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Statistical detection and modeling of the over-dispersion of winter storm occurrence

M. Raschke

Correspondence to: M. Raschke (mathiasraschke@t-online.de)

a. Thinning and over-dispersion

The survival probability that a storm event of a sample with given return period CRP_{old} is also member of the sample with CRP_{new}, being CRP_{old}>CRP_{new}, is $P_{survival}$=CRP_{old}/CRP_{new}. Following to Ross (2007, Example 3.16 and 3.18), the expectation and variance of the new count variable X_{new} is

$$E(X_{new}) = E\left(\sum_{i=1}^{X_{old}} I_{new,i}\right) = E(X_{old})E(I_{new}) \text{ and} \tag{A1}$$

$$V(X_{new}) = V\left(\sum_{i=1}^{X_{old}} I_{new,i}\right) = E(X_{old})V(I_{new}) + V(X_{old})E(I_{new})^2 . \tag{A2}$$

The binary random variable $I_{new,i}$ describes whether the storm event i is member of the new return level with $I_{new,i}$=1 or if it is thinned out with $I_{new,1}$ =0. We can also declare I_{old} for the old sample, but there is only one kind of realization with I_{old}=1 being considered here. Figure A1 illustrates the thinning out.

The random variable I_{new} is Bernoulli distributed with expectation $E(I)$ and variance $V(I)$

$$E(I) = P_{survival} \text{ and} \tag{A3}$$

$$V(I) = P_{survival}(1 - P_{survival}) . \tag{A4}$$

Now I introduce the relation

$$V(X_{old}) = E(X_{old}) + \beta E(X_{old})^2 \tag{A5}$$

Where the over-dispersion parameter β>0, which is determined by variance and expectation of count variable X_{old}. Eq. (A2) is modified for the new count variable with Eq. (A3,A4) to

$$V(X_{new}) = E(X_{old})P_{survival}(1 - P_{survival}) + E(X_{old})P^2{}_{survival} . \tag{A6}$$

This equation can be simplified as follows:

$$V(X_{new}) = E(X_{old})P_{survival} + \beta E(X_{old})^2 P^2{}_{survival}\,, \tag{A7}$$

wherein $E(X_{old})P_{survival}$ is replaced by $E(X_{new})$ according to Eq.(1,3) and we get

$$V(X_{new}) = E(X_{new}) + \beta E(X_{new})^2\,. \tag{A8}$$

The resulting Eq.(A8) is basically equal to Eq.(A5). Therefore, Eq. (A5) is universal and applies to X_{old} and X_{new}. This is not a totally new inference, as it was already derived for other purposes (e.g., Mack 2002). I want to stress the fact that these results apply if the storm events are independent from each other and occur in time according to an inhomogeneous Poisson process. Eq.(A5,A8) can be proven by simple Monte Carlo simulations (not shown).

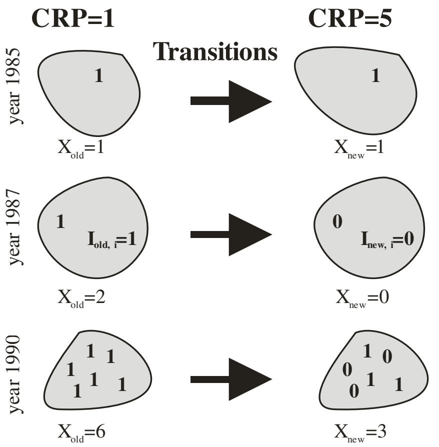

Figure A1: Transition of the count variable *X* of number of storms per season and the corresponding binary variable *I*. The examples are for observations of the DWD samples (Karremann 2014, Fig. 3).

b. The storm samples

Table B1: Analysed samples; the data DWD, NCEP and ERAI of historic storms are from Karremeann et al. (2014; Fig. 2 and supplementary Tab. B1)

Sample type		DWD			NCEP			ERAI			GMC corr		
Considered return period (CRP) [a]		1	2	5	1	2	5	1	2	5	1	2	5
Number *X* of storm events per season	0	14	21	26	12	19	26	12	18	25	1734	2593	3378
	1	8	6	3	9	8	3	10	10	4	1258	1065	621
	2	6	2	0	7	2	0	6	1	1	666	341	84
	3	0	0	1	1	1	1	0	1	0	286	78	8
	4	1	0	0	1	0	0	2	0	0	108	10	0
	5	0	1	0	0	0	0	0	0	0	30	5	1
	6	1	0	0	0	0	0	0	0	0	8	0	0
	7	0	0	0	0	0	0	0	0	0	2	0	0

References see brief communication.