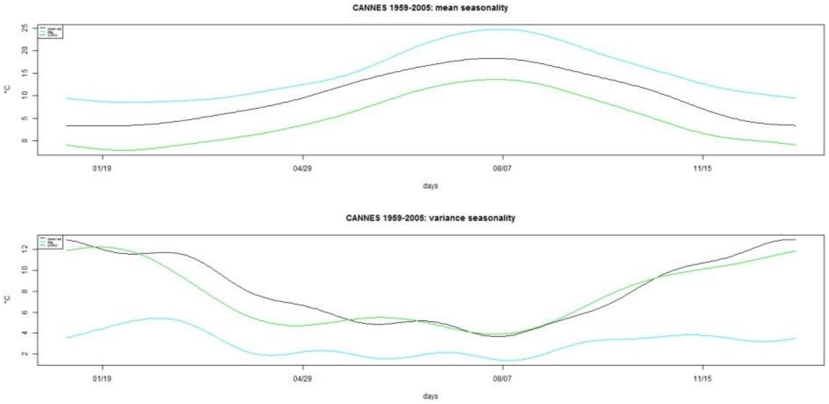
Cold waves

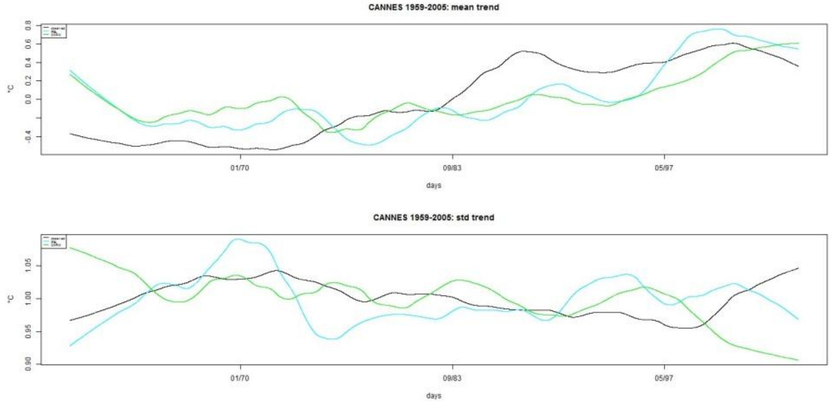
- 22 temperature time series in France
- 3 ≠ thresholds: 0°C, q10%, q5%
- Frequency of events of ≠ lengths (from 1 day to > 15 days)
- 2 climate models (IPSL-CM5-MR and CNRM-CM5)
- 2 future periods (2060; 2100); 2 RCPs (4.5, 8.5)

Use of the stochastic model

- 100 simulations of Z(t) based on observations
- Climate model:
  - Present: X(t) with observed seasonalities and model trends
  - Future: Smf = Smo + (Smm2 – Smm1)

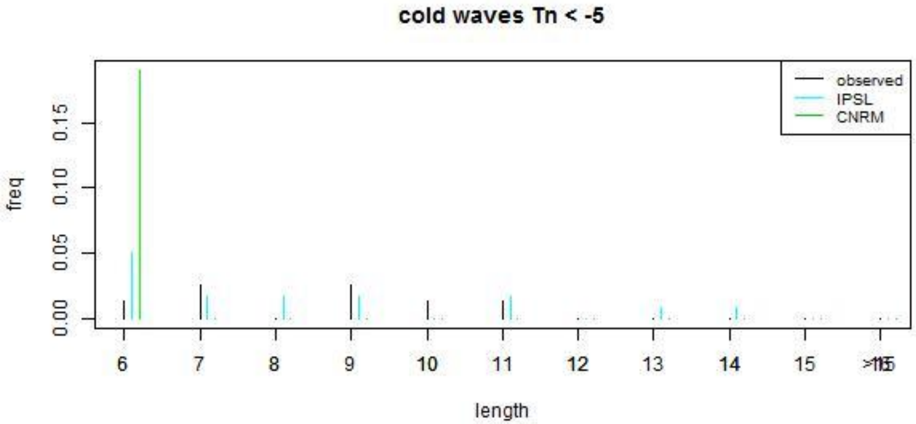
    Svf = Svo*Svm2/Svm1

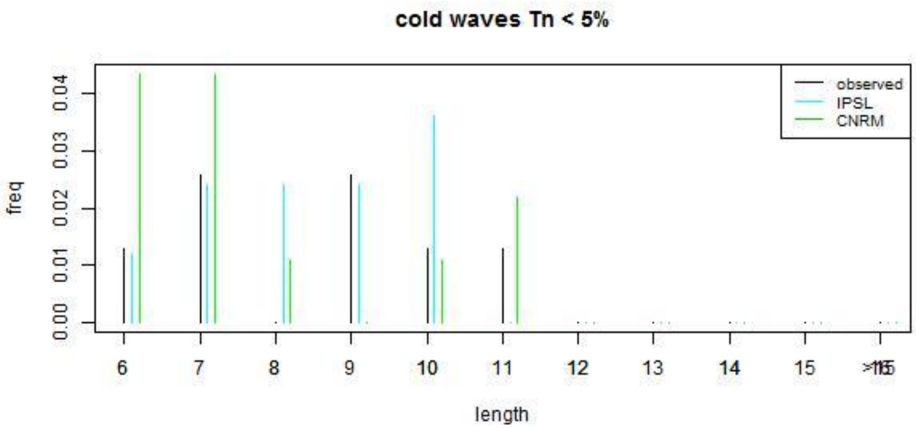


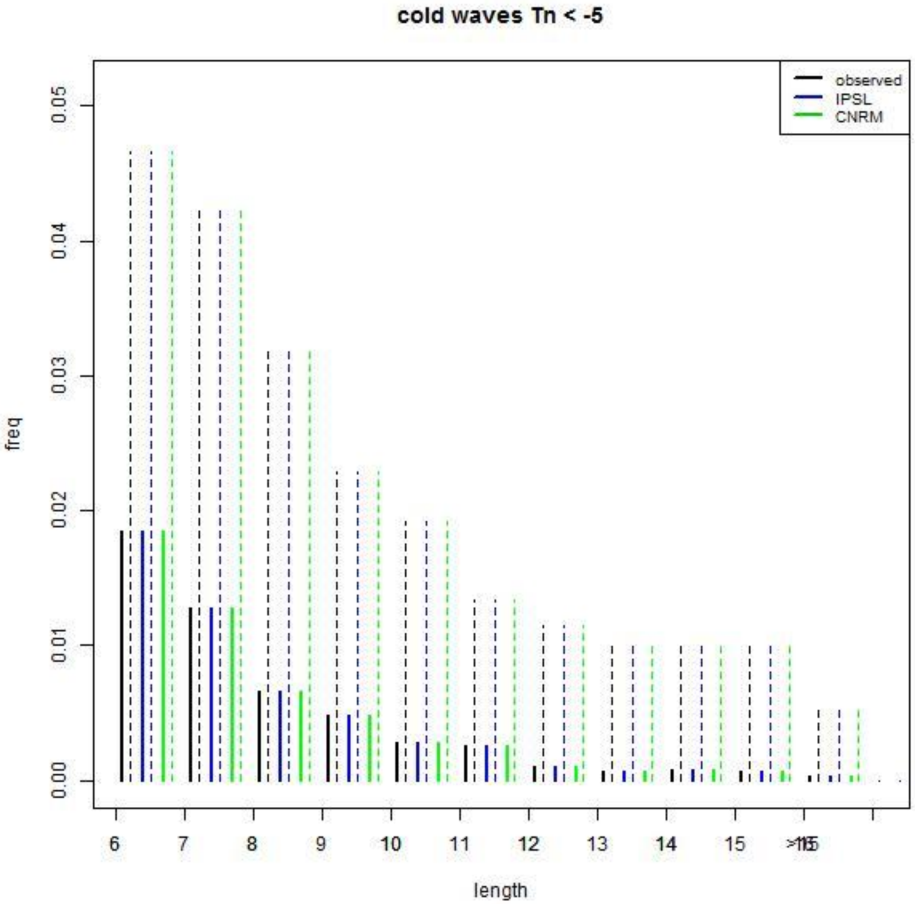


Generator’s advantage

Example: Boulogne sur mer; Threshold = q5%







Ability to produce long events, even for extreme thresholds
gives confidence intervals

Significant changes in frequency

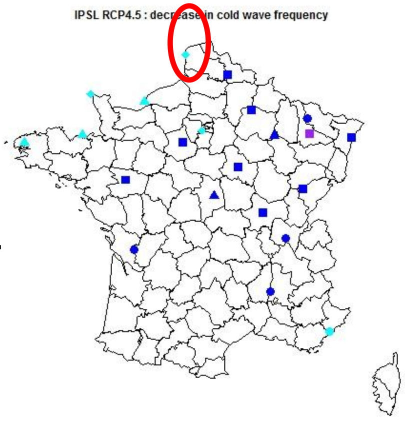
Period 2: 2100   RCP 4.5

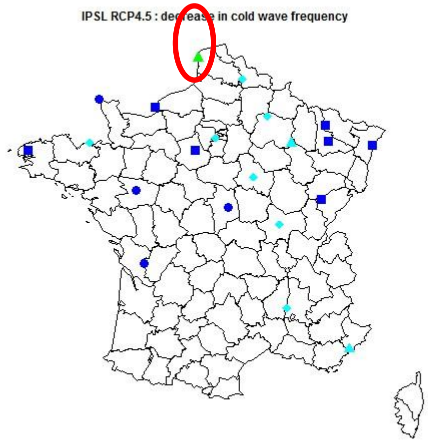
Climate model, threshold present

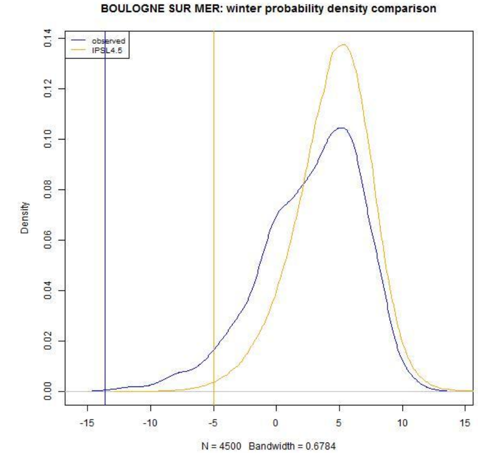
Observations with threshold shift

Importance of variance change

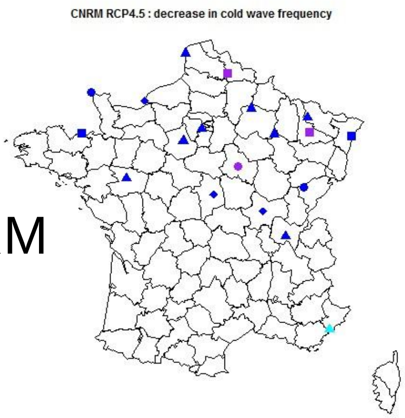
IPSL

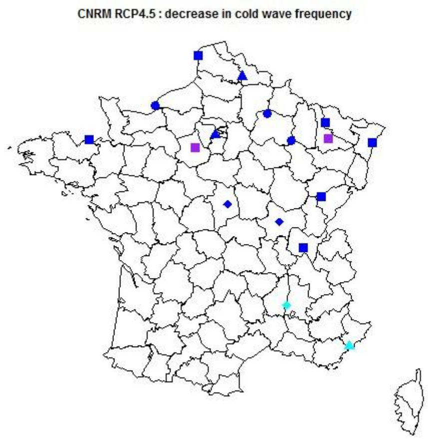


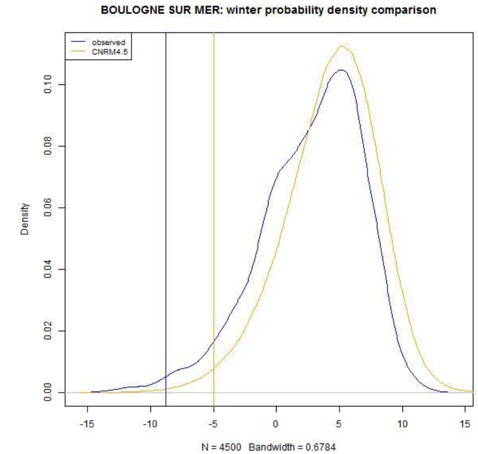




CNRM







■ 1d ● 2d ▲ 3d ◆ 4d ■ 5d ● 6d ▲ 7d ◆ 8d ■ 9d ● 10d ▲ 11d ◆ 12d ■ 13d ● 14d ▲ 15d ◆ >15d

Conclusion and perspectives

- Generator => reliable representation of distribution of temperature time-series, even the tails and heat or cold wave frequencies
- Weakness: use of EVT to estimate the shape parameters and the bounds
- Identified limitation: long events when the threshold lies in the far tail
- Works in progress:
  - Improvement of estimation of the shape parameter ξ with different non parametric estimators (Hill and his extensions)
  - Improvement of the quality of extremes by carefully analyzing correlation over high (and below low) percentiles
  - Direct estimation of the bounds not using the estimation of extreme parameters

THANKS!