

Supporting Information For  
**Measuring Spatio-Temporal Civil War Dimensions Using Community-Based Dynamic  
 Network Representation (CoDNet)**

CONTENTS

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This appendix includes three parts. In the first part, we report maps reflecting different operationalization parameter choices, climate-conflict relationships, and ground truth data from rebellions in India. In the second part we discuss our variables and their construction and report a table with summary statistics of all variables. The third part report a large number of sensitivity analyses, where our CoDNet based indicators are operationalized using different temporal and parameter choices to illustrate the robustness of our findings from the main paper.

## I. SUPPLEMENTARY FIGURES OF CoDNets

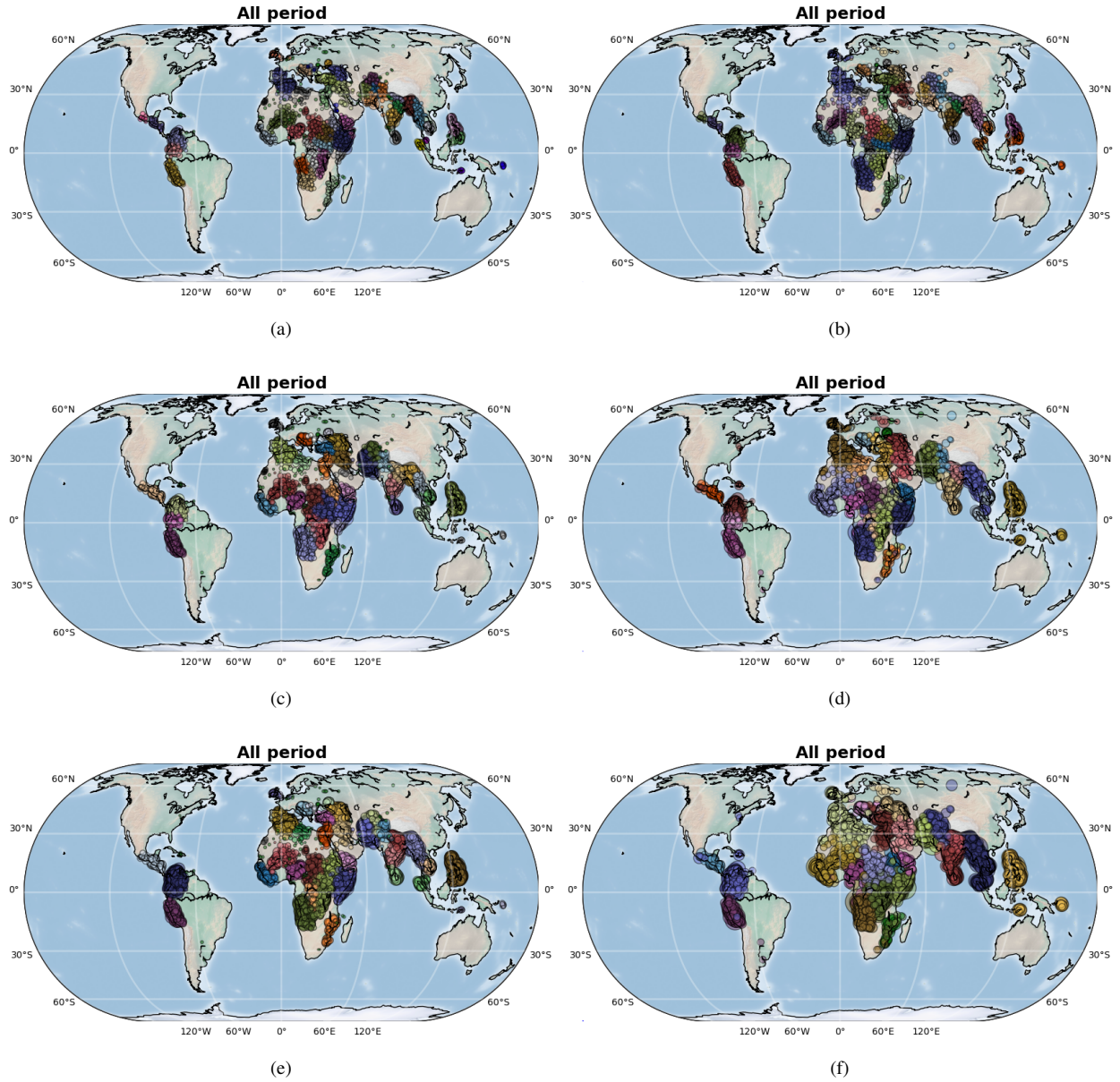


Fig. A1. Supplemental figure of the aggregated year-networks snapshot with different values of  $K$  and  $d_{\max}$  distance, for the global temporal communities of conflicts encompassing 26 years of data between 1989 and 2014 across the entire globe. (a) and (b) for  $K = 3$ ; (c) and (d) for  $K = 7$ ; and (e) and (f) for  $K = 11$ . The left column of figures (a), (c), and (e) is for  $d_{\max} = 500$  Km. The right column of figures is without a distance limit.

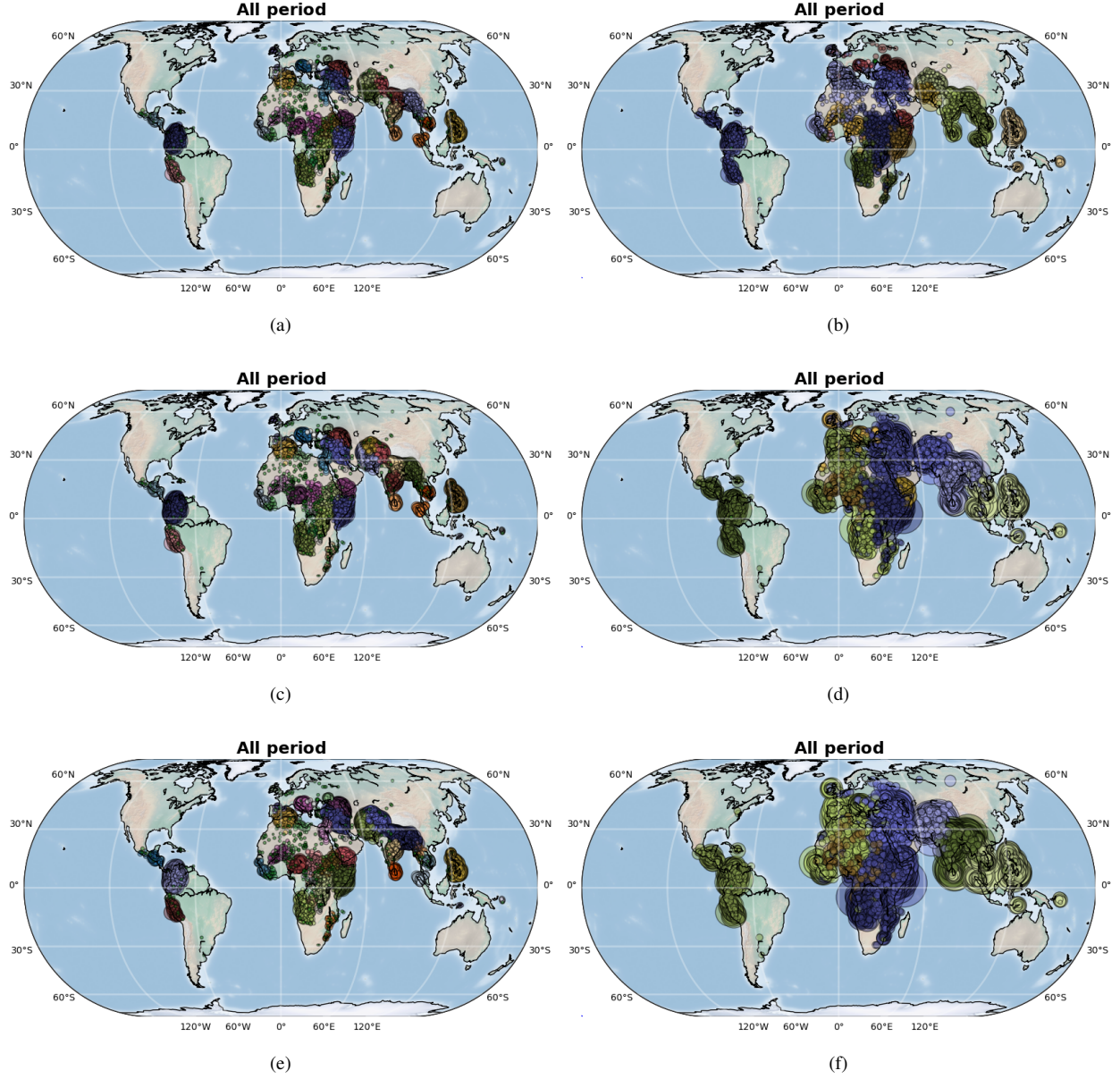


Fig. A2. Supplemental figures by considering a monthly sliding window of snapshots aggregated over all the period of data between 1989 and 2014 across the entire globe. We varied the values of  $K$  and  $d_{\max}$  distance for the global temporal communities of conflicts, where (a) and (b) are for  $K = 3$ ; (c) and (d) for  $K = 7$ ; and (e) and (f) for  $K = 11$ . The left column of figures (a), (c), and (e) is for  $d_{\max} = 500$  Km. The right column of figures is without a distance limit.

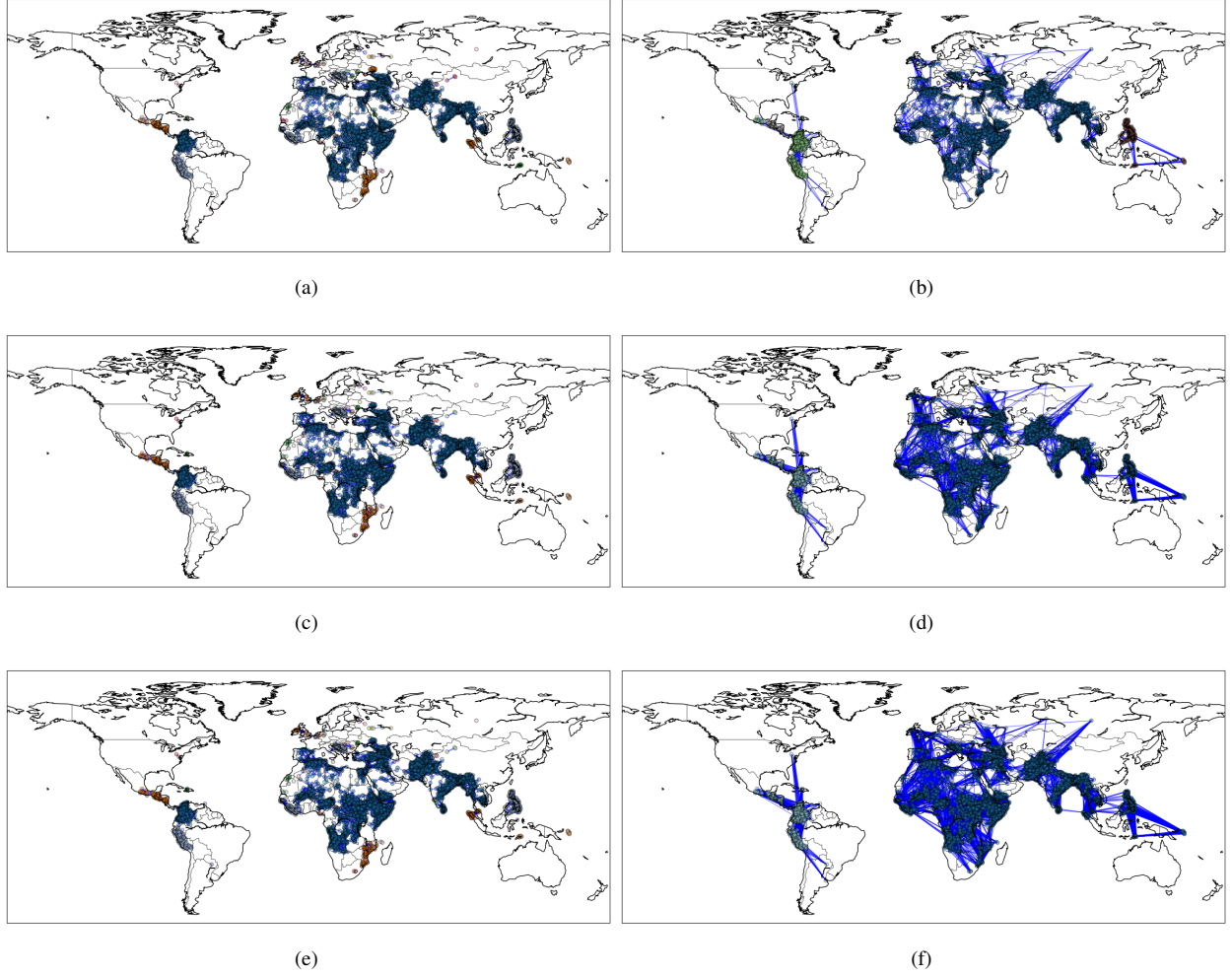


Fig. A3. Supplemental figures considering different values of  $K$  and  $d_{\max}$  distance for the global temporal network of conflicts encompassing 26 years of data between 1989 and 2014. Colors in the nodes represent same component. Networks (a) and (b) for  $K = 3$ ; (c) and (d) for  $K = 7$ ; and (e) and (f) for  $K = 11$ . The left column of figures (a), (c), and (e) is for  $d_{\max} = 500$  Km. The right column of figures is without distance limit.



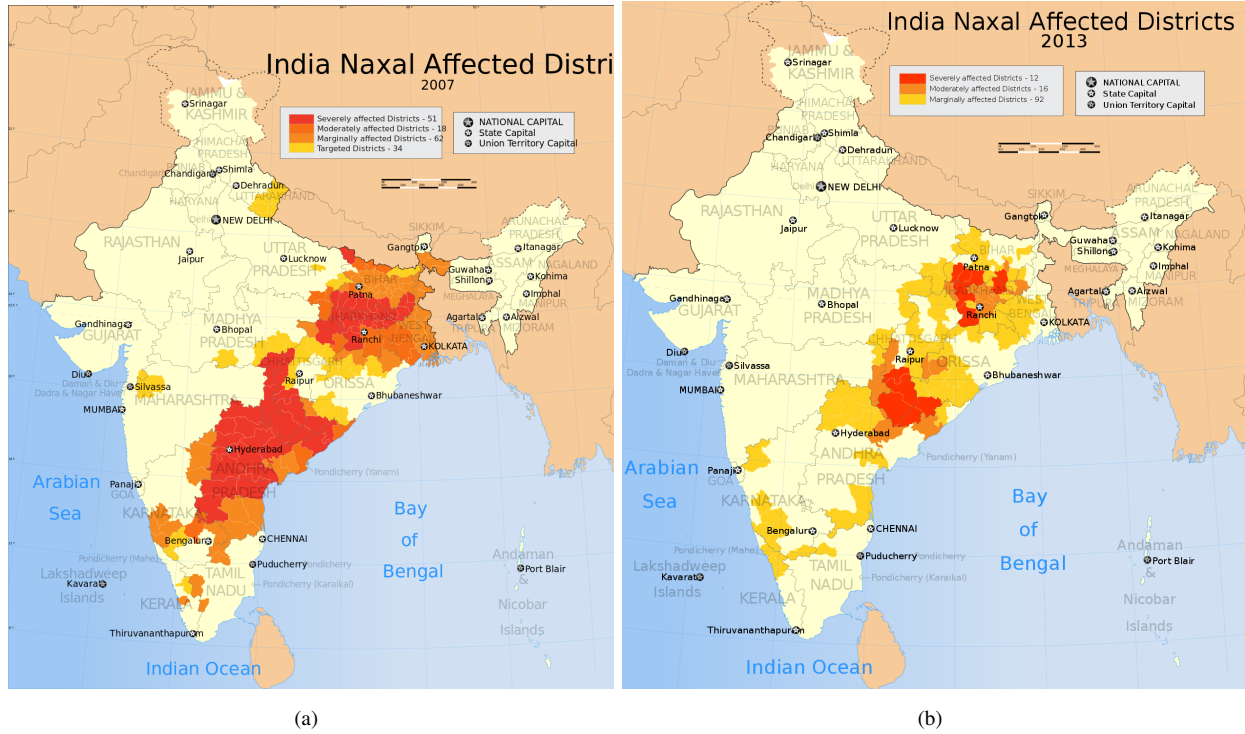
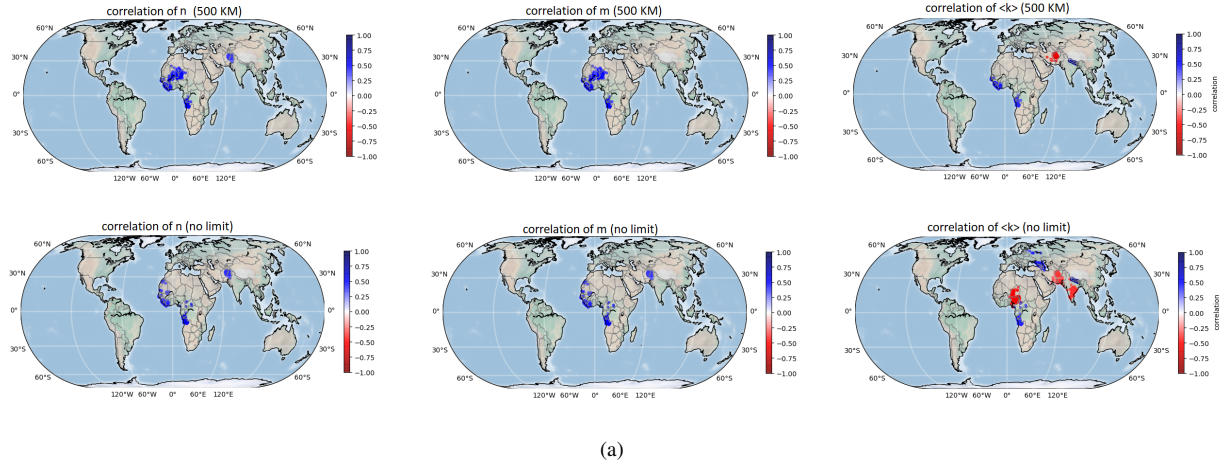


Fig. A4. Map of Observed Naxalite Rebel Conflict Clusters. *Source:* Institute for Conflict Management

### Spearman correlations with Precipitation



### Spearman correlations with Temperature

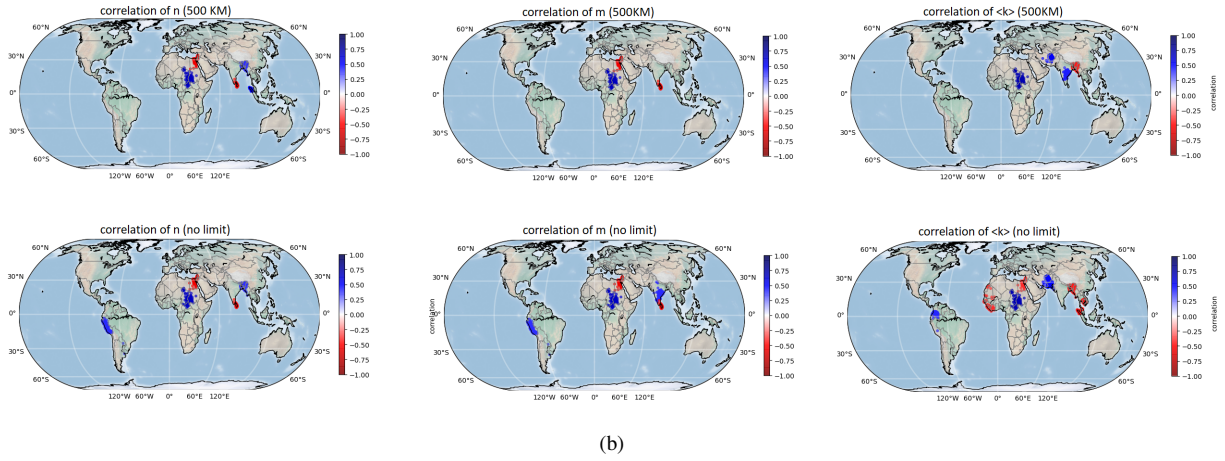


Fig. A5. Correlation between the Network-Based Spatio-Temporal metrics of Conflict Clusters with Temperature and Precipitation around the world in the entire period. We show the regions with significant Spearman p-value lower than 0.05.

## II. VARIABLE DISCUSSION AND SUMMARY STATISTICS

*Conflict counts<sub>it</sub>*: This variable is operationalized as the number of annual events within a given cell  $i$  during a given year  $t$  that adhered to the definition developed by UCDP as involving: “a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle- related deaths in a calendar year” [1].

*Nighttime light<sub>it</sub>*: The nighttime light data used in our models were obtained from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System Nighttime Lights Time Series data series (version 4). This variable was operationalized in two stages. In the first stage, the number of pixels (0.08 degree grid cells) with illumination in a given cell were counted and aggregated to the grid cell  $i$  level for each year  $t$  in the data. In the next stage, the resulting data were calibrated to account for intersatellite differences and interannual sensor decay, where values were standardized to be between 0 (no emissions) and 1 (highest observed value) as to ensure they are effective for the purpose of time-series cross sectional analysis [2]

*Population<sub>it</sub>*: This variable – also obtained from PRIO-Grid [2] – measures the number of people within a given grid cell. Information on this variable is only available for the years 1995, 2000, and 2005. Accordingly, the data were first aggregated for each grid cell  $i$  for these specific years, and then interpolated to the yearly level using a last value carried forward approach. This variable was also logged prior to entering the model, considering the wide range of values on this indicator and the potential inferential biases not accounting for this issue might cause.

*Precipitation<sub>it</sub>*: This indicator measures the total amount (in millimeter) of rainfall recorded within a given grid cell  $i$  during a given year  $t$  based on monthly meteorological statistics from the GPCP v.2.2 Combined Precipitation Data Set. Annual levels were calculated by multiplying daily rainfall averaged by the number of days in each month, and then to calculate yearly totals [2]. Since the original data only reported the daily average for each month, we multiplied the daily average by the number of days in each month in order to obtain approximate monthly totals, from which yearly totals were estimated. This variable was also log prior to entering the model, considering the wide range of values on this indicator and the potential inferential biases not accounting for this issue might cause.

*Drought<sub>it</sub>*: This variable gives the ratio of consecutive months that experienced drought – defined as locations and times where SPI1 values fell below -1.5 standard deviations below rainfall mean within said grid cell – to 12 months within a given grid cell  $i$ .

*Temperature<sub>it</sub>*: This variable measures the yearly mean temperature (in degrees Celsius) recorded in a given grid cell [2].

*Ethnic exclusion<sub>it</sub>*: This variable is defined as the number of distinct ethnic groups excluded from power observed within a given grid cell during a given year [3].

TABLE A1  
SUMMARY STATISTICS OF ALL VARIABLES

	Minimum	Median	Mean	Max	SD
Dependent variables					
<i>Conflict counts<sub>it</sub></i>	0	0	0.052	361	1.358
<i>Average intensity<sub>it</sub></i>	0	0	0.146	4.5	0.705
<i>Dispersion<sub>it</sub></i>	0	0	0.881	81	5.289
<i>Intraconnectivity<sub>it</sub></i>	0	0	1.600	143	9.702
<i>Average intensity (month const.)<sub>it</sub></i>	0	0	0.183	8.605	0.956
<i>Dispersion (month const.)<sub>it</sub></i>	0	0	1.294	36	7.975
<i>Intraconnectivity (month const.)<sub>it</sub></i>	0	0	3.558	542	24.810
<i>Average intensity (k=3, no limit)<sub>it</sub></i>	0	0	0.160	4.5	0.748
<i>Dispersion (k=3, no limit)<sub>it</sub></i>	0	0	1.030	106	6.163
<i>Intraconnectivity (k=3, no limit)<sub>it</sub></i>	0	0	1.906	90	11.443
<i>Average intensity (k=7, 500)<sub>it</sub></i>	0	0	0.308	9.643	1.497
<i>Dispersion (k=7, 500)<sub>it</sub></i>	0	0	1.121	118	6.886
<i>Intraconnectivity (k=7, 500)<sub>it</sub></i>	0	0	4.444	476	28.174
<i>Average intensity (k=7, no limit)<sub>it</sub></i>	0	0	0.367	10	1.693
<i>Dispersion (k=7, no limit)<sub>it</sub></i>	0	0	1.413	127	7.840
<i>Intraconnectivity (k=7, no limit)<sub>it</sub></i>	0	0	5.834	504	32.681
<i>Average intensity (k=11, 500)<sub>it</sub></i>	0	0	0.451	14.571	2.235
<i>Dispersion (k=11, 500)<sub>it</sub></i>	0	0	1.426	136	8.546
<i>Intraconnectivity (k=11, 500)<sub>it</sub></i>	0	0	8.633	883	54.492
<i>Average intensity (k=11, no limit)<sub>it</sub></i>	0	0	0.586	15.533	2.652
<i>Dispersion (k=11, no limit)<sub>it</sub></i>	0	0	1.804	148	9.745
<i>Intraconnectivity (k=11, no limit)<sub>it</sub></i>	0	0	11.607	931	63.802
Independent variables					
<i>Nighttime light<sub>it</sub></i>	0	0.037	0.057	1	0.066
<i>Population<sub>it</sub></i> <sup>1</sup>	0	8.280	7.788	16.721	3.693
<i>Precipitation<sub>it</sub></i> <sup>1</sup>	0.116	6.416	6.274	8.719	1.060
<i>Drought<sub>it</sub></i>	0	0	0.042	1.750	0.057
<i>Temperature<sub>it</sub></i>	-25.029	10.574	10.117	57.546	14.055
<i>Ethnic exclusion<sub>it</sub></i>	0	0	0.485	6	0.603

<sup>1</sup> Natural log

### III. SENSITIVITY ANALYSES

In this section we report a battery of models designed to test the sensitivity of our findings. We begin by estimating our main models on a sample where networks were operationalized based on month- rather than year-level networks, before being aggregated to the annual level in Table A2 (note that the count indicator and the model estimates therein is unaffected, considering no network construction was employed). Our results in this sample are even more robust than in the main analysis where only annual information is used.

In Table A3, we then operationalize our latent indicators using the same  $K = 3$  nearest neighbors as used in the main analysis, but imposing no geodesic distance limits on our  $d_{max}$  parameter. In Tables A4–A5, we then change our number-of-nearby-cells parameters to  $K = 7$  and  $K = 11$ , respectively, estimating each set of models therein twice, once using our original  $d_{max} = 500KM$  and again without any  $d_{max}$  distance limits. Our results from Tables A3–A5 are not only robust, but actually become even stronger, thereby providing additional support for our findings regarding the importance of using latent geospatial dimensions to operationalize civil war incidence.

TABLE A2  
DETERMINANTS OF GEOSPATIAL CONFLICT, 1992-2012 – MONTHLY LEVEL NETWORK COMPOSITION

	Count	Average intensity	Dispersion	Intraconnectivity
	(13)	(14)	(15)	(16)
<i>Nighttime light<sub>it</sub></i>	−0.836** (0.235)	0.089** (0.022)	0.826** (0.192)	2.919** (0.733)
<i>Population<sub>it</sub></i> <sup>1</sup>	0.034** (0.009)	0.018** (0.002)	0.201** (0.019)	0.904** (0.081)
<i>Precipitation<sub>it</sub></i> <sup>1</sup>	0.018** (0.004)	0.005** (0.002)	0.093** (0.014)	0.172** (0.051)
<i>Drought<sub>it</sub></i>	0.007 (0.014)	0.032** (0.005)	0.340** (0.054)	1.125** (0.212)
<i>Temperature<sub>it</sub></i>	0.005** (0.002)	0.001** (0.0004)	0.004 (0.004)	0.023 (0.015)
<i>Ethnic exclusion<sub>it</sub></i>	0.006 (0.023)	0.012** (0.005)	0.039 (0.036)	0.290** (0.138)
<i>DV<sub>t−1</sub></i>	0.480** (0.042)	0.683** (0.004)	0.757** (0.003)	0.720** (0.004)
Observations	1,040,428	1,040,428	1,040,428	1,040,428
R <sup>2</sup>	0.519	0.949	0.940	0.904
Adjusted R <sup>2</sup>	0.492	0.946	0.936	0.899

<sup>†</sup> indicates  $p < .1$ ; \* indicates  $p < .05$ ; \*\* indicates  $p < .01$ .

Variable coefficients are reported with standard errors clustered by grid cell in parentheses. We do not report fixed effects due to space constraints.

<sup>1</sup> Natural log

## REFERENCES

- [1] “Ucdp ged codebook version 21.1,” Department of Peace and Conflict Research, Uppsala University, 2021. [Online]. Available: <https://ucdp.uu.se/downloads/ged/ged211.pdf>
- [2] Tollefsen, A. Forø, H. Strand, and H. Buhaug, “Prio-grid: A unified spatial data structure,” *Journal of Peace Research*, vol. 49, no. 2, pp. 363–374, 2012.
- [3] M. Vogt, N.-C. Bormann, S. Rüegger, L.-E. Cederman, P. Hunziker, and L. Girardin, “Integrating data on ethnicity, geography, and conflict: The ethnic power relations data set family,” *Journal of Conflict Resolution*, vol. 59, no. 7, pp. 1327–1342, 2015.

TABLE A3  
**DETERMINANTS OF GEOSPATIAL CONFLICT, 1992-2012 –  $K = 3$ , NO LIMIT**

	Average intensity	Dispersion	Intraconnectivity
	(17)	(18)	(19)
<i>Nighttime light<sub>it</sub></i>	0.004 (0.018)	1.050** (0.235)	1.830** (0.455)
<i>Population<sub>it</sub></i> <sup>†</sup>	0.002* (0.001)	0.165** (0.019)	0.319** (0.037)
<i>Precipitation<sub>it</sub></i> <sup>†</sup>	0.012** (0.001)	0.117** (0.015)	0.246** (0.028)
<i>Drought<sub>it</sub></i>	0.011** (0.004)	0.057 (0.040)	0.120 (0.075)
<i>Temperature<sub>it</sub></i>	0.001** (0.0003)	−0.0001 (0.003)	0.002 (0.005)
<i>Ethnic exclusion<sub>it</sub></i>	−0.003 (0.003)	−0.010 (0.033)	−0.016 (0.064)
<i>DV<sub>t−1</sub></i>	0.527** (0.005)	0.757** (0.005)	0.743** (0.005)
Observations	1,040,428	1,040,428	1,040,428
R <sup>2</sup>	0.941	0.923	0.918
Adjusted R <sup>2</sup>	0.938	0.918	0.913

<sup>†</sup> indicates p<sub>1</sub>.1; \* indicates  $p < .05$  ; \*\* indicates  $p < .01$ .

Variable coefficients are reported with standard errors clustered by grid cell in parentheses. We do not report fixed effects due to space constraints.

<sup>1</sup> Natural log



TABLE A4  
DETERMINANTS OF GEOSPATIAL CONFLICT, 1992-2012 –  $K=7$

	500KM			Unlimited		
	Average intensity	Dispersion	Intraconnectivity	Average intensity	Dispersion	Intraconnectivity
	(20)	(21)	(22)	(23)	(24)	(25)
<i>Nighttime light<sub>it</sub></i>	0.077** (0.029)	0.799** (0.228)	3.865** (0.986)	−0.022 (0.028)	0.486* (0.261)	2.090* (1.129)
<i>Population<sub>it</sub></i> <sup>1</sup>	0.007** (0.002)	0.176** (0.019)	0.732** (0.081)	0.010** (0.002)	0.173** (0.020)	0.738** (0.086)
<i>Precipitation<sub>it</sub></i> <sup>1</sup>	0.029** (0.003)	0.105** (0.016)	0.456** (0.068)	0.024** (0.003)	0.102** (0.017)	0.452** (0.073)
<i>Drought<sub>it</sub></i>	0.021** (0.008)	0.034 (0.043)	0.196 (0.186)	0.023** (0.007)	0.156** (0.050)	0.792** (0.218)
<i>Temperature<sub>it</sub></i>	0.002** (0.001)	0.0004 (0.003)	−0.005 (0.013)	0.002** (0.001)	−0.009** (0.003)	−0.043** (0.014)
<i>Ethnic exclusion<sub>it</sub></i>	−0.005 (0.006)	0.011 (0.031)	0.155 (0.139)	−0.004 (0.005)	0.041 (0.042)	0.257 (0.188)
<i>DV<sub>t−1</sub></i>	0.625** (0.004)	0.779** (0.005)	0.759** (0.005)	0.669** (0.004)	0.790** (0.005)	0.773** (0.005)
Observations	1,040,428	1,040,428	1,040,428	1,040,428	1,040,428	1,040,428
R <sup>2</sup>	0.952	0.934	0.925	0.968	0.933	0.927
Adjusted R <sup>2</sup>	0.950	0.931	0.921	0.966	0.930	0.923

† indicates  $p < .1$ ; \* indicates  $p < .05$ ; \*\* indicates  $p < .01$ .

Variable coefficients are reported with standard errors clustered by grid cell in parentheses. We do not report fixed effects due to space constraints.

<sup>1</sup> Natural log

TABLE A5  
DETERMINANTS OF GEOSPATIAL CONFLICT, 1992-2012 –  $K=11$

	500KM			Unlimited		
	Average intensity	Dispersion	Intraconnectivity	Average intensity	Dispersion	Intraconnectivity
	(26)	(27)	(28)	(29)	(30)	(31)
<i>Nighttime light<sub>it</sub></i>	0.141** (0.043)	1.001** (0.238)	7.980** (1.600)	−0.004 (0.043)	0.754** (0.281)	5.425** (1.951)
<i>Population<sub>it</sub></i> <sup>1</sup>	0.013** (0.003)	0.216** (0.021)	1.485** (0.144)	0.016** (0.002)	0.194** (0.021)	1.364** (0.148)
<i>Precipitation<sub>it</sub></i> <sup>1</sup>	0.035** (0.003)	0.118** (0.017)	0.791** (0.116)	0.043** (0.003)	0.125** (0.020)	0.932** (0.133)
<i>Drought<sub>it</sub></i>	0.057** (0.011)	0.242** (0.055)	2.044** (0.367)	0.060** (0.009)	0.257** (0.062)	2.198** (0.417)
<i>Temperature<sub>it</sub></i>	0.001 (0.001)	0.0004 (0.004)	−0.008 (0.027)	0.003** (0.001)	−0.007 (0.004)	−0.044 (0.029)
<i>Ethnic exclusion<sub>it</sub></i>	−0.0003 (0.009)	0.008 (0.032)	0.238 (0.231)	−0.007 (0.007)	0.003 (0.041)	0.079 (0.293)
<i>DV<sub>t−1</sub></i>	0.670** (0.003)	0.753** (0.004)	0.734** (0.004)	0.721** (0.003)	0.779** (0.005)	0.759** (0.005)
Observations	1,040,428	1,040,428	1,040,428	1,040,428	1,040,428	1,040,428
R <sup>2</sup>	0.959	0.942	0.934	0.976	0.944	0.939
Adjusted R <sup>2</sup>	0.957	0.939	0.930	0.975	0.941	0.935

† indicates  $p < .1$ ; \* indicates  $p < .05$ ; \*\* indicates  $p < .01$ .

Variable coefficients are reported with standard errors clustered by grid cell in parentheses. We do not report fixed effects due to space constraints.

<sup>1</sup> Natural log