Supplemental Material Table of Contents

Table S1. Number of patients with missing baseline covariates

Characteristic	Number missing
Age	0
Female	25
Race/ethnicity	0
Year of dialysis initiation	0
Education college or above	5198
Percent below federal poverty level	5263
Monthly housing cost	5290

Table S2. Characteristics of hurricanes that brought hurricane-force winds to one or more study counties

Hurricane[a]	Year	Counties exposed, n[b]	Percent of exposed patients who died within 30 days of hurricane	Maximum sustained wind speed (knots), mean (range)[c]	Cumulative precipitation (mm), mean (range)[c,d]
Bonnie	1998	10	3.4	79.2 (64.3-93.1)	129.9 (84.1-166.0)
Earl	1998	1	0.0	64.8 (64.8-64.8)	211.7 (211.7-211.7)
Georges	1998	5	1.9	73.7 (68.5-83.3)	138.3 (87.9-165.4)
Bret	1999	4	5.0	68.6 (65.3-91.7)	153.7 (110.8-196.4)
Floyd	1999	10	1.6	71.2 (64.3-75.8)	134.4 (79.2-159.4)
Irene	1999	2	2.9	64.7 (64.4-65.0)	201.3 (158.6-233.6)
Lili	2002	3	3.0	67.9 (65.5-69.9)	133.8 (125.4-144.9)
Claudette	2003	2	5.0	65.8 (64.3-66.2)	88.1 (73.1-91.9)
Isabel	2003	11	1.2	68.0 (64.1-81.7)	117.2 (72.0-149.0)
Charley	2004	12	1.8	76.7 (67.1-107.3)	116.1 (79.4-146.7)
Frances	2004	5	1.3	69.5 (64.8-87.4)	122.9 (93.9-194.7)
Ivan	2004	5	1.5	77.8 (67.9-85.4)	121.6 (114.1-158.2)
Jeanne	2004	8	3.3	72.5 (66.2-98.1)	135.5 (101.4-161.9)
Dennis	2005	4	2.5	80.8 (74.6-87.0)	121.5 (116.2-137.4)
Katrina	2005	17	1.9	69.7 (64.4-97.0)	138.0 (80.9-197.2)
Rita	2005	5	2.9	75.7 (67.3-82.0)	206.8 (154.9-243.6)
Wilma	2005	4	2.2	73.0 (64.8-79.5)	69.1 (53.5-116.7)
Humberto	2007	2	1.1	67.0 (64.3-67.6)	118.7 (116.3-130.2)
Dolly	2008	1	0.0	64.3 (64.3-64.3)	149.7 (149.7-149.7)
Gustav	2008	12	1.6	71.3 (64.7-87.1)	178.0 (131.2-240.3)
Ike	2008	9	1.9	73.2 (65.5-88.8)	203.6 (104.5-235.8)
Irene	2011	3	3.3	67.1 (64.9-68.5)	253.9 (239.3-310.9)
Sandy[e]	2012	1	3.5	64.5 (64.5-64.5)	
Arthur[e]	2014	2	1.2	74.9 (69.3-76.2)	
Matthew[e]	2016	1	1.2	68.0 (68.0-68.0)	
Harvey[e]	2017	8	1.2	74.7 (68.5-103.2)	
Irma[e]	2017	9	1.5	73.3 (65.6-91.9)	

[a] Hurricane exposure is defined by exposure to a tropical cyclone that brought local peak wind speeds of ≥ 64 knots in the county of residence.

[b] Includes counties in which a dialysis-dependent patient lived at the time hurricane exposure

[c] Values in this column represent the mean and range across counties in which a dialysis-dependent patient lived at the time hurricane exposure.

[d] Cumulative precipitation is a sum of daily precipitation from 5 days before to 3 days after the hurricane.

[e] Precipitation data are unavailable for the hurricane.

Table S3. Multiplicative effect modification terms for the association of hurricanes and mortality by subgroup

Covariate	Effect modification term hazard ratio, 95% confidence interval	P value for effect modification
Sex		
Male	Reference	
Female	0.90 (0.78 to 1.04)	0.17
Race and ethnicity		
Hispanic	1.00 (0.81 to 1.24)	0.97
Non-Hispanic Black	1.17 (1.00 to 1.37)	0.05
Non-Hispanic White	Reference	
Other	1.19 (0.68 to 2.08)	0.53
Year of dialysis initiation		
1997-2003	Reference	
2004-2010	0.89 (0.76 to 1.04)	0.13
2011-2017	0.99 (0.76 to 1.29)	0.92
Cause of ESKD		
Diabetes	Reference	
Hypertension	1.01 (0.86 to 1.19)	0.88
Glomerulonephritis	1.06 (0.78 to 1.43)	0.72
Other	1.03 (0.83 to 1.28)	0.77
Dialysis modality		
In-center hemodialysis	Reference	
Combined home modalities[a]	1.05 (0.79 to 1.39)	0.74
Percent below federal poverty level		
Quartile 1	Reference	
Quartile 2	1.03 (0.84 to 1.27)	0.75
Quartile 3	1.08 (0.88 to 1.32)	0.45
Quartile 4	1.12 (0.92 to 1.37)	0.25

[a] Combined home hemodialysis and peritoneal dialysis. Unknown dialysis modality excluded from effect modification analysis due to insufficient outcomes. ESKD, end stage kidney disease.

Table S4. Multiplicative effect modification terms for the association of hurricanes and mortality by state of residence.

State[a]	Effect modification term hazard ratio, 95% confidence interval	P value for effect modification
Alabama	Reference	
Florida	1.26 (0.67 to 2.36)	0.47
Louisiana	0.88 (0.44 to 1.73)	0.70
Mississippi	1.33 (0.62 to 2.88)	0.46
New Jersey	1.78 (0.85 to 3.74)	0.13
North Carolina	1.37 (0.65 to 2.88)	0.41
South Carolina	1.23 (0.50 to 3.03)	0.66
Texas	1.24 (0.65 to 2.35)	0.52

[a] Georgia and Virginia were excluded from effect modification analysis due to insufficient outcomes.

Table S5. Associations of hurricane exposure and mortality across varied post-storm mortality periods among dialysis-dependent patients in the United States Renal Data Systems population from 1997 to 2017

Post-storm exposure period	Demographic and socioeconomic status-adjusted model[a]	
	Hazard ratio (95% confidence interval)	P value
1 day	2.02 (1.51 to 2.69)	<0.001
3 days	1.59 (1.31 to 1.92)	<0.001
7 days	1.32 (1.15 to 1.51)	<0.001
14 days	1.17 (1.06 to 1.30)	0.002
30 days	1.13 (1.05 to 1.22)	<0.001
60 days	1.04 (0.99 to 1.10)	0.16
90 days	1.03 (0.98 to 1.07)	0.28

[a] Adjusted for age, sex, race and ethnicity, year of dialysis initiation, educational attainment, poverty level, and monthly housing cost

Table S6. Characteristics of tropical storms or hurricanes that brought gale-force or higher winds to one or more study counties

Tropical storm/hurricane[a]	Year	Counties exposed, n[b]	Percent of exposed patients who died within 30 days of tropical storm/hurricane	Maximum sustained wind speed (knots), mean (range)[c]	Cumulative precipitation (mm), mean (range)[c,d]
Danny	1997	53	2.1	44.3 (34.3-58.4)	73.9 (31.1-175.9)
Bonnie	1998	80	0.7	46.7 (34.1-93.1)	56.4 (1.2-166.0)
Charley	1998	2	0.0	36.2 (36.2-36.5)	113.7 (110.6-125.5)
Earl	1998	140	1.9	41.2 (34.4-64.8)	80.3 (30.7-214.1)
Frances	1998	15	1.5	36.6 (34.0-43.6)	70.1 (30.2-156.3)
Georges	1998	49	1.9	51.2 (34.8-83.3)	72.3 (4.2-264.0)
Mitch	1998	10	2.5	42.0 (36.1-51.5)	81.0 (65.6-109.5)
Bret	1999	20	1.7	52.8 (34.2-91.7)	107.5 (34.3-196.4)
Dennis	1999	28	1.3	40.2 (34.6-54.5)	153.7 (46.1-262.1)
Floyd	1999	161	2.1	43.1 (34.1-75.8)	138.6 (32.9-222.8)
Harvey	1999	3	2.0	40.5 (35.3-44.7)	108.4 (102.0-139.2)
Irene	1999	29	2.4	55.3 (34.8-65.0)	179.2 (18.4-242.6)
Gordon	2000	16	2.1	37.7 (34.3-46.8)	93.2 (56.7-121.3)
Helene	2000	17	1.6	35.6 (34.0-39.9)	112.6 (70.5-166.6)
Allison	2001	20	1.8	36.9 (34.2-41.3)	226.3 (46.0-387.7)
Barry	2001	27	2.2	41.8 (34.4-51.8)	76.1 (39.6-151.3)
Gabrielle	2001	21	2.2	41.0 (35.5-54.9)	149.9 (108.7-186.0)
Fay	2002	4	4.0	36.5 (34.7-45.2)	134.6 (85.5-153.2)
Gustav	2002	2	3.7	36.2 (35.6-36.9)	43.3 (41.6-44.6)
Hanna	2002	7	1.7	39.5 (35.7-42.4)	40.2 (20.9-50.5)
Isidore	2002	36	1.5	43.1 (34.3-50.5)	262.4 (80.4-348.4)
Lili	2002	44	2.2	44.6 (34.1-69.9)	90.0 (13.6-144.9)
Bill	2003	18	1.9	42.5 (34.2-45.3)	209.4 (84.8-278.8)
Claudette	2003	43	1.8	38.7 (34.1-66.2)	44.1 (11.3-137.9)
Erika	2003	3	1.0	42.7 (38.8-47.9)	50.0 (45.9-53.2)
Grace	2003	1	10.7	34.7 (34.7-34.7)	176.2 (176.2-176.2)

Isabel	2003	157	1.6	45.2 (34.3-81.7)	89.8 (37.9-198.1)
Alex	2004	23	0.4	39.6 (34.9-51.7)	77.2 (54.0-118.9)
Charley	2004	84	1.3	50.7 (34.2-107.3)	94.7 (47.3-192.0)
Frances	2004	56	1.4	48.0 (34.1-87.4)	151.5 (47.3-313.3)
Gaston	2004	34	1.6	41.4 (34.0-59.3)	81.4 (10.7-204.7)
Ivan	2004	56	1.8	52.2 (34.1-85.4)	108.2 (15.0-188.6)
Jeanne	2004	48	2.2	50.5 (34.0-98.1)	114.2 (37.9-191.9)
Arlene	2005	4	1.8	38.8 (36.7-43.5)	109.0 (87.5-116.9)
Cindy	2005	19	1.8	41.7 (34.2-54.3)	154.2 (46.9-207.6)
Dennis	2005	44	1.8	51.8 (34.3-87.0)	145.9 (85.3-237.8)
Emily	2005	4	1.6	42.6 (37.1-45.3)	124.2 (80.6-149.2)
Katrina	2005	96	1.8	57.8 (34.7-97.0)	108.4 (16.3-197.2)
Ophelia	2005	26	1.5	39.5 (34.4-54.6)	76.9 (16.1-185.0)
Rita	2005	44	1.8	42.8 (34.3-82.0)	77.6 (9.7-284.6)
Tammy	2005	11	2.2	38.2 (34.3-39.3)	138.0 (91.8-284.9)
Wilma	2005	18	2.1	65.4 (34.2-79.5)	95.8 (53.5-224.0)
Alberto	2006	19	1.5	34.9 (34.1-37.2)	94.2 (50.2-136.0)
Ernesto	2006	92	1.5	36.4 (34.2-47.0)	148.4 (44.9-246.8)
Barry	2007	14	1.4	36.5 (34.2-37.7)	74.7 (30.9-122.9)
Erin	2007	26	1.8	36.8 (34.6-47.7)	129.6 (15.4-189.7)
Gabrielle	2007	10	1.1	37.7 (34.9-42.4)	26.4 (2.5-88.4)
Humberto	2007	38	1.7	45.7 (34.1-67.6)	40.8 (4.1-137.2)
Dolly	2008	14	1.6	49.1 (34.2-64.3)	125.1 (30.4-184.3)
Edouard	2008	16	1.6	37.3 (34.5-50.6)	79.7 (23.3-89.3)
Fay	2008	61	1.7	41.5 (34.1-58.7)	214.4 (54.8-402.7)
Gustav	2008	59	1.7	54.9 (34.1-87.1)	169.9 (57.0-287.6)
Hanna	2008	144	1.5	38.6 (34.0-55.2)	93.1 (19.8-150.9)
Ike	2008	242	1.8	48.7 (34.1-88.8)	111.3 (11.7-235.8)
Kyle	2008	1	4.0	35.3 (35.3-35.3)	88.2 (88.2-88.2)
Claudette	2009	6	2.1	35.4 (34.1-37.8)	86.1 (66.4-138.3)
Hermine	2010	22	1.5	39.3 (34.3-51.8)	132.1 (56.5-221.9)

Irene	2011	157	1.6	45.4 (34.0-68.5)	167.1 (57.3-310.9)
Lee	2011	34	1.4	36.7 (34.2-39.9)	237.9 (61.4-312.8)
Beryl[e]	2012	27	1.3	38.3 (34.0-51.0)	
Isaac[e]	2012	53	1.4	48.4 (34.5-63.3)	
Sandy[e]	2012	116	1.6	46.6 (34.0-64.5)	
Andrea[e]	2013	81	1.3	37.9 (34.0-40.5)	
Arthur[e]	2014	55	1.2	41.5 (34.3-76.2)	
Ana[e]	2015	5	1.2	36.6 (34.3-38.7)	
Bill[e]	2015	14	1.2	40.8 (34.1-49.9)	
Colin[e]	2016	20	1.7	41.4 (34.6-44.9)	
Hermine[e]	2016	130	1.2	44.0 (34.0-63.1)	
Julia[e]	2016	20	0.9	39.1 (34.5-44.1)	
Matthew[e]	2016	94	1.4	45.8 (34.0-68.0)	
Cindy[e]	2017	11	1.4	39.7 (35.8-44.1)	
Emily[e]	2017	5	1.5	36.1 (34.9-37.4)	
Harvey[e]	2017	45	1.2	43.0 (34.1-103.2)	
Irma[e]	2017	72	1.6	47.8 (34.1-91.9)	
Nate[e]	2017	33	1.4	43.8 (34.1-60.6)	

[a] Tropical storm/hurriane exposure is defined by exposure to a tropical cyclone with local peak wind speeds of ≥ 34 knots in the county of residence.

[b] Includes counties in which a dialysis-dependent patient lived at the time tropical storm/hurricane exposure

[c] Values in this column represent the mean and range across counties in which a dialysis-dependent patient lived at the time tropical storm/hurricane exposure.

[d] Cumulative precipitation is a sum of daily precipitation from 5 days before to 3 days after the tropical storm/hurricane

[e] Precipitation data are unavailable for the tropical storm/hurricane

Table S7. Associations of tropical storm/hurricane exposure and mortality across varied post-storm mortality periods among dialysis-dependent patients in the United States Renal Data Systems population from 1997 to 2017

Post-storm exposure period	Demographic and socioeconomic status-adjusted model[a]	
	Hazard ratio (95% confidence interval)	P value
1 day	2.14 (1.99 to 2.31)	<0.001
3 days	1.41 (1.34 to 1.49)	<0.001
7 days	1.16 (1.12 to 1.21)	<0.001
14 days	1.07 (1.04 to 1.10)	<0.001
30 days	1.02 (1.00 to 1.05)	0.02
60 days	1.01 (0.99 to 1.02)	0.31
90 days	1.02 (1.01 to 1.03)	0.001

[a] Adjusted for age, sex, race and ethnicity, year of dialysis initiation, educational attainment, poverty level, and monthly housing cost

Figure S1. Schematic of time-varying hurricane exposure and 30-day mortality with examples to illustrate exposure and outcome
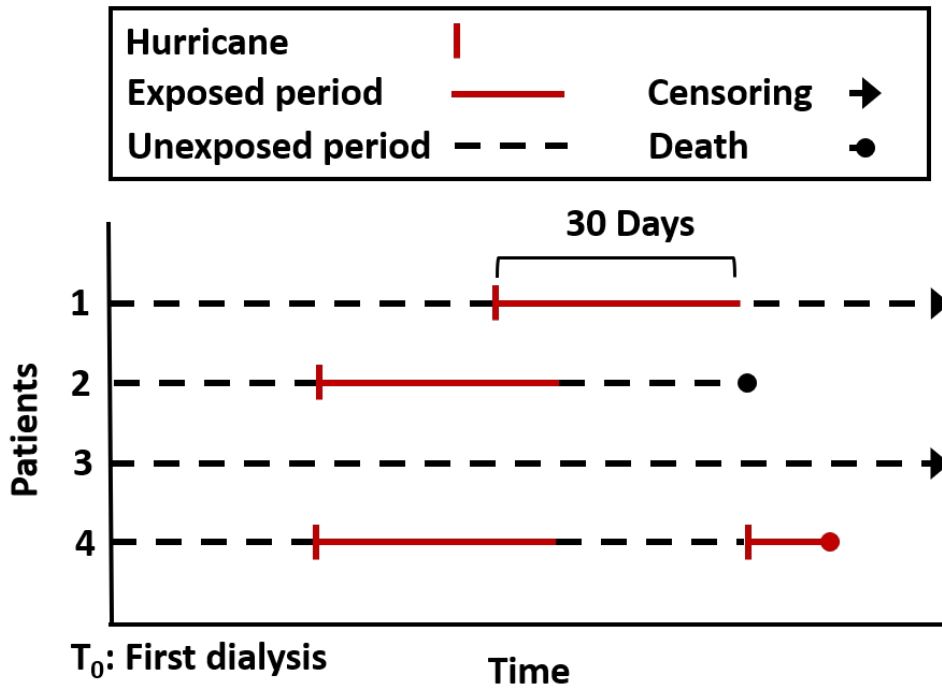
Patient 1 experiences a hurricane and is censored following the 30-day mortality period. Patient 2 experiences a hurricane and dies following the 30-day mortality period. Patient 3 is unexposed to a hurricane. Patient 4 dies within the 30-day mortality period following their second hurricane exposure.

Figure S2. Adjusted survival of dialysis-dependent patients in the United States living in a county with a hurricane exposure from 1997 to 2017, delineated by county among counties with the 25th to 75th percentile adjusted survival
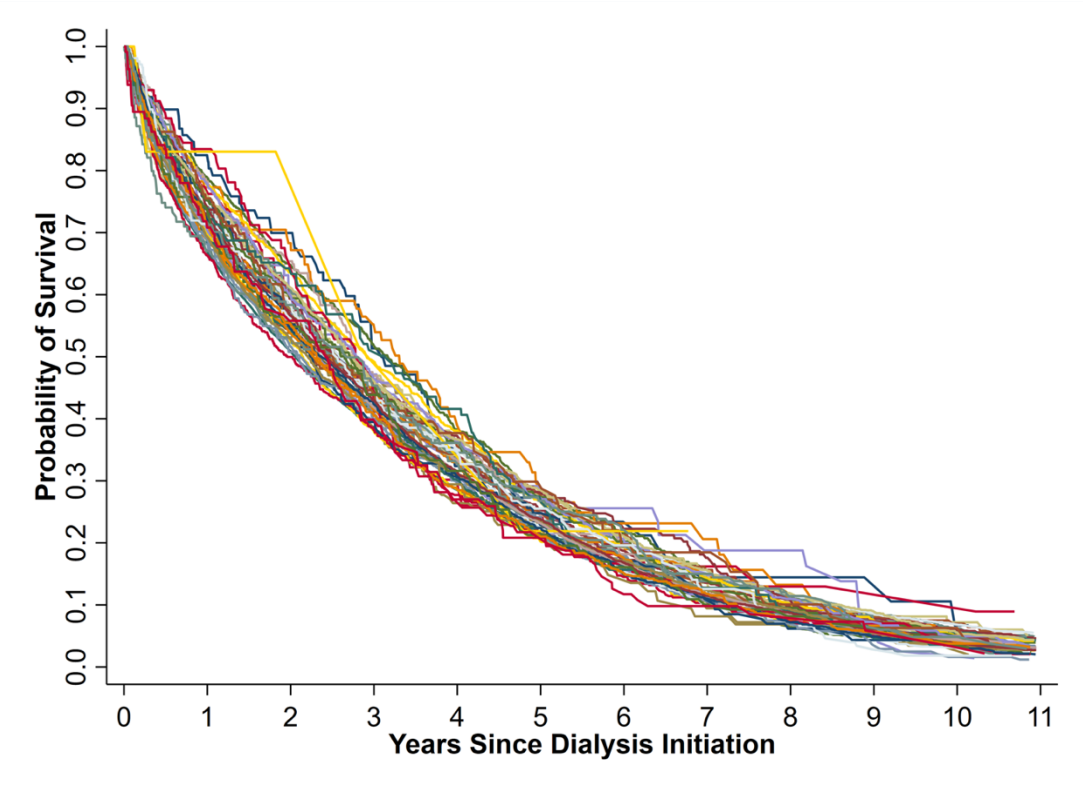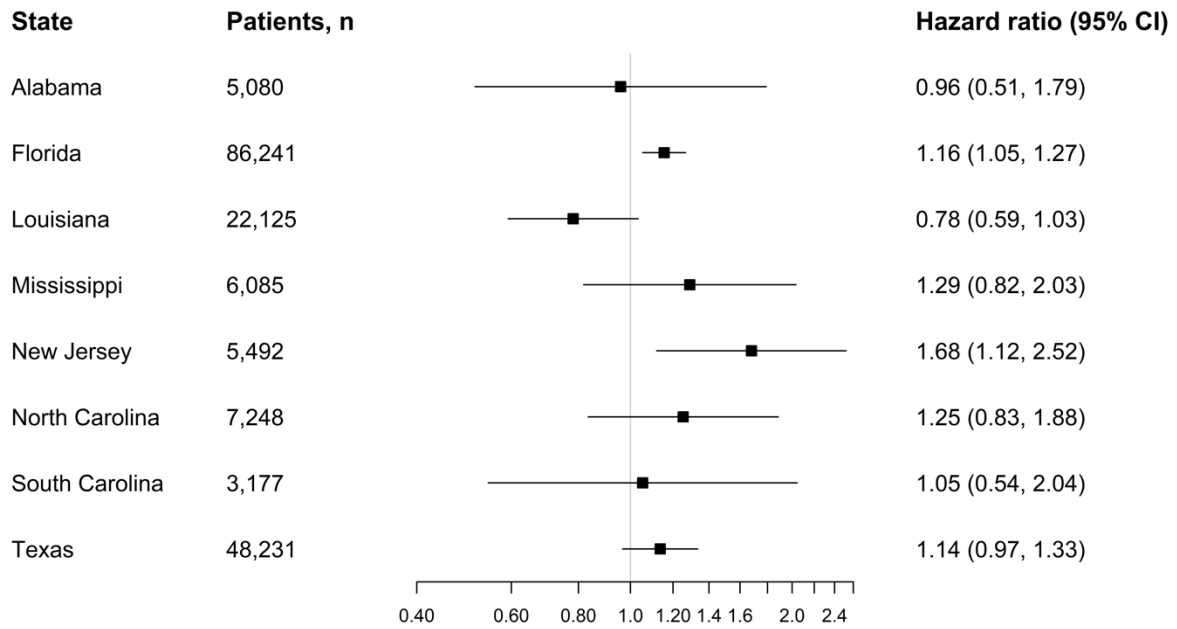
Figure S3. Forest plot demonstrating the associations of hurricane exposure and mortality in dialysis-dependent patients in the United States from 1997 to 2017, stratified by state

State	Patients, n		Hazard ratio (95% CI)
Alabama	5,080		0.96 (0.51, 1.79)
Florida	86,241		1.16 (1.05, 1.27)
Louisiana	22,125		0.78 (0.59, 1.03)
Mississippi	6,085		1.29 (0.82, 2.03)
New Jersey	5,492		1.68 (1.12, 2.52)
North Carolina	7,248		1.25 (0.83, 1.88)
South Carolina	3,177		1.05 (0.54, 2.04)
Texas	48,231		1.14 (0.97, 1.33)

0.40   0.60   0.80   1.0 1.20 1.4 1.6   2.0   2.4

Note: Georgia and Virginia were excluded from the forest plot due to insufficient outcomes

Figure S4. Map of the number of patient-tropical storm/hurricanes experienced by dialysis-dependent patients in the United States by county from 1997 to 2017. Tropical storm/hurricane exposure is defined by exposure to a tropical cyclone with local peak wind speeds of ≥ 34 knots in the county of residence.
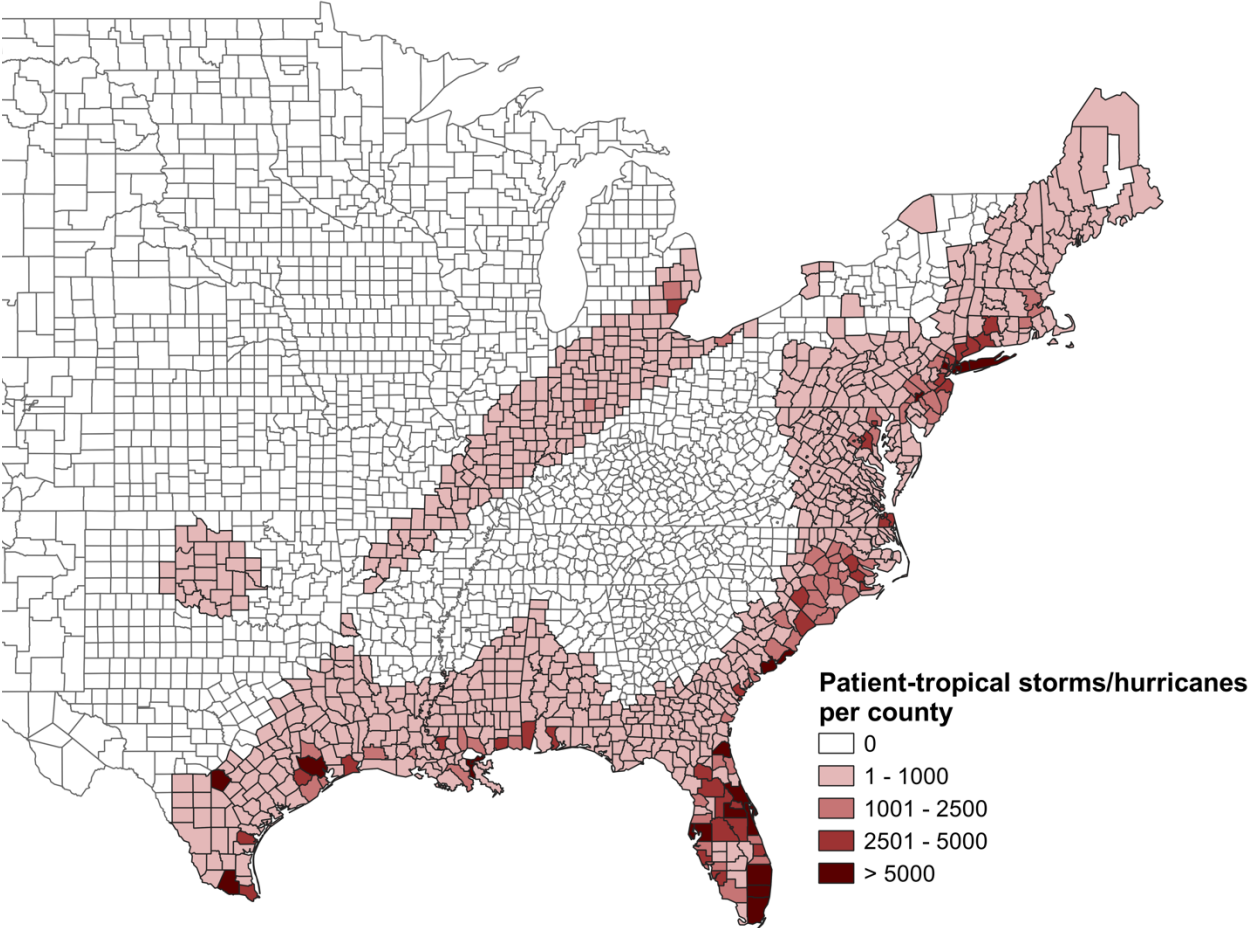

Patient-tropical storms/hurricanes per county
- 0
- 1 - 1000
- 1001 - 2500
- 2501 - 5000
- > 5000

Figure S5. Tropical storm/hurricane-associated mortality hazard ratios across varying post-storm mortality periods