CLIMATE CHANGE AND VIOLENT CONFLICT IN EUROPE OVER THE LAST MILLENNIUM

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Abstract

We investigate the relationship between a thousand-year history of violent conflict in Europe and various reconstructions of temperature and precipitation. We find that conflict was more intense during colder periods. This relationship is weakening over time, and is not robust to the details of the climate reconstruction or to the sample period. We thus confirm Zhang et al. (2006, Climatic Change, 76, 459-477) that, at least in temperate climates, global warming would, if anything, lead to reduced violent conflict.

Key words

History, violent conflict, Europe

1. Introduction

In the gloomier scenarios of climate change, violent conflict plays a key part. War would break out over declining water resources, and millions of refugees would cause mayhem. The Nobel Peace Prize of 2007 was partly awarded to the IPCC and Al Gore for their contribution to slow climate change and thus prevent war. Scenarios of climate-change-induced violence can be painted with abandon, because there is in fact very little research to either support or refute such claims. The broader literature on violent conflict and environmental scarcity suggests that climate change would at most be a contributing factor to violent conflict, but no attempts have been made to quantify these insights and apply it to climate change. Zhang *et al.* (2006) broke new ground. They construct a dataset of climate and violent conflict for China for the last millennium, and show that the Chinese are more inclined to fight each other when it is cold. They link this to reduced agricultural productivity. Here, we replicate their research for Europe, for which similar data are available.

Research into the determinants of violent conflict has concluded that resource scarcity is at best a contributing factor to, but never a cause of war (Alesina and Spolaore, 2005; Collier and Hoeffler, 1998, 2005; Homer-Dixon, 1991, 1992; Homer-Dixon *et al.*, 1993; Maxwell and Reuveny, 2000). The corollary is that climate-change-induced resource scarcity would not lead to war either, although it may intensify pre-existing conflicts.

Clearly, an intensification of conflict would be something to worry about. Butkiewicz and Hanakkaya (2005) find that political instability (i.e., the chance of war) reduces per capita economic growth in the poorest countries by 2% per year – although actual war has no significant effect in their model. Conflict may thus be a big factor in the economic impacts of climate change (cf. Tol *et al.*, 2000), but, as said, it is not clear whether climate change would lead to conflict. Barnett (2006) argues that conflict directly increases vulnerability – conflict also indirectly increases vulnerability through its adverse impact on development (Yohe and Tol, 2002).

Despite the conclusions of studies quoted above, it is possible to imagine a scenario in which climate change does cause violent conflict. One example may be prolonged drought, perhaps in the Horn of Africa (Held *et al.*, 2006), followed by mass migration. The impact on conflict is speculative. Firstly, migration is the result from a complex of push and pull factors, not from a single push factor (McGregor, 1994; McLeman and Smit, 2006). Secondly, drought is only a real problem for the poor; a scenario like this would happen only if warming and drying outpace development. If not, food imports (Reilly and Schimmelpfennig, 1999) or desalination (Zhou and Tol, 2005) may be the preferred options. Thirdly, drought is a slow-onset disaster. It may exhaust people before they move. Poor and exhausted people are unlikely to take up arms, and if they do, they are probably not very effective. The human suffering would be substantial nonetheless.

A potentially more serious example is rapid sea level rise in the major deltas of Asia and Africa. Coastal plains are often fertile and hence densely populated (Nicholls and Small, 2002). Without coastal protection, inundation, erosion and saltwater intrusion would drive many people to higher grounds (Nicholls and Tol, 2006). They may resettle peacefully, or start quarrelling with their new neighbours. One can speculate about the consequences of large-scale migrations today. In West Africa, for instance, the situation is already so tense that additional refugees are unlikely to do any good – note that the coasts of Cameroon, Gabon and Nigeria are particularly vulnerable to sea level rise. Similarly, forced migration of large numbers of Bengali from the coastal plain to the hills of northern Indian and Bangladesh would not be without problems either, and may even escalate to nuclear war. However, these impacts will not be on today’s world. Sixty-seven years ago, Western Europe was at war. In 2075, South Asia and West Africa may be stable and prosperous.

The study by Zhang *et al.* (2006) is the only one to look explicitly at the relationship between climate change and violent conflict. They conclude that conflict was more prevalent during cold periods of Chinese history, and speculate that food scarcity is the reason. We here repeat their analysis for Europe.

Section 2 presents the data, followed by descriptive statistics in Section 3. Section 4 discusses the results of regression analysis. Section 5 concludes.

2. Data

Although the historical literature on violent conflict in Europe is large, surveys that cover extended periods and provided quantified data are scarce. Our source is http://www.warscholar.com/. This has data on the number of conflicts only. The selection criterion is whether a conflict is significant enough to be noted by historians. This undoubtedly led to an under representation of earlier conflicts, particularly in areas without central authority. There are no data on the number of military involved in the conflict, or the area affected. Note that large wars (e.g., the Thirty Years War, World War I and II) are registered as multiple conflicts, and that large battles (e.g., Azincourt, Verdun) are separately registered too. The indicator therefore captures the intensity as well as the frequency of conflict.

The climatic data for 1500–1900 stem from the gridded datasets of Luterbacher et al. (2004) for temperature and Pauling et al. (2005) for precipitation; see also Xoplaki et al. (2005). These reconstructions are based on instrumental and proxy-based records. In this study annual mean values of European temperature and precipitation have been used for the analysis. For the period prior to 1500 different reconstructions of northern hemispheric temperatures of the last millennium have been used. Data have been downloaded from the NOAA paleoclimate web-page http://www.ncdc.noaa.gov/paleo/recons.html.

Additionally, results from a model simulation with the coupled atmosphere-ocean model ECHO-G forced with reconstructions of solar and volcanic activity and greenhouse gas concentrations (GHG) have been used for this analysis (von Storch et al., 2004).

3. Descriptive statistics

In the following we present a correlation analysis between selected climatic data fields and war fare in Europe. An important point that is also addressed is on the statistical significance of the correlations. Results are given for both, spatially resolved patterns for Europe and averaged for Europe and the Northern Hemisphere. Additional to results based on observational and proxy studies also information from the output of climate model simulations will be analysed.

Figure 2 shows the (Pearson) correlation maps between war conflicts and temperature and precipitation, respectively. The right panels are based on unfiltered climatic data. In the left panels data have been smoothed with a 10 years Hamming window. According to Figure 2, temperatures are negatively correlated with war conflicts over central and northern Europe. Positive correlations are evident over the Balkans. The basic pattern is similar for data filtered with a 10 year Hamming window, whereas the higher correlations are possibly due to filtering-out of the interannual climate variability.

For precipitation, correlations are positive in a band from Scandinavia over mid-Europe to the Balkans. The pattern is spatially more inhomogeneous than the one for temperature, emphasizing the local to regional-scale character of precipitation. For the pre-filtered data the pattern is also similar, albeit with higher correlations. The higher correlations might be again caused by the smoothing of the annual precipitation data.

Standard tests for the significance of correlations assume that the samples are independent. However, this assumption is violated for the war data, because data show serial autocorrelations in the order of r_1=0.81; (r_1 is the autocorrelation coefficient with one year lag). Also, the annual temperature data show weak serial autocorrelations. To estimate more robustly the effect of the serial autocorrelations on the levels of statistical significance of the correlations, the region 10° W-30° E and 40° N-60° N has been selected and its average temperature and precipitation considered (cf. Figure 2).

Different filters and lags have been applied on the data. Results for temperatures are listed in Table 1; for temperature and precipitation in Tables 1 and 2. The statistical significance of the correlations has been estimated by Monte-Carlo simulations. Here, the original (Gaussian) white-noise time series have been transformed to first-order autoregressive processes according to the estimated values of the lag-1 autocorrelation of observed temperature and precipitation, respectively. (The serial autocorrelation of temperature is r_1=0.15, for precipitation r_1=0.) One thousand synthetic time series have been correlated with the war time series and the lower 2.5% and upper 97.5% confidence levels have been derived from the resulting correlations.

Results for precipitation show correlations even lower than for temperature. This might be related to the fact that regions with temperature correlations of the same sign (cf. Figure 3) are different than regions with the same sign of precipitation correlation. The averaging leads to the mixture of regions showing correlations with different signs. Therefore correlations of the area-averaged fields are lower than the spatially resolved.

Figure 4 shows that the correlations are stronger in the more distant past. This confirms the agricultural hypothesis. Agriculture became progressively less important over the period, because of improved cultivation methods and better fertilizers.

The upper part of Table 3 shows correlations between European war data and temperatures of the Northern Hemisphere based on different reconstructions extending back to year 1000. Results are given for the whole period 1000–1990 and for the pre-industrial era 1000–1750. The temperature according to Mann (2003) correlates best with the number of violent conflicts, and the data of d’Arrigo (2006) shows weakest correlation. Differences between the two periods are not as clear-cut as for the European temperatures. For some reconstructions correlations are even lower in the early period (Esper, 2002; Moberg, 2005).

The strength of correlations does however considerably differ among the different simulations, which can most likely be attributed to the different amount of serial autocorrelations of the different reconstructions. This is also supported by the change in the significance threshold related to the 2.5% significance level. The latter is highest for reconstructions showing highest correlations. Thus it can be concluded that the basic correlation between NH temperature and European wars is slightly negative and that the strength of the correlation is strongly influenced by the serial autocorrelations of the reconstruction under consideration.

The lower part of Table 3 shows correlations between wars and simulated temperatures with a global GCM. Here changes of solar and volcanic activity and GHG concentrations have been used to force the model in the period 1000–1990 (Erik). To test the plausibility of results also correlations between a simulation with the same climate model and war with constant external forcing has been calculated (Control) (Zorita et al., 2003).

Correlations between the simulated temperatures and European wars also show negative correlations, consistent with results obtained for reconstructions based on observational data and proxy data. For the control simulation correlations are zero. Therefore one might hypothesize that also changes in external forcings, such as solar and volcanic activity, partly influenced the warfare in the last millennium.

The correlation analysis thus confirms the finding of Zhang *et al*. (2006): In the temperature zone, abnormally cold weather coincides with violent conflict, and may cause it. The effect may have grown weaker as Europe developed. At the same time, the conclusion is not particularly convincing as the correlations is neither strong nor robust. In the next section, we use regression analysis to look into the same issue.

4. Regression analysis

Table 4 shows the results from a number of regression models. In the first model, the number of violent conflicts is regressed on the temperature (according to Mann, 2003). The estimated effect is strong – 9 conflicts per degree cooling – and highly significant. This model does not pass any diagnostic checks, however. Particularly, the errors are autocorrelated. The second model adds as explanatory variables the numbers of conflicts in the previous two years. These are highly significant, because conflicts tend to last longer than a few years. Lags between 3 and 10 years are not significant (results not shown). With this correction for autocorrelation, the temperature effect is estimated to be much weaker – one conflict per degree cooling – and it is significant at the 5% level but not at the 1% level. Recall that there are almost 1,000 observations.

Many things have changed in Europe in the last 1,000 years, and one would expect that the relationship between temperature and violent conflict has changed too. Therefore, we included interaction terms between temperature on the one hand and year and year-squared on the other hand. All three terms are highly significant (cf. Table 4). Note that the linear term is significant only if the quadratic term is included as well (results not shown). The combined effect of the three temperature terms is shown in Figure 5. It is significant at the 5% level between 1300 and 1650 only. This period roughly coincides with the period of maximum conflict. Including a trend break in 1517 (the start of the Reformation) does not affect the overall pattern, although the period of a significant effect of temperature on conflict is delayed to 1400-1725 (cf. Figure 5). The Reformation dummy is *negative* (cf. Table 4).

Table 4 also includes a model with a quadratic trend that is not interacted with temperature. The temperature effect is no longer significant. However, this model describes the data less well than the model with time interactions. Furthermore, if both trend and interaction terms are included, then the latter are more significant.

Table 5 shows the estimated effect of temperature on violent conflict for various subsamples. The period 1300-1725 is the initial sample, and this is extended in steps of 50 years. A model with two lags and no interaction terms is used. The effect of temperature is insignificant for the subsamples. The temperature is significant only if almost the entire sample is used to estimate the model.

Table 6 repeats this analysis, but now with subsamples starting at either end of the total sample. Table 6 confirms Table 5. The significance of the temperature effect is due to the gradient in temperature between either end of the sample and the middle. Short-term variations in temperature have no effect on violent conflict; but the long-term variations do.

Table 7 shows the results for the seven alternative temperature reconstructions. Only four are significant at the 5% level. The Mann temperature correlates best with the war record.

The regression analysis confirms the correlation analysis. One can make the case that violent conflict was more frequent and intense during cold periods. However, this case is weaker for some temperature reconstructions than for others. Furthermore, the main signal is in the secular trends, rather than decadal and annual variations. Europe gradually cooled and then warmed over the millennium, while conflict worsened and then waned.

5. Discussion and conclusion

In this paper, we study the relationship between climate change and violent conflict over the past millennium in Europe. Our results do not show a clear-cut picture: We present some evidence that abnormally cold periods were abnormally violent, as do Zhang *et al.* (2006). However, we also show that this evidence is not particularly robust. If one has strong priors that climate change causes conflict, our results provide confirmation. However, if one has strong priors that there is no link, our results do not overthrow such doubt. If anything, cold implies violence, and this effect is much weaker in the modern world than it was in mediaeval times. This implies that future global warming is not likely to lead to (civil) war between (within) European countries. Should anyone ever seriously have believed that, this paper does put that idea to rest.

We also showed the importance in estimating the proper level of statistical significance. The data series for both climate and war, show serial autocorrelations, affecting the threshold values for the statistical significance at a given level. This can lead – despite the high correlations in terms of absolute values – to false conclusions on the real strength of the correlations.

More research will have to be done. Conflict may be due to cold in the temperate climates of China (Zhang *et al*., 2006) and Europe (this paper). It does not follow that a warmer future would be more peaceful. The relationship between temperature and warfare may be reversed in the tropics. Data availability and quality may be an issue. A finer statistical analysis would be worthwhile too. We consider the ultimate cause (climate change) and final effect (violent conflict), but one could include more parts of the causal chain (e.g., climate change, agricultural production, economic deprivation, violent conflict). All this is deferred to future research.

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Table 1. Pearson correlation coefficients between war and temperature (according to Luterbacher et al., 2004). Time-series have been detrended prior to the analysis. For the time-series, a Hamming window has been applied. In parentheses threshold values of the 2.5% level of significance (two-tailed) are given.

Filter/lag	0	5	10	15
0	-0.14 (-0.11)	-0.10	0.00	0.00
5	-0.22 (-0.19)	-0.18	0.00	0.00
10	-0.24 (-0.26)	-0.25	0.00	0.00
20	-0.27 (-0.36)	-0.29	-0.18	-0.11

Table 2. Pearson correlation between European war data and temperature (according to Luterbacher et al., 2004) and precipitation (according to Pauling, 2005) for the periods 1500-1700 and 1701-1900. Time series have been de-trended prior to analysis. For the filtered time series a Hamming window has been applied. In parentheses threshold values of the 2.5% level of significance (two-tailed) are given.

	Temperature		Precipitation	
Period	1500-1700	1701-1900	1500-1700	1701-1900
Filter:				
0	-0.30 (-0.15)	0	+0.16 (0.06)	0
5	-0.39 (-0.26)	0	+0.23 (0.25)	0
10	-0.43 (-0.37)	0	+0.24 (0.37)	0
20	-0.42 (-0.52)	0	+0.19 (0.52)	0

Table 3. Pearson correlation between European war data for different temperature reconstructions of the Northern Hemisphere. Time series have been de-trended prior to analysis. In parentheses threshold values of the 2.5% level of significance (two-tailed) are given based on 1000 Monte Carlo simulations.

	1000-1990	1000-1750
Crowley 2000	-0.19 (-0.21)	-0.24
Esper 2002	-0.21 (-0.15)	-0.11
Mann 2003	-0.33 (-0.36)	-0.33
D'Arrigo 2006	-0.14 (-0.12)	-0.15
Moberg 2005	-0.23 (-0.21)	-0.18
Zorita, 2003, Northern Hemisphere[a]	-0.31 (-0.21)	-0.32
Zorita, 2003, Europe[a]	-0.18 (-0.10)	-0.14
Control Northern Hemisphere[a]	0	0
Control Europe[a]	0	0

[a] Temperature from a climate model simulation forced with reconstructions of solar and volcanic activity and greenhouse gas concentrations.

Table 4. Regression results: The number of conflicts in Europe (war) is regressed on a time trend (time), temperature, and conflict levels in previous years. Standard deviations are given in brackets.

		Base	AR	Time-variant	Reformation	Time trend
Constant	10^0	1.10	0.10	0.31	0.55	-4.79
		(0.24)	(0.12)	(0.14)	(0.18)	(1.48)
Time	10^{-3}					7.05
						(2.19)
Time^2	10^{-6}					2.25
						(0.74)
Temperature	10^0	-8.62	-0.99	18.53	24.36	-0.38
		(0.83)	(0.42)	(6.19)	(6.75)	(0.54)
Temp*time	10^{-1}			-0.27	-0.32	
				(0.08)	(0.09)	
Temp*time^2	10^{-6}			9.37	1.05	
				(2.70)	(0.27)	
Luther					-0.34	-0.31
					(0.16)	(0.16)
War (t-1)	10^0		0.76	0.75	0.74	0.75
			(0.03)	(0.03)	(0.03)	(0.03)
War (t-2)	10^0		0.13	0.11	0.11	0.11
			(0.03)	(0.03)	(0.03)	(0.03)
R^2_{adj}		0.10	0.79	0.80	0.80	0.80
LL		-2241.47	-1512.89	-1505.67	-1503.36	-1504.81

Table 5. Estimated effect of the temperature on the number of conflicts in Europe, using the AR model of Table 4, for different subsamples.

Sample	Mean	St.dev.
1300-1725	-0.43	(0.83)
1275-1750	-0.59	(0.78)
1250-1775	-0.90*	(0.74)
1225-1800	-0.87*	(0.69)
1200-1825	-0.57	(0.67)
1175-1850	-0.60	(0.63)
1150-1875	-0.49	(0.60)
1125-1900	-0.58	(0.59)
1100-1925	-1.02*	(0.57)
1075-1950	-0.87*	(0.51)
1050-1975	-0.94**	(0.45)
1002-1980	-0.99**	(0.42)

Table 6. Estimated effect of the temperature on the number of conflicts in Europe, using the AR model of Table 4, for different subsamples.

Sample	Mean	St.dev.	Sample	Mean	St.dev.
1002-1200	-1.22*	(1.08)	1800-1980	-0.39	(0.83)
1002-1300	-0.35	(0.71)	1700-1980	-0.61	(0.70)
1002-1400	-0.86*	(0.67)	1600-1980	-1.57**	(0.63)
1002-1500	-1.38**	(0.65)	1500-1980	-1.68**	(0.61)
1002-1600	-1.21**	(0.59)	1400-1980	-1.16**	(0.58)
1002-1700	-1.14**	(0.52)	1300-1980	-0.97*	(0.53)
1002-1800	-1.22**	(0.50)	1200-1980	-0.84*	(0.49)
1002-1900	-0.87*	(0.48)	1100-1980	-0.94**	(0.46)
1002-1980	-0.99**	(0.42)	1002-1980	-0.99**	(0.42)

Table 7. Estimated effect of the temperature on the number of conflicts in Europe, using the AR model of Table 4, for different temperature reconstructions.

Temperature	Mean	St.dev.
Crowley	-0.93**	(0.40)
D’Arrigo	-0.20*	(0.18)
Erik – Europe	-0.08*	(0.05)
Erik – Northern Hemisphere	-0.32**	(0.12)
Esper	-0.46*	(0.30)
Mann	-0.99**	(0.42)
Moberg	-0.35**	(0.17)

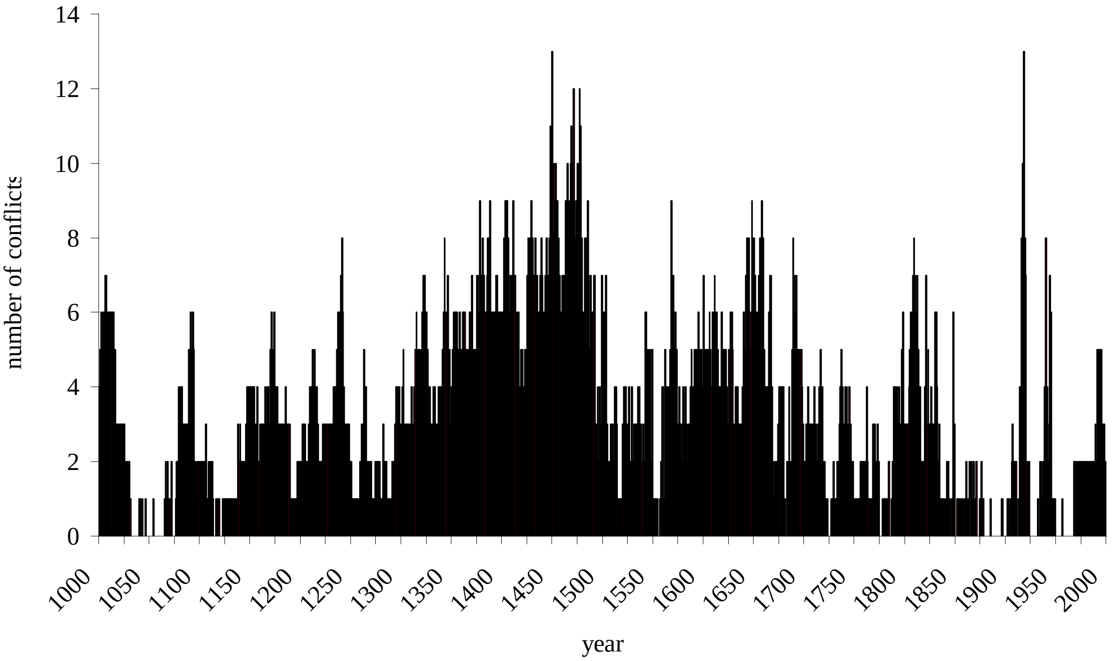

Figure 1. Annual number of violent conflicts in Europe according to www.warscholar.com

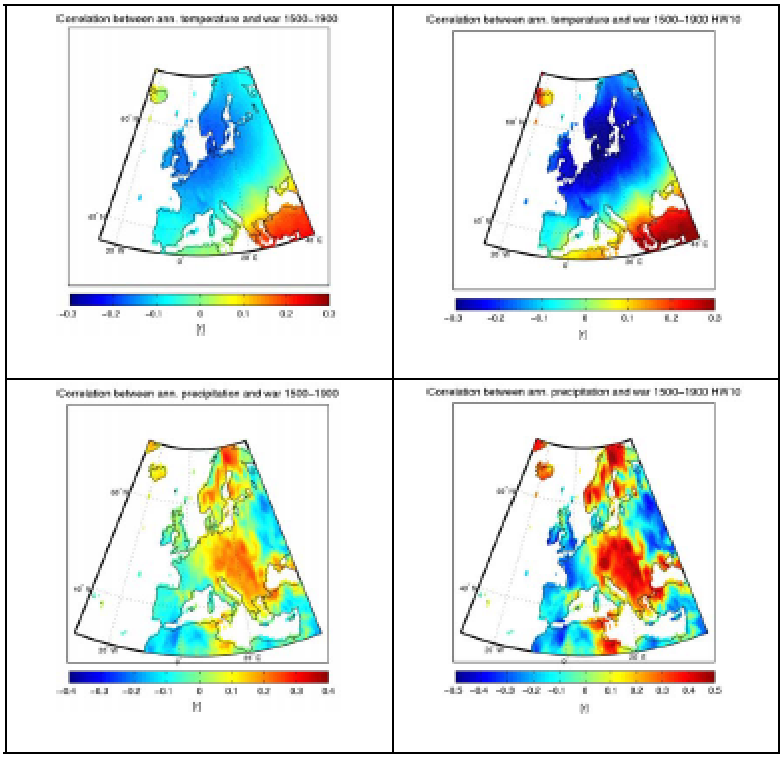

Figure 2. Correlation maps between war conflicts and temperature (upper) and precipitation (lower) during the period 1500-1900. The left panels show results for unfiltered data, the right panels shows results for data pre-filtered with a 10-year Hamming window.

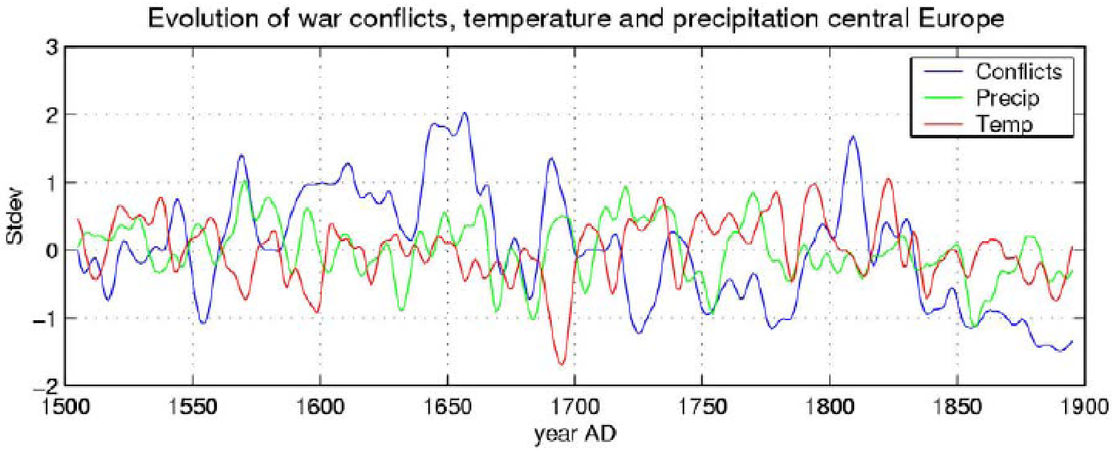

Figure 3. Standardized time series of war conflicts, temperature and precipitation for Central Europe. Time series have been filtered with a 10 year Gaussian filter.

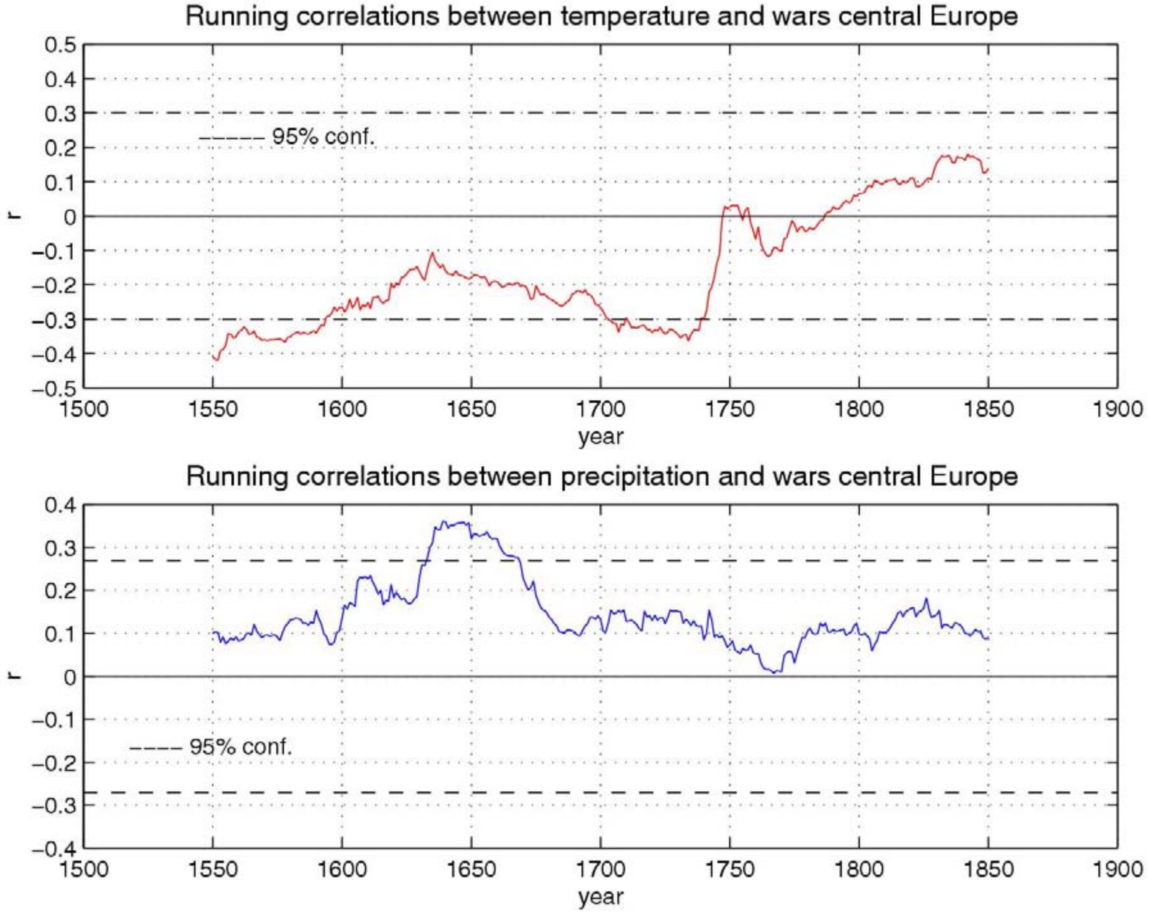

Figure 4. Running correlations with a 50 year window between climate time series (temperature: top panel; precipitation: bottom panel) in central Europe and wars. The dashed lines indicate the 95% confidence intervals based on 1000 Monte Carlo simulations.

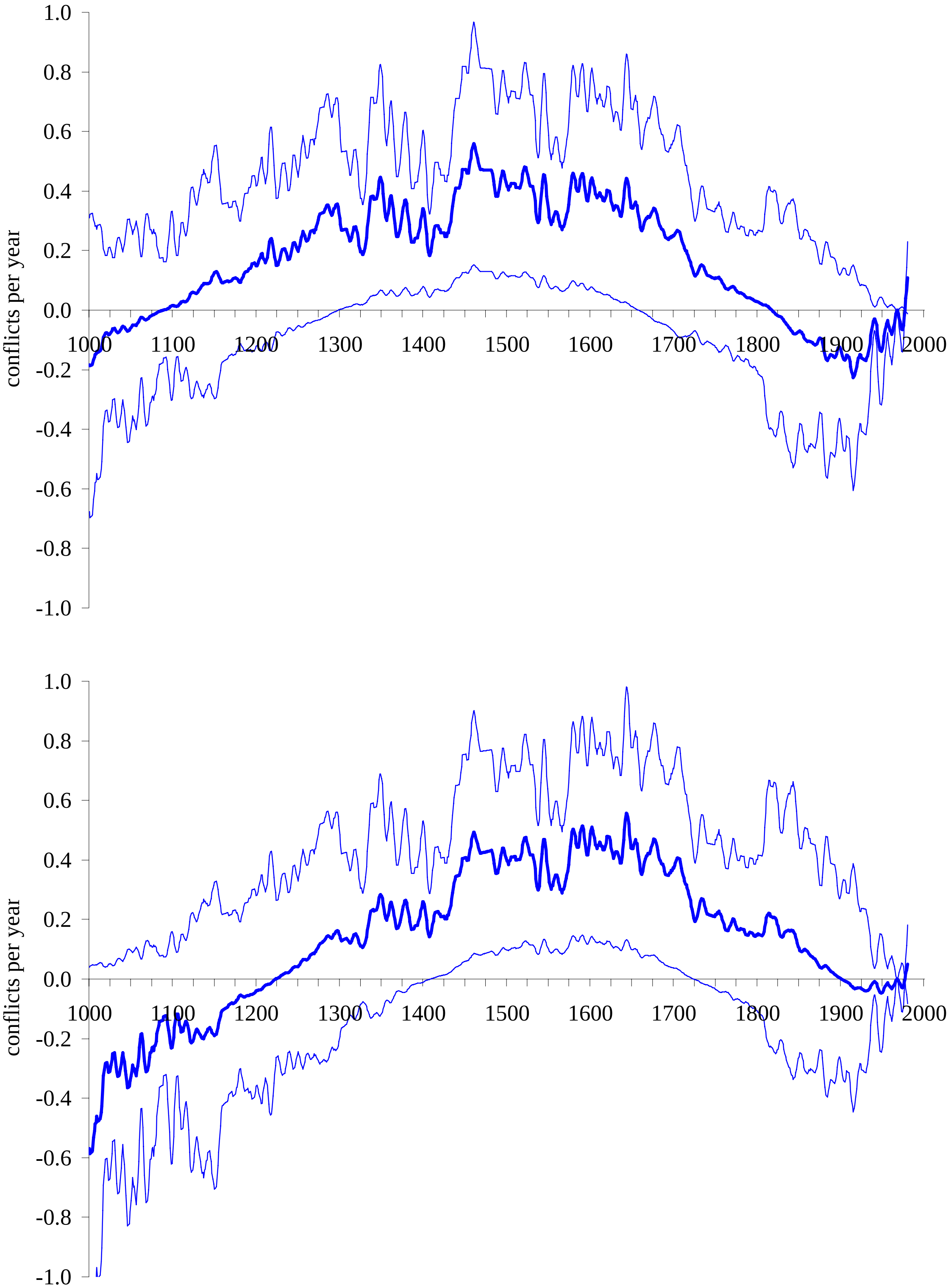

Figure 5. Predicted number of wars due to temperature (according to Mann) without a Reformation dummy (top panel) and with a Reformation dummy (bottom panel). The thick line is the expected value, the thin lines its 95% confidence interval.

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