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Supplementary appendix

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Supplementary Material

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Table S1. Summary of the study periods, number of locations, deaths and TC in the 14 countries.

	Period	No. of deaths	No. of locations	Mean of TC days per decade (range)
Northern America				
USA	1973-2006	12178167	93	3 (1,9)
Canada	1986-2015	1092024	68	2 (1,4)
Latin America and the Caribbean				
Mexico	1998-2014	2551522	6	2 (1,3)
Guatemala	2009-2016	62715	1	3 (3,3)
French Caribbean	2000-2015	19986	1	4 (4,4)
Southern Europe				
Spain	1990-2014	141794	1	1 (1,1)
Eastern Asia				
China	2000-2018	2223501	11	19 (3,28)
Japan	1972-2015	11782631	49	11 (2,24)
South Korea	1997-2018	2401473	28	6 (2,16)
South-eastern Asia				
Philippines	2006-2019	726196	11	17 (12,17)
Thailand	1999-2008	102304	5	2 (1,2)
Vietnam	2009-2013	108173	2	5 (3,6)
Australia and New Zealand				
Australia	2009-2017	117247	43	3 (2,6)
New Zealand	2000-2018	167465	22	2 (1,2)
Overall		33675198	341	5 (1,28)

Abbreviations: TC, tropical cyclones.

Table S2. Average of tropical cyclone exposure days and change per decade between 1980-2019 by continent and UN-regions at the global $0.5^\circ \times 0.5^\circ$ resolution grid level.

	Average of TC days per decade (range)	Average of change in TC days per decade (range)
Globe	3 (1,35)	-0.06 (-7.20, 5.10)
Americas	2 (1,12)	0.19 (-3.20, 3.50)
Northern America	2 (1,11)	0.38 (-2.80, 3.20)
Latin America and the Caribbean	2 (1,12)	-0.07 (-3.20, 3.50)
Asia	3 (1,35)	0.03 (-7.20, 5.10)
Eastern Asia	4 (1,28)	-0.12 (-6.10, 4.20)
South-eastern Asia	4 (1,35)	-0.82 (-7.20, 1.70)
Southern Asia	3 (1,14)	0.74 (-3.00, 5.10)
Western Asia	1 (1,2)	0.18 (-0.50, 0.60)
Africa	3 (1,12)	-0.15 (-2.90, 1.80)
Sub-Saharan Africa	3 (1,12)	-0.15 (-2.90, 1.80)
Europe	1 (1,1)	0.20 (-2.50, 0.60)
Eastern Europe	1 (1,1)	0.22 (-0.60, 0.60)
Southern Europe	1 (1,1)	0.10 (0.10, 0.10)
Oceania	2 (1,17)	-0.48 (-6.30, 1.30)
Australia and New Zealand	2 (1,17)	-0.48 (-6.30, 1.30)
Other regions in Oceania	3 (1,12)	-0.22 (-1.60, 0.10)

Abbreviations: TC, tropical cyclone; UN-regions, regions grouping according to the UN Statistics Division (M49).

Table S3. Global cumulative relative risks of mortality associated with different tropical cyclone metrics over lag 0-14 days after excluding locations without all-cause mortality data (11 out of 341 locations).

Cyclone metrics	Threshold ^a	All-cause mortality
Two-category		
Tropical cyclone	≥ 17.5	1.06 (1.04, 1.08)
—	≥ 22.5	1.06 (1.03, 1.09)
—	≥ 27.5	1.09 (1.05, 1.12)
Three-category		
Gale to violent storm	17.5 – 32.8	1.05 (1.01, 1.09)
Hurricane	≥ 32.9	1.21 (1.11, 1.31)

^aDefined by the maximum windspeed (m/s) of peak sustained winds.

Table S4. Meta-analysis and meta-regression models for explaining variation in tropical cyclone short-term mortality effects across countries.

Model	P^a	I^2 (%)
None^b	<0.0001	88.6
Single predictor^c		
Continent	<0.0001	35.5
GDP per capita	<0.0001	77.4
Median population age	<0.0001	88.5
Population density	<0.0001	88.8
Gender ratio	<0.0001	89.4
Full^c	0.22	28.1

Abbreviations: GDP, gross domestic product.

^ap-value for Q test

^bmeta-regression model with one predictor at a time

^cmeta-regression model with all predictors

Table S5. Global and regional estimated excess deaths associated with TCs per 1000 deaths^a (with 95% eCIs).

	1980-1999	2000-2019	Overall (1980-2019)	Decadal change (%)
Global^b	3.4 (2.5, 4.5)	3.3 (2.3, 4.4)	3.3 (2.4, 4.3)	-1.4 (-8.3, 6.5)
Americas	8.2 (6.3, 10.4)	8.0 (6.1, 10.2)	8.1 (6.4, 10.1)	-1.3 (-7.0, 5.1)
Northern America	4.0 (2.8, 5.5)	2.8 (2.0, 3.6)	3.2 (2.4, 4.2)	-15.8 (-20.5, -10.1)
Latin America and the Caribbean	13.4 (10.4, 17.1)	18.2 (13.5, 24.1)	15.9 (12.3, 20.2)	17.9 (9.4, 27.5)
Asia	3.1 (2.1, 4.2)	3.0 (2.0, 4.1)	3.0 (2.1, 4.0)	-1.2 (-9.1, 8.1)
South-eastern Asia	8.0 (4.7, 12.2)	8.5 (5.5, 12.5)	8.3 (5.3, 11.9)	2.9 (-7.3, 15.9)
Southern Asia	3.8 (2.7, 5.2)	3.6 (2.8, 4.4)	3.7 (2.8, 4.6)	-3.8 (-9.5, 3.0)
Eastern Asia	1.7 (1.1, 2.4)	1.8 (0.8, 2.9)	1.8 (1.0, 2.6)	1.4 (-10.0, 14.6)
Oceania	3.9 (2.6, 5.5)	1.8 (0.9, 2.9)	3.1 (2.0, 4.3)	-26.6 (-31.5, -20.9)
Australia and New Zealand	5.3 (3.7, 7.1)	2.9 (1.7, 4.3)	4.6 (3.2, 6.1)	-22.6 (-27.6, -17.0)
Other regions in Oceania	0.6 (-0.7, 2.3)	0.8 (0.0, 1.7)	0.7 (-0.2, 1.9)	14.6 (-47.3, 22.3)

Abbreviations: eCI, empirical confidence intervals; TC, tropical cyclone.

^aAmong the TC-exposed grids.

^bAfrica, Europe, West Asia and Central Asia were excluded due to the absence of tropical cyclone exposure or deaths.

Table S6. Leading ten countries for TC-related excess deaths per 1000 deaths (with 95% eCIs) between 1980 and 2019.

Country	1980-1999	2000-2019	Overall (1998-2019)
Myanmar (Burma)	86.5 (62.4, 118.9)	88.0 (44.0, 157.2)	87.2 (54.8, 134.0)
Honduras	54.7 (44.5, 67.8)	34.0 (27.7, 41.3)	49.6 (40.7, 60.4)
Nicaragua	38.7 (31.0, 47.6)	53.6 (42.8, 66.1)	42.9 (34.7, 52.3)
Haiti	39.4 (31.8, 48.8)	44.6 (35.8, 55.0)	42.8 (34.8, 52.4)
Guatemala	36.9 (29.5, 45.8)	45.2 (36.4, 55.2)	38.7 (31.4, 47.4)
Cuba	12.6 (8.2, 18.5)	27.9 (15.3, 44.7)	22.0 (12.9, 33.9)
Bangladesh	18.4 (14.5, 23.1)	23.9 (21.0, 27.2)	21.1 (17.8, 24.9)
Dominican Republic	9.7 (7.0, 12.8)	13.7 (9.8, 18.3)	12.1 (8.9, 16.0)
Jamaica	6.4 (4.6, 8.4)	13.1 (9.2, 18.0)	11.2 (8.0, 15.0)
Belize	5.3 (3.9, 7.0)	9.5 (7.0, 12.5)	8.5 (6.4, 11.0)

Abbreviations: eCI, empirical confidence intervals; TC, tropical cyclone.

Table S7. TC-related average excess deaths per grid and TC day, average excess deaths per 100,000 residents and excess deaths per 1000 deaths (with 95% eCIs) by country income classification.

Income group ^a	1980-1999	2000-2019	Overall (1998-2019)
Average excess deaths per grid and TC day (95% eCIs)			
High	1.06 (0.79, 1.37)	1.30 (1.01, 1.61)	1.07 (1.33, 0.84)
Upper middle	4.34 (3.19, 5.60)	5.51 (3.46, 7.86)	4.53 (5.98, 3.22)
Lower middle	27.22 (20.94, 34.83)	26.29 (19.70, 34.20)	23.75 (29.99, 18.42)
Low	0.01 (0.00, 0.03)	0.01 (-0.01, 0.03)	0.01 (0.01, 0.02)
Average excess deaths per 100,000 residents (95% eCIs)			
High	4.94 (3.67, 6.38)	3.79 (2.56, 5.19)	7.19 (9.70, 4.97)
Upper middle	5.28 (3.83, 6.90)	6.69 (4.56, 9.17)	12.47 (16.27, 9.08)
Lower middle	15.44 (11.42, 20.09)	14.47 (11.09, 18.40)	30.55 (38.49, 23.57)
Low	0.01 (-0.01, 0.02)	0.01 (-0.01, 0.04)	0.02 (0.06, -0.02)
Average excess deaths per 1000 deaths (95% eCIs)			
High	3.57 (2.65, 4.61)	2.46 (1.65, 3.40)	2.69 (3.60, 1.89)
Upper middle	2.95 (2.18, 3.82)	4.14 (3.00, 5.45)	3.56 (4.52, 2.70)
Lower middle	10.59 (8.18, 13.41)	8.41 (6.50, 10.65)	9.65 (11.99, 7.61)
Low	0.01 (0.00, 0.02)	0.02 (-0.01, 0.05)	0.01 (0.05, -0.01)

Abbreviations: eCI, empirical confidence intervals; TC, tropical cyclone.

^aThe World Bank country income classification is based on gross national income per capita.

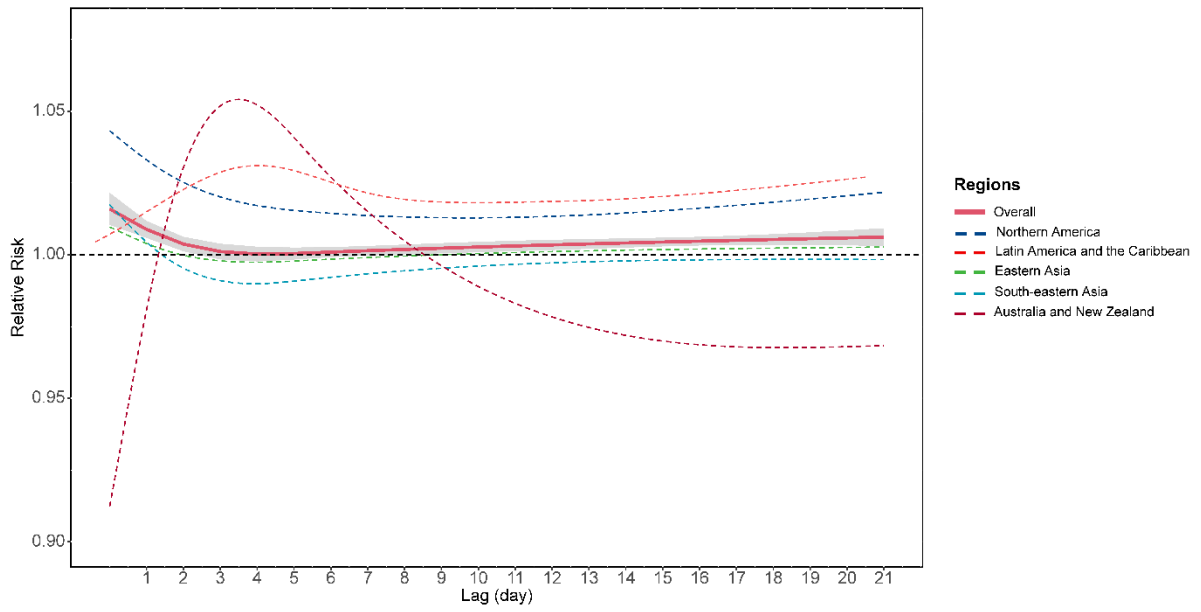


Fig. S1. Overall and regional lag effects of tropical cyclone on all-cause mortality along lag 0–21 day.

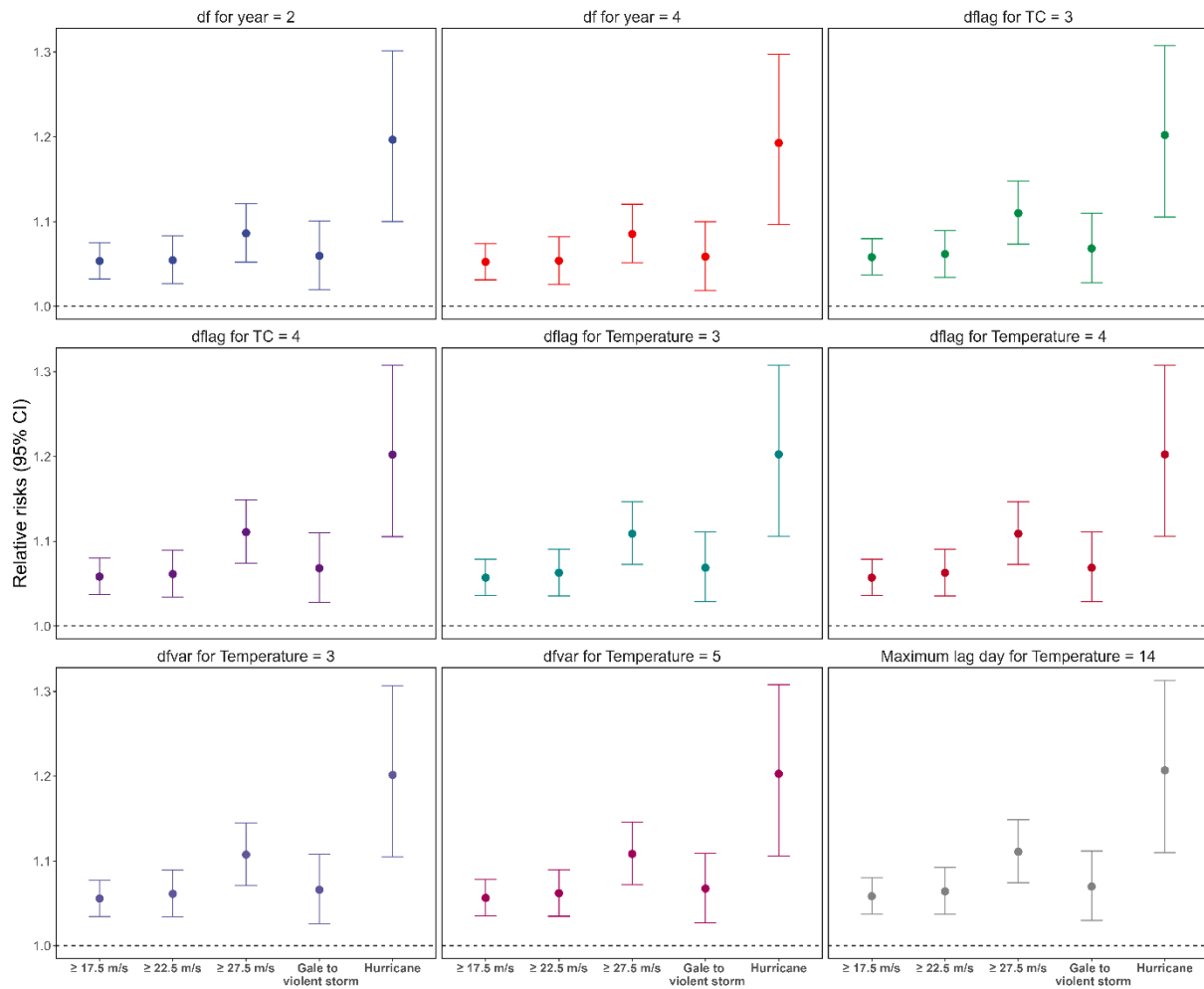


Fig. S2. Sensitivity analysis on mortality risks associated with tropical cyclone (TC) metrics defined as different thresholds of maximum sustained wind speed by re-specifying model. The TC metrics along the x-axis are two-category (e.g., ≥ 17.5 m/s versus < 17.5 m/s) or three-category (gale to violent storm [17.5 m/s- 32.9 m/s] and hurricane [≥ 32.9 m/s]) versus unexposed [< 17.5 m/s]). Abbreviations: df, degree of freedom; dfvar, df for predictor in the crossbasis term; dflag, df for lag effects in the crossbasis term.

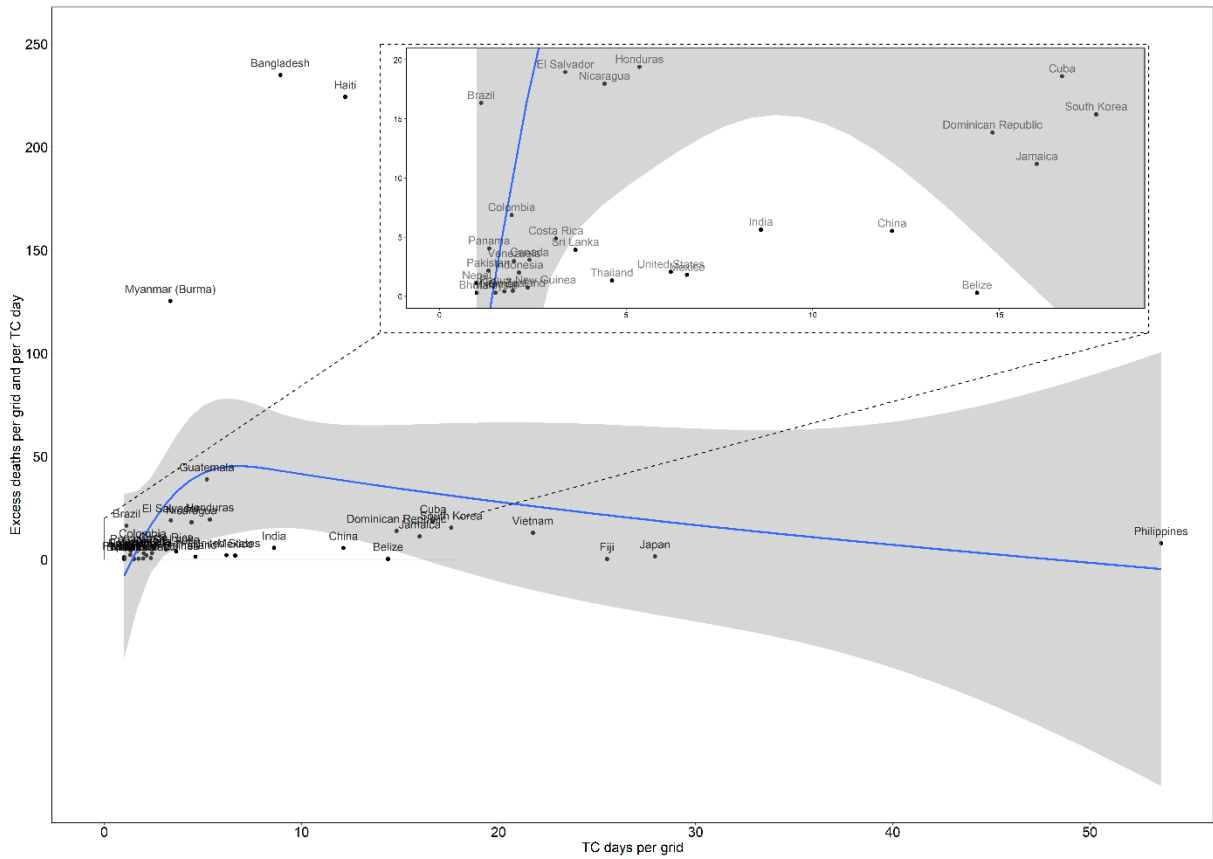


Fig. S3. The relationship of country-level tropical cyclone (TC)-related excess deaths per grid and per TC day with the number of TC days per grid among the TC-exposed grids over 1980-2019. The blue line (predicted value) and the shaded area (95% CI) were fitted using a linear model with a natural spline function of 3 degrees of freedom.