Answer to comment of referee #1

Compound extremes in a changing climate - a Markov Chain approach

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Dear referee,

Thank you for your detailed review of the paper. In the following, you can find our answers to your comments which are written in red text color.

1 Specific comments

Section 3 discussion of results (approx L250 on), it would be good to see some comparison with other research on the persistence of extremes in different regions and possible causes. e.g. Sillmann & Croci-Maspoli 2009, Furrer et al 2010, Photiadou et al 2014. Furrer, E.M., R.W. Katz, M.D. Walter, and R. Furrer, 2010: "Statistical modeling of hot spells and heat waves." Climate Research, 43, 191-205 Photiadou, C., Jones, M., Keellings, D., Dewes, C., 2014. Modeling European hot spells using extreme value analysis. Clim. Res. 58, 193–207. doi:10.3354/cr01191 Sillmann, J., Croci-Maspoli, M., 2009. Present and future atmospheric blocking and its impact on European mean and extreme climate. Geophys. Res. Lett. 36, L10702. doi:10.1029/2009GL038259

This is a good point and we will include a more thourough comparison with other research on the persistence of extremes in the discussion section of the revised version.

Similarly a sentence or two comparing the reliability of different models and observations would be good - e.g. CFSR and ERA-40 can be very different. This could be in the data section.

Thank you for this comment, we will include this in the data section (Section 2.1. in the original manuscript). An additional interesting application of the method is also to detect differences in observational datasets and models concerning the dynamical behavior of extreme events.

Did you test the significance of the changes in the reference period as well as the future? How did you account for uncertainty in the results?

Regarding the **uncertainty**, we took advantage of the applied ensemble approach. In Fig. 2 (of the original manuscript) we show the results of the ensemble for the reference period, where we use a box plot for the ensemble: box = ensemble median and interquartile range, whiskers = ensemble minimum/maximum, gray bars: ensemble mean. This information is given in the text caption, to make it clear, we will include it in the text under Sect. 4 (of the original manuscript).

Similar box plots accounting for the ensemble uncertainty have been used in Figs. 3, 8, 9 (where for the change signal, the changes were calculated for each ensemble member individually and then displayed in the same manner). As can also be seen from the figures we did not account for the uncertainties in the observational E-OBS dataset and consider the observations approximately as the truth. Nevertheless we will include an additional section in the revised version where we calculated the error of the descriptors by a FT-resampling algorithm. For this we used the MIAAFT algorithm (Venema et al., 2006) which in addition to preserving the original distribution of the data also preserves the auto and cross-correlation of the temperature and precipitation time series. 100 surrogate data sets for the 6 regions used throughout the paper were calculated for the E-Obs data set in the reference period (1971-2000) and their standard deviation taken as the error (by using the exact same regions the values are transferable to later chapter which would not be possible had we chosen a different number of data points). An overview of the errors can be seen in Tab. 1. In comparison to differences between regions and time periods, the error is small but we will include it in the discussions of Sect. 3 and 4. Regarding the **significance** we use the ensemble uncertainty, as mentioned above, and show in Sect. 4.2 that we use the nonparametric Mann-Whitney-Wilcoxon test for the change signal (Figs. 8, 9). The p-values are shown below the bars in the respective figures.

	DJF			JJA		
	P	R	E	P	R	E
reg1	0.010	1.701	0.004	0.007	1.183	0.009
reg2	0.011	2.182	0.010	0.010	2.055	0.010
reg3	0.010	2.563	0.005	0.009	0.923	0.007
reg4	0.008	1.150	0.005	0.008	0.990	0.011
reg5	0.010	2.45	0.010	0.008	1.103	0.009
reg6	0.007	0.797	0.004	0.009	1.150	0.009

Table 1: Estimation of the error of the descriptors by using MIAAFT surrogates for winter (DJF) and summer(JJA) extremes. Values are calculated for the 6 regions of Fig. 1.

L338 note about relative extremes - This should really be mentioned in the method section along with how you selected the extremes (e.g. thresholds, and at which level). Possibly a table of extremes would be informative for comparison?

We mentioned the thresholds in a later section of the text:

- cold and wet in winter (DJF): temperature anomaly (Ta) < 10th percentile and precipitation anomaly (Pa) > 75th percentile)
- heat and drought in summer (JJA): Ta >95th percentile and EDI < 25th percentile

but it is a good idea and we will include the thresholds in the methods section.

2 Technical corrections

L3 "the number of occurrences" L9 types L11 replace "which are" with "including" L12 rogue comma before fullstop. L26 occurrences L36 changes in the number of L46 should this be chaotic attractor? L107 please put into present tense to match the rest of the text. L115 ditto L145 unnecessary comma at start of line. L180 "number of states" L189 and 192 "Thus in the sense of successive compound ..." L216 should this be per 100 days? L245 maybe say very rare? There are a lot of extremes in that sentence. L273 highest persistence is Figure 9 caption rogue fullstop before Percentages.

thank you for the correction of our english. In L216 1000days is correct because this number refers to the total number of days, not only the compound extreme states.

References

Venema, V., Meyer, S., García, S. G., Kniffka, A., Simmer, C., Crewell, S., Löhnert, U., Trautmann, T., and Macke, A.: Surrogate cloud fields generated with the iterative amplitude adapted Fourier transform algorithm, Tellus A, 58, 104–120, 2006.