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Abstract

Theisen (JPR, 2012) recently constructed a novel high-resolution data set of intergroup and political conflict in Kenya (1989-2004) and examined whether the risk of conflict onset and incidence responds to annual pixel-level variations in temperature and precipitation. Thiesen concluded that only extreme precipitation is associated with conflict incidence and that temperature is unrelated to conflict, seemingly at odds with recent studies that found a positive association at the pixel scale (O'laughlin et al., PNAS 2012), at the country scale (Burke et al., PNAS 2009), and at the continental scale (Hsiang et al., Nature 2011) in Africa. Here we show these findings can be reconciled when we correct the erroneous coding of *temperature-squared* in Thiesen. In contrast to the original conclusions presented in Theisen, both conflict onset and conflict incidence are significantly and positively associated with local temperature in this new and independently assembled data set.

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Recent studies have demonstrated that climatic events which produce temporary warming are associated with a temporary increase in violent intergroup conflict at a variety of spatial scales (Burke et al, 2009; Hsiang et al, 2011; O'Loughlin et al, 2012). In a recent analysis, Theisen (2012) independently assembled a unique high-resolution (0.25°x0.25°) panel data file of intergroup conflict events in Kenya (1989-2004) and examined whether the positive intertemporal association between local temperature and local conflict was detectable in this new data set. Theisen regresses measures of conflict onset (an indicator for the first year in which 25 deaths arise from a conflict) and conflict "events" (an indicator for all years in which a conflict exceeding 25 deaths in a given year occurs) on CRU estimates for $precipitation$ and $precipitation^2$, while also controlling for country fixed effects, year fixed effects and spatial and temporal lags of local conflict (see Theisen (2012) for variable and model details). Theisen then repeats this exercise using $temperature$ and $temperature^2$ as regressors instead of $precipitation$ and $precipitation^2$. Because neither temperature coefficient is statistically significant, Theisen concludes that higher temperatures are not associated with higher rates of conflict in this context, in apparent disagreement with the above findings.

We point out here that the disagreement between Theisen and earlier results in Africa is an artifact of a coding error, which when fixed brings the results of Theisen into alignment with these other studies. Theisen measures both temperature and precipitation in terms of pixel-specific z-scores with mean zero and pixel-specific standard deviation of one. Theisen reports that these variables are then squared and both the linear and squared terms are included in each regression to account for the potential non-linearity of conflict with respect to each variable. However, the replication files for Theisen indicate that constants were added to both *temperature* and *precipitation* before these variables were squared. Figure 1 displays the values for $temperature^2$ and $precipitation^2$ used in Theisen compared with the correct values. Although the addition of a constant before squaring these variables seems like a small change – in fact it has no effect on the coefficients for these terms – it alters the appearance of regression coefficients so that it looks as though there is no significant association between temperature and conflict when there actually is. To see why, note that the econometric model of interest has the form

$$conflict = \beta_0 + \beta_1 T + \beta_2 T^2 \quad (1)$$

where T is temperature. Thiesen replaced T by $\tilde{T} = T + C$ in the third term of Eq. 1, where C is a constant. This changes the third term to be

$$\begin{aligned}\tilde{T^2} &= (T+C)^2 \\ &= T^2 + 2TC + C^2. \end{aligned} \tag{2}$$

If we were to estimate a regression model using this third term, the coefficients we obtain would not be identical to those in Eq. 1. Instead, we would obtain

$$\begin{aligned} conflict &= \tilde{\beta_0} + \tilde{\beta_1}T + \tilde{\beta_2}\tilde{T^2} \\ &= \tilde{\beta_0} + \tilde{\beta_1}T + \tilde{\beta_2}T^2 + 2\tilde{\beta_2}TC + \tilde{\beta_2}C^2 \\ &= \underbrace{(\tilde{\beta_0} + \tilde{\beta_2}C^2)}_{\beta_0} + \underbrace{(\tilde{\beta_1} + 2\tilde{\beta_2}C)}_{\beta_1} T + \underbrace{\tilde{\beta_2}}_{\beta_2} T^2 \end{aligned} \tag{3}$$

where the second equality comes from substitution of Eq. 2. Because Thiesen added a constant before squaring climate variables, he reports $\tilde{\beta_1}$ and $\tilde{\beta_2}$, rather than β_1 and β_2. As indicated by the underbraces in Eq. 3, $\beta_2 = \tilde{\beta_2}$ so the coefficients on *temperature*^{2} and *precipitation*^{2} are unbiased. However, the primary coefficient of interest $\beta_1 = \tilde{\beta_1} + 2\tilde{\beta_2}C$. Because Theisen focuses only on $\tilde{\beta_1}$, he underestimates the linear effect of temperature.

In Table 1 we replicate the results of Thiesen's Model 1, 5, 7 and 11 which concern the effects of current temperature and precipitation. We then present corrected estimates using the correct coding of *precipitation*^{2} and *temperature*^{2}. As predicted by Eq. 3, the coefficients on the squared terms do not change when we correct their coding but the coefficients on the linear terms do change. In the case of temperature, the linear effects become larger and significant. By inspecting Theisen's original coding of *precipitation*^{2} and *temperature*^{2}, we determine that $C_{temp} = 2.3959$ and $C_{precip} = 2.5903$ (the size of the offset observable in Figure 1) – allowing us to verify that the bias in Theisen is entirely attributable to the term $2\tilde{\beta_2}C$ derived in Eq. 3.

It actually would have been possible to accurately construct an estimate for β_1 with correct standard errors using the results originally reported in Thiesen. Following Thiesen's estimate of Eq. 3 one would have simply needed to compute $\tilde{\beta_1} + 2\tilde{\beta_2}C$ while accounting for the covariance between $\tilde{\beta_1}$ and $\tilde{\beta_2}$. This calculation would have correctly revealed the statistically significant association between temperature and conflict[1].

[1] For example, in the case of Thiesen's Model 11 (using the notation of the replication file), this is accomplished with the Stata command "`nlcom stdevtemp+2*temposq*2.395948`" following the original regression command.

While correcting this coding error did not alter the significance of precipitation results (although it does alter their magnitude), it substantially increases the significance of the temperature results (columns 4 and 9 in Table 1). Because only the coefficient on *temperature* is significant, we also estimate a model that is restricted to be linear in both temperature and precipitation – in part because it remains difficult to quickly determine the marginal effect of *temperature* in the corrected model and in part because we wish to simultaneously model the effect of temperature and precipitation, since the two might be omitted variables for one another. In this linear model, we continue to obtain a marginally significant effect on conflict onset and a significant effect of temperature on conflict incidence (columns 5 and 11 in Table 1). Again, these linearized models could have been obtained in the original analysis by Thiesen since they do not depend on the variables that were incorrectly coded. Had these models been estimated in the original analysis, they too would have revealed the significant association between temperature an conflict. Finally, we estimate a model that simultaneously accounts for the effects of temperature and precipitation as well as the corrected values of temperature-squared and precipitation-squared and find that the linear effect of temperature is unchanged and remains statistically significant (columns 6 and 12 in Table 1).

We conclude that temperature has a significant and robust effect on both local conflict onset and local conflict incidence in modern Kenya based on a corrected analysis of this novel and unique data set. This reconciles the stated disagreement in findings between Theisen (2012) and earlier work (Burke et al, 2009). Furthermore, it brings the findings in Theisen (2012) into alignment with numerous other findings throughout the literature (Hsiang et al, 2013; Hsiang and Burke, 2013).

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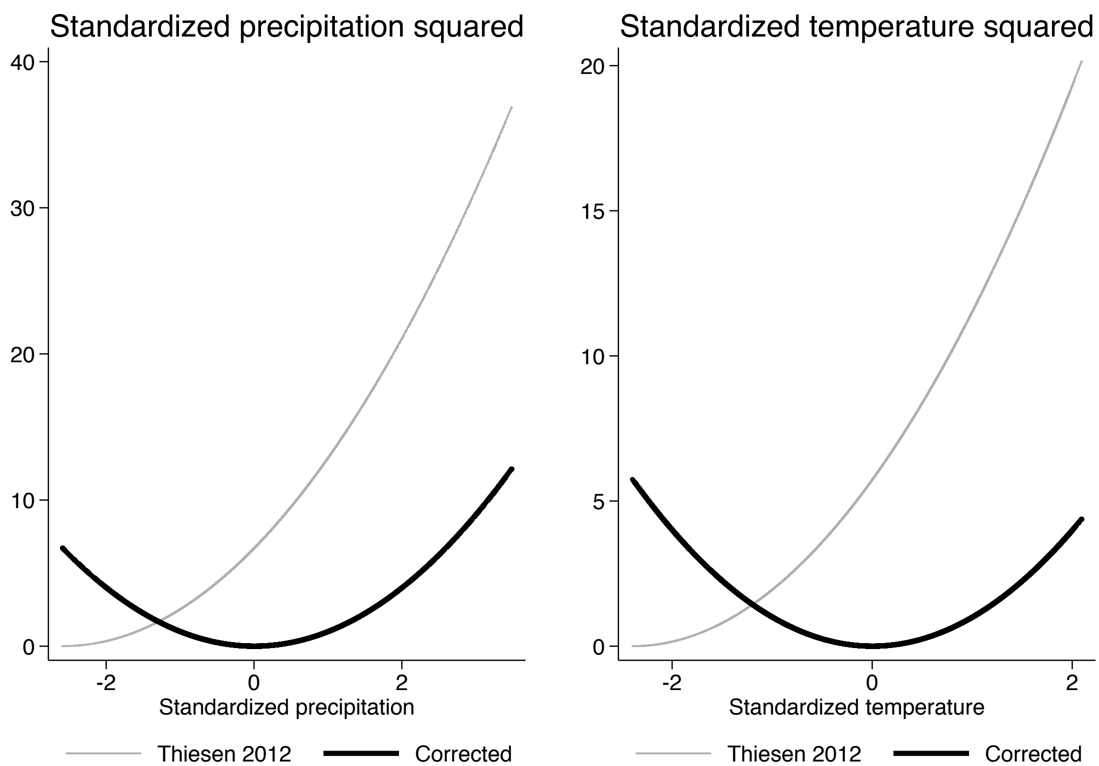
Standardized precipitation squared
40
30
20
10
0
-2
0
2
Standardized precipitation
Thiesen 2012
Corrected
Standardized temperature squared
20
15
10
5
0
-2
0
2
Standardized temperature
Thiesen 2012
Corrected

Figure 1

Table 1: Correcting squared weather variables changes the significance of temperature

	Dependent Variable: Intergroup and political conflict onset ("Conflict")					
	(1)	(2)	(3)	(4)	(5)	(6)
	Model 1		Model 5		Linearized	Quadratic
	original	corrected	original	corrected		
Precipitation	0.00264	-0.00000			-0.00006	0.00008
	(0.00268)	(0.00065)			(0.00068)	(0.00066)
Precipitation^2	-0.00051	-0.00051				-0.00036
	(0.00050)	(0.00050)				(0.00051)
Temperature			0.00172	0.00344*	0.00325*	0.00327*
			(0.00453)	(0.00180)	(0.00171)	(0.00172)
Temperature^2			0.00036	0.00036		0.00048
			(0.00098)	(0.00098)		(0.00101)
Observations	13,520	13,520	13,520	13,520	13,520	13,520

	Dependent Variable: Intergroup and political conflict incidence ("Events")					
	(7)	(8)	(9)	(10)	(11)	(12)
	Model 7		Model 11		Linearized	Quadratic
	original	corrected	original	corrected		
Precipitation	0.01335**	0.00292**			0.00236*	0.00319**
	(0.00565)	(0.00126)			(0.00130)	(0.00128)
Precipitation^2	-0.00201**	-0.00201**				-0.00183*
	(0.00102)	(0.00102)				(0.00101)
Temperature			0.00464	0.00635**	0.00691**	0.00634**
			(0.00668)	(0.00307)	(0.00291)	(0.00303)
Temperature^2			0.00036	0.00036		0.00046
			(0.00157)	(0.00157)		(0.00156)
Observations	13,520	13,520	13,520	13,520	13,520	13,520

Temperature and Precipitation are measured in cell-specific standardized z-scores, as in Theisen (2012). Models as in Thiesen (2012) include pixel fixed effects, year fixed effects, a lagged spatial lag and a variable describing the "decay of time since last event" assuming a 2 year half-life. Outcome variables are described in Thiesen (2012). Standard errors clustered by pixel as in Thiesen (2012). "Corrected" models replace the incorrectly coded variables for Precipitation^2 and Temperature^2 with corrected values. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.