Bias correction with harmonic functions – Exploiting the smoothness in time

M. Fischer, H.W. Rust, U. Ulbrich
Institute of Meteorology, FU Berlin

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Freie Universität Berlin

1. Introduction

Systematic shifts between climate model simulations and observed data typically hamper their direct use for impact studies: a post-processing in form of a bias correction is needed. Typically, the difference in monthly means are added to the simulations. Here, we suggest using harmonic functions to get a smooth seasonal cycle and to adjust each day in the year individually.

2. Observation data

Research Site	Data	variables
Bergen	WFDEI*	all
Veluwe	WFDEI*	all
Wupper	WFDEI*	all
Badalona	WFDEI*	all
Tagus River	WFDEI*	all
	Stations	$T_1, T_2, T_{mean}, RR, v$

*WFDEI: WATCH forcing data ERA-Interim [1], [2] interpolated to simulation's grid

3. Implementation

This bias correction approach is currently implemented in the *DECO* plugin of *FREVA* evaluation system (https://freva.met.fu-berlin.de/) based on the R package *VGAM* [3].

7. Conclusion

We use harmonic functions to obtain a smooth seasonal cycle of simulation and observed data instead of adjusting with the climatological mean of each month. This implies:

- **individual bias correction** for each day → no artifical jumps at the end of a month
- consistent approach for **several parameters** using different distributions
- **physical consistencies**: no negative values for positive parameters, $T_{min} < T_{max}$

8. Outlook

- **correcting variance** of each distribution (VGLM)
- **cross-validated model selection** for more robustness for future datasets

References

[1] Weedon et al.,2014: *The WFDEI meteorological forcing data set: Watch forcing data methodology applied to ERA-Interim reanalysis data*, Water Resour. Res., 50(9):7505-7514

[2] Rust et al., 2015: *Discontinuous Daily Temperatures in the WATCH Forcing Datasets.* J. Hydrometeo 16.1: 465-472.

[3] Yee,2015: *Vector Generalized Linear and Additive Models: With an Implementation in R.*, Springer Series in Statistics

[4] P. McCullagh and J. Nelder, 1989: *Generalized Linear Models*, CRC Press, Boca Raton, Fla, 2 edition

[5] M. B. Priestley,1992: *Spectral Analysis and Time Series*, Academic Press, London

[6] Wilks,2011: *Statistical Methods in Atmospheric Sciences*, Vol. 100, Academic press

4. Distributional assumptions

variable	long name	distribution
T_1	$T_{max} - T_{min}$	log-Gaussian
T_2	$T_{max} + T_{min}$	Gaussian
T_{mean}	mean surface temperature	Gaussian
v	near-surface wind speed	log-Gaussian
P	surface air pressure	Gaussian
LW_{down}	longwave incoming radiation	log-Gaussian
SW_{down}	shortwave incoming radiation	log-Gaussian
Q_{air}	near-surface specific humidity	log-Gaussian
RR	precipitation amount for rainy days	Gamma

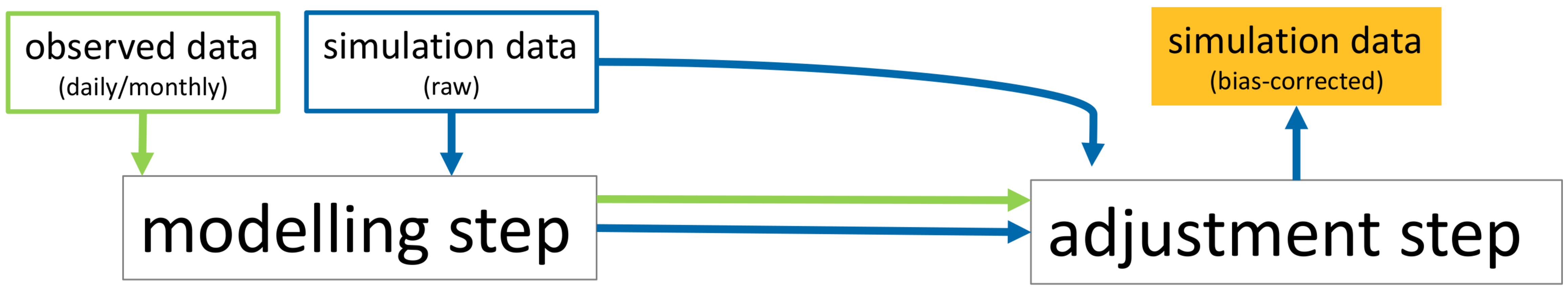
min/max temperature

- transformation to ensure $T_{min} < T_{max}$

$$T_1 = T_{max} - T_{min}$$
$$T_2 = T_{max} + T_{min}$$

- back-transforming after bias-correction of T_1 and T_2
- postive parameters: all except T_2 and T_{mean}

5. Modelling approach

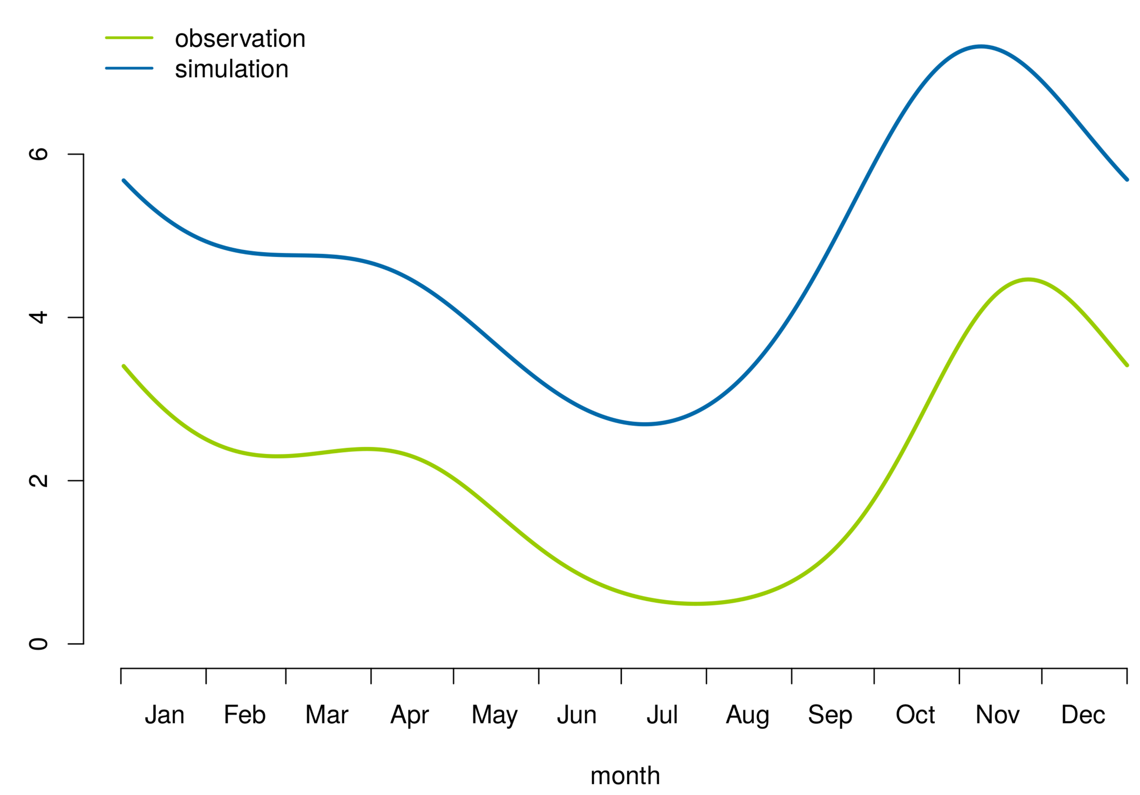


- using generalized linear models [4]
- seasonal cycle: smooth function over days of the year [5] for expected value

$$\mu_t = \mu_0 + \sum_{k=1}^{K} (\mu_{ks} \sin(k\omega t) + \mu_{kc} \cos(k\omega t))$$

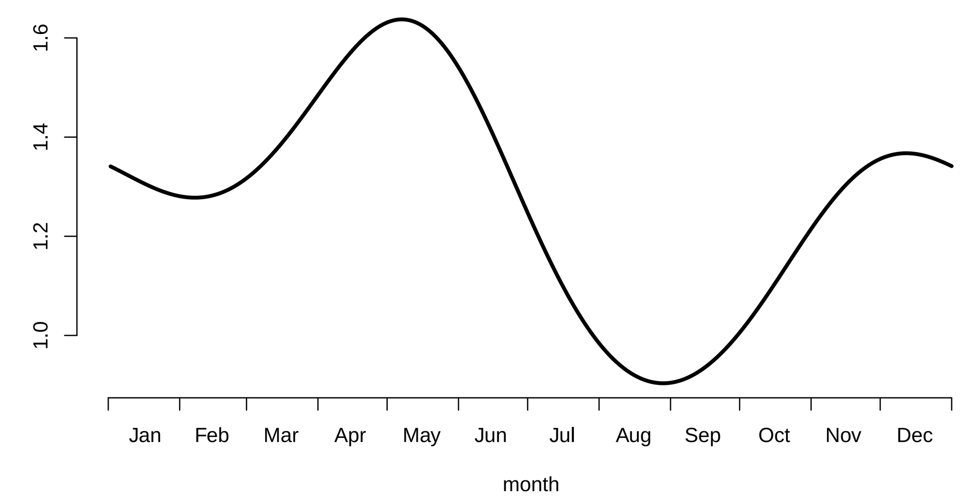
with $\omega = 2\pi/365.25$, t as the day of the year (0,...,365) and order of harmonic function K (monthly data: t the center day of each month)
- selection of K (only for observed data): BIC [6]

→ **output**: seasonal cycles for expectation



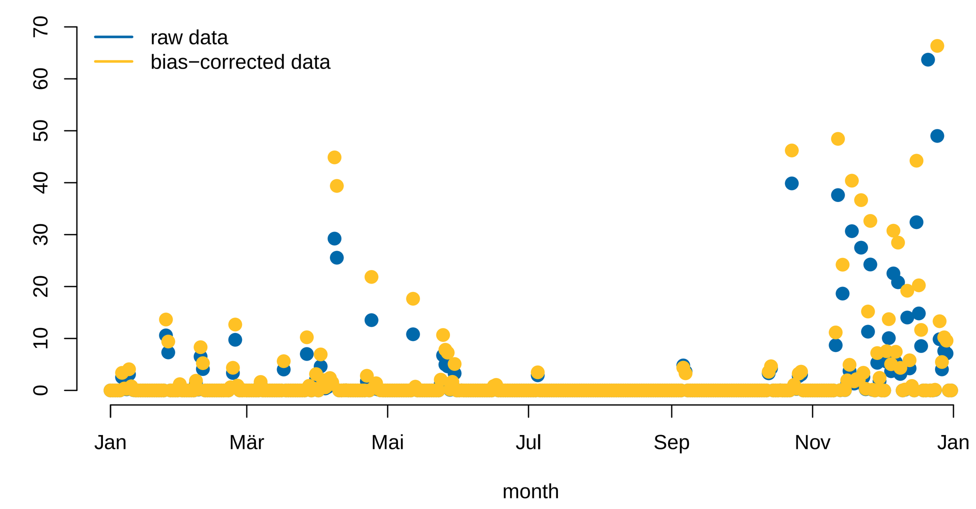
- **Difference between seasonal cycles** of observation $\bar{o}$ and simulation $\bar{s}$

$$\Delta(t) = \begin{cases} \bar{o}(t) - \bar{s}(t) & \text{for Gaussian} \\ \frac{\bar{o}(t)}{\bar{s}(t)} & \text{for others} \end{cases}$$



- **Obtain bias-corrected values**

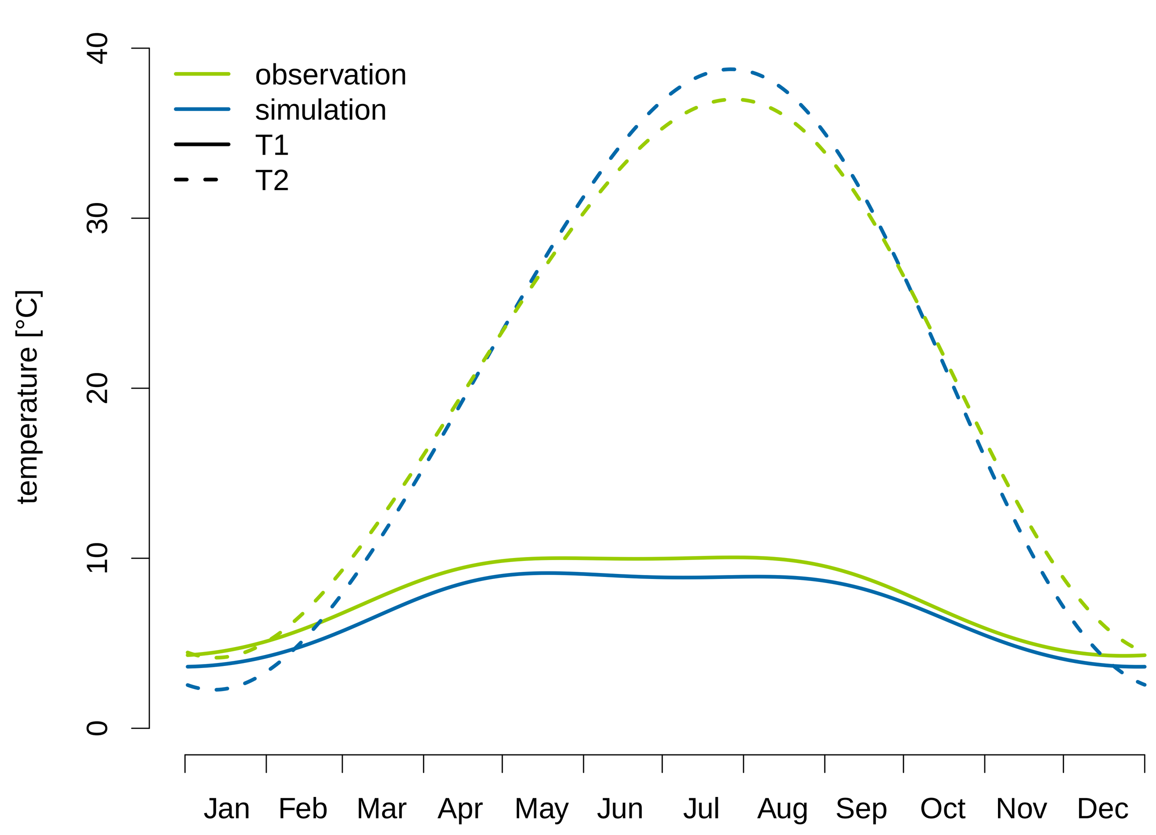
$$x_{\text{corr}} = \begin{cases} x(t) + \Delta(t) & \text{for Gaussian} \\ x(t) \cdot \Delta(t) & \text{for others} \end{cases}$$



6. Example: Bias Correction for T_{max} and T_{min}

→ analyses for one grid point at Wupper research site

seasonal cycles



simulation
(raw - bias-corrected)