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Supplementary Materials for

Rapidly expanding nuclear arsenals in Pakistan and India portend regional and global catastrophe

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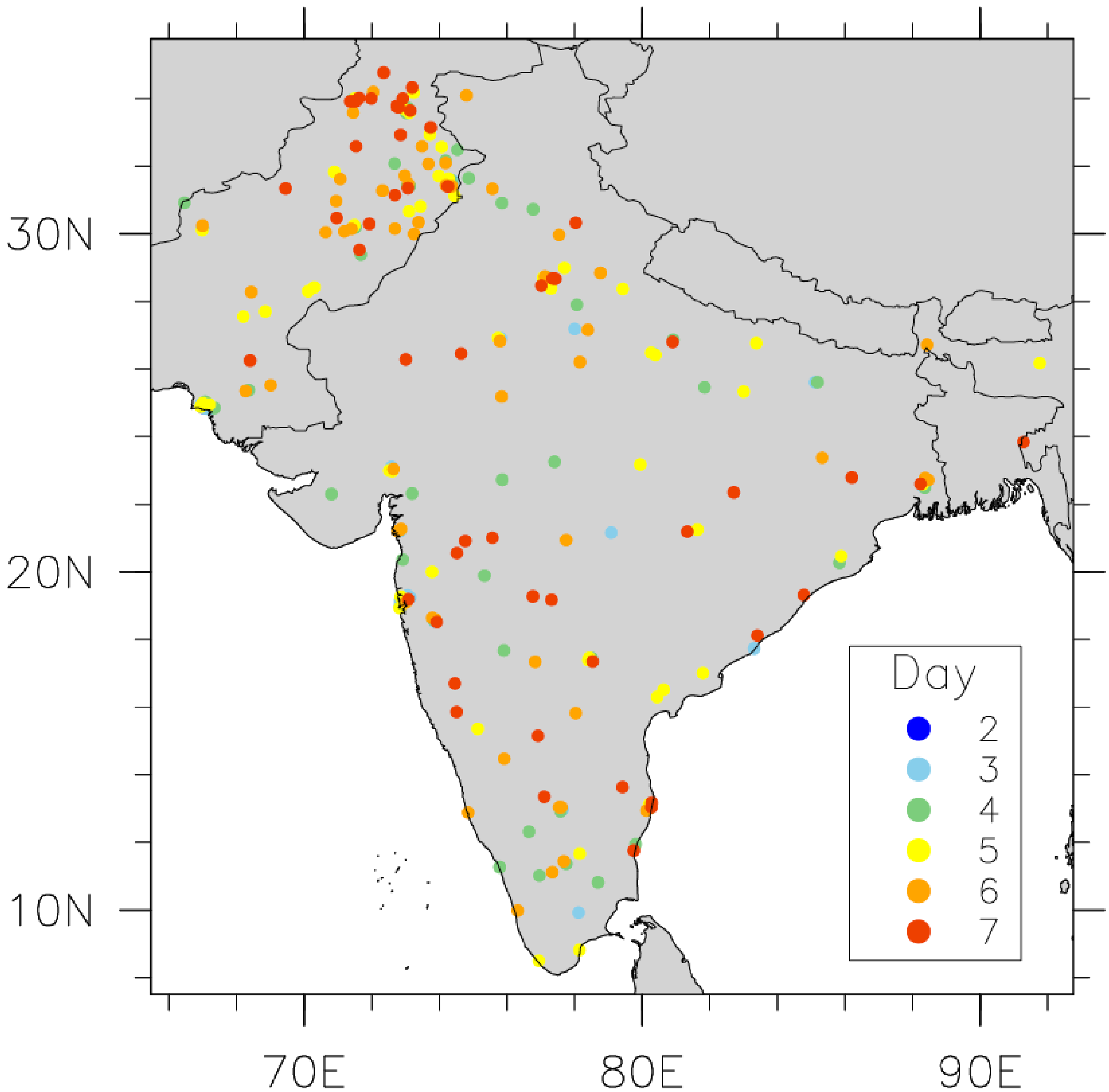

Fig. S1. Urban targets in table S1 scenario for 50-kt weapons. Different colors represent different days of the war. No urban targets are attacked on Day 1. In dense urban areas, some of the dots overlap on the low spatial resolution of fig. S1, for instance in Karachi on the southern coast of Pakistan.

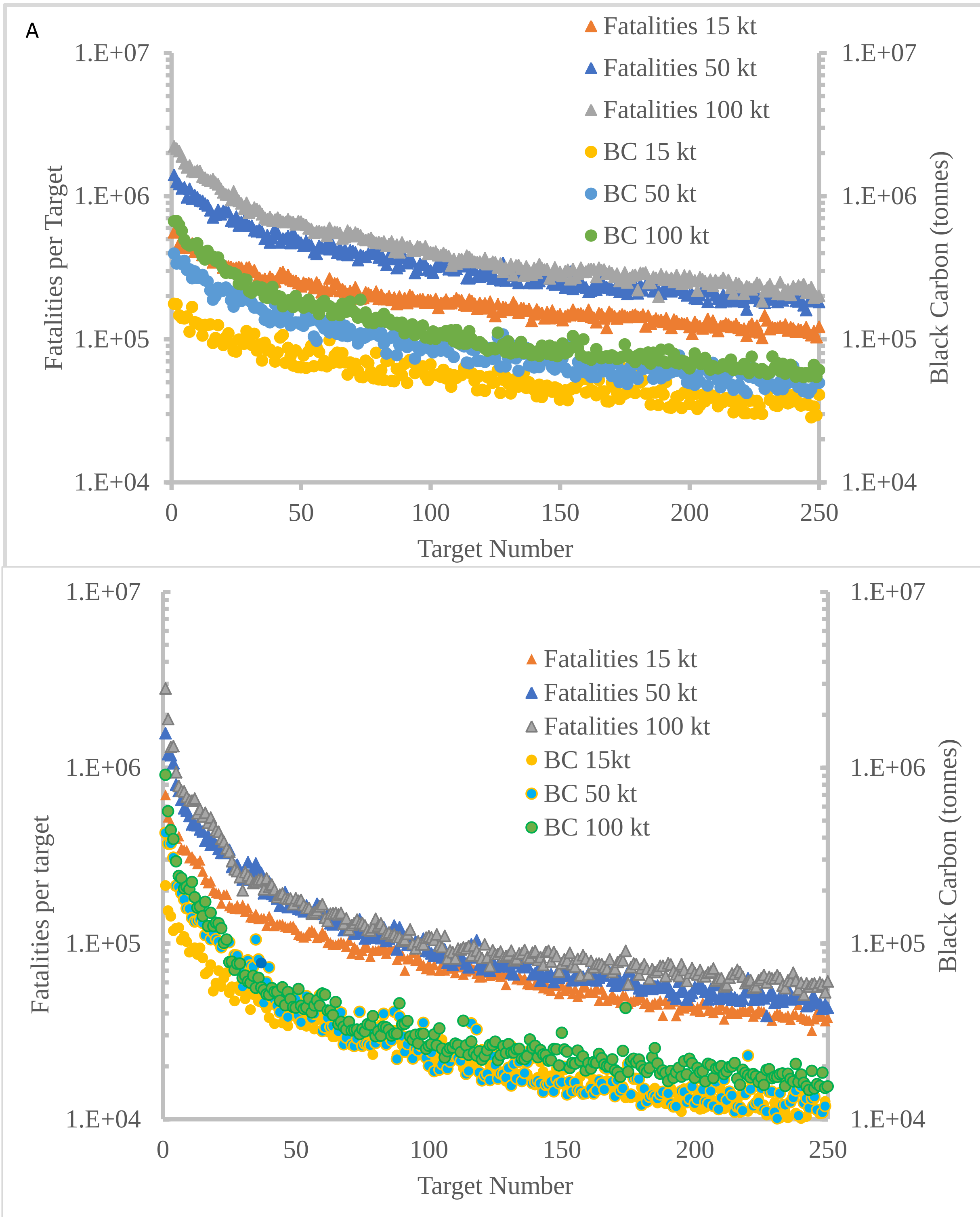

Fig. S2. Fatalities and BC emissions from individual targets in (A) India, (B) Pakistan, where the first 250 potential targets have been ordered by population density (refer to the Methods Section in the main text for a discussion of target point selection).

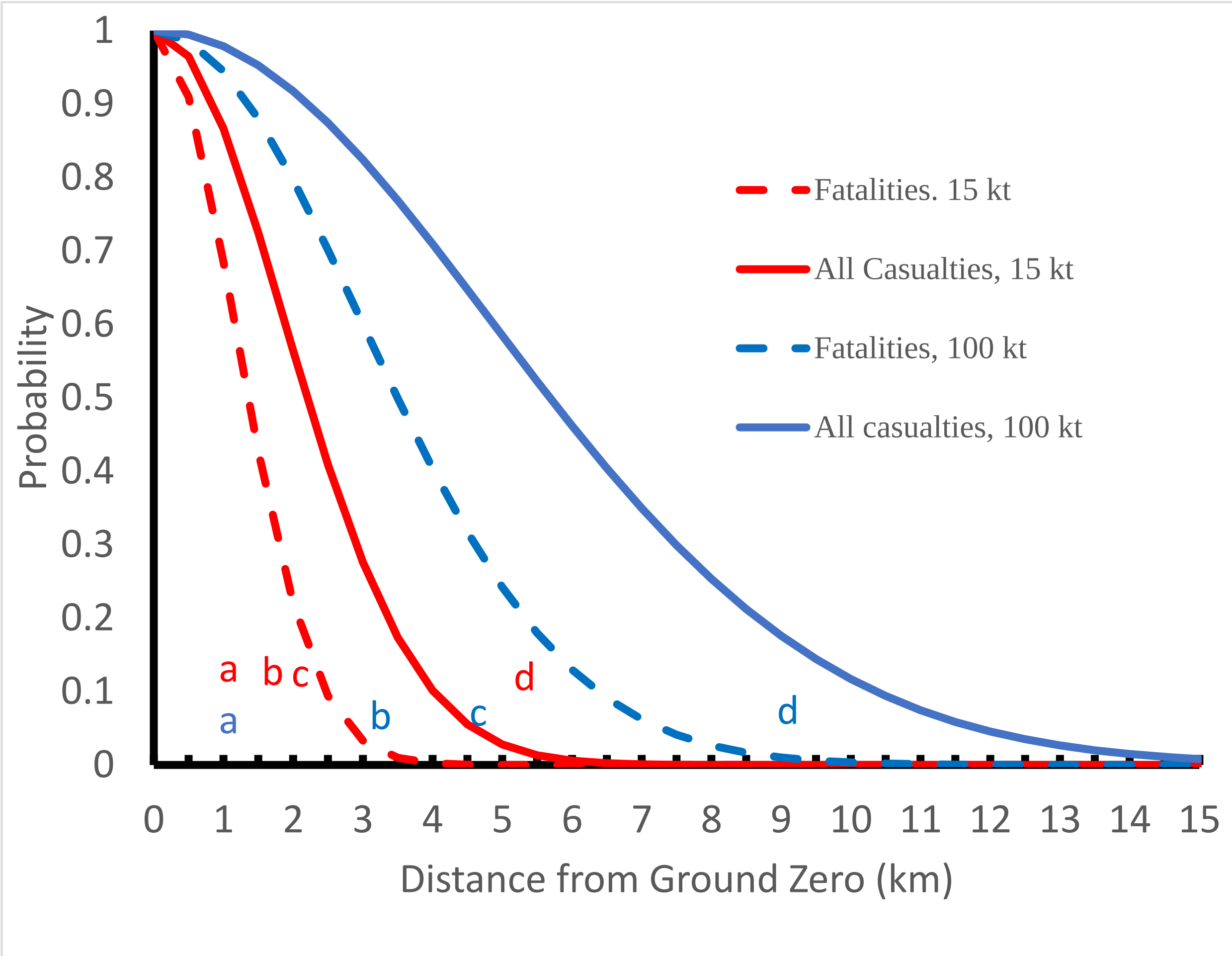

Fig. S3. Probability of fatalities or casualties as a function of distance from ground zero for 15 kt (red) and 100 kt (blue) air bursts at the optimum altitude to cause 5 psi (345 hPa) blast damage, based on data from Hiroshima and Nagasaki during WWII (*16*). The WWII data were fit to Gaussian functions whose widths (i.e., the scaling factors for the range from ground zero) are assumed to increase proportionally to the square root of the weapon yield (where we note that this assumption is equivalent to the adopted scaling of the area of initial fire ignition as being proportional to yield for airbursts) (*15*, *14*6. While the probability curves are empirical, they are also closely related to the distances at which various physical phenomena occur that are likely to cause injuries. These distances are indicated in the figure by the following letters (color coded according to blast yield, as above): (a) a 500 rem prompt radiation dose, which would be fatal to 50% of the exposed population; (b) a 5 psi. shock wave overpressure, which would destroy residential and other poorly reinforced buildings; (c) a 10 cal/cm^2 (4.2x10^5 J/m^2) thermal pulse, which would cause serious burns and ignite easily flammable materials; and (d) a 1 psi. shock wave, which would blow out glass windows and create dangerous shrapnel fields.

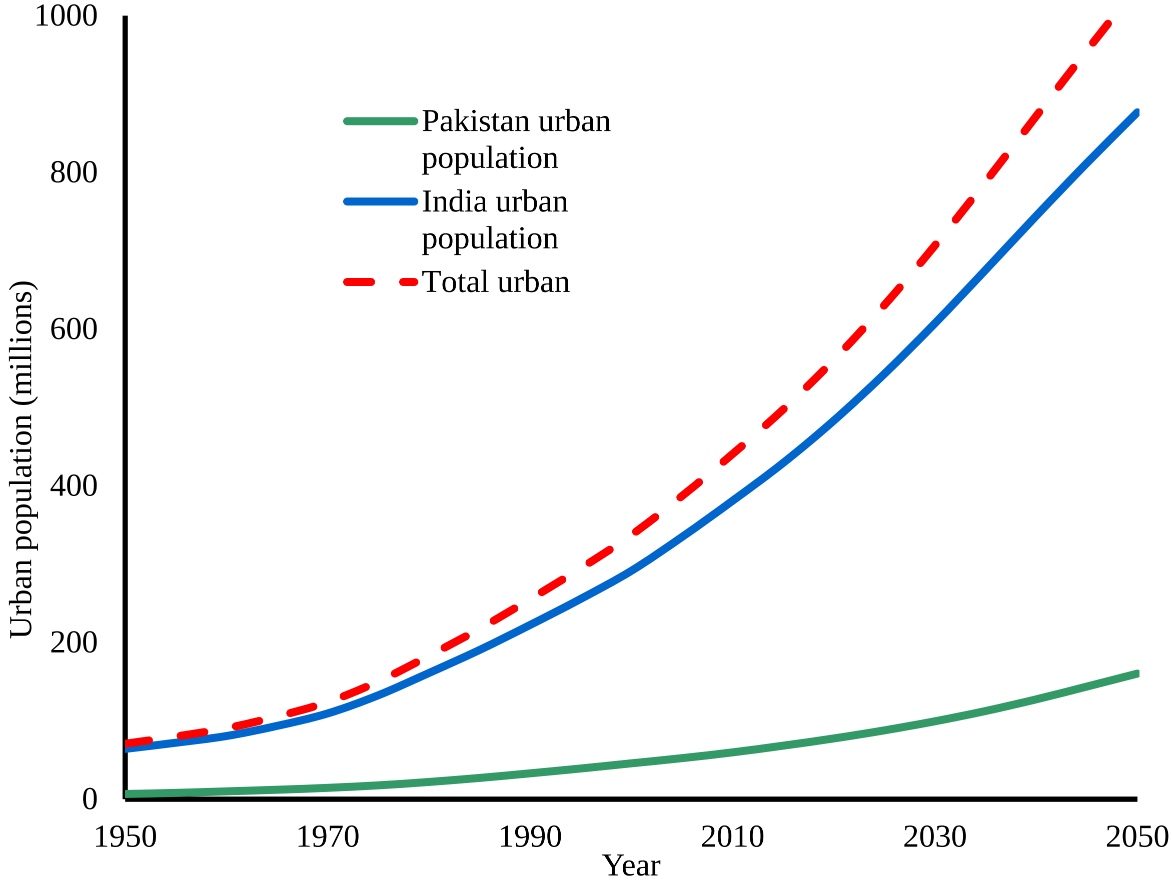

Fig. S4. Estimated urban populations of India, Pakistan, and total for both nations (*19*).

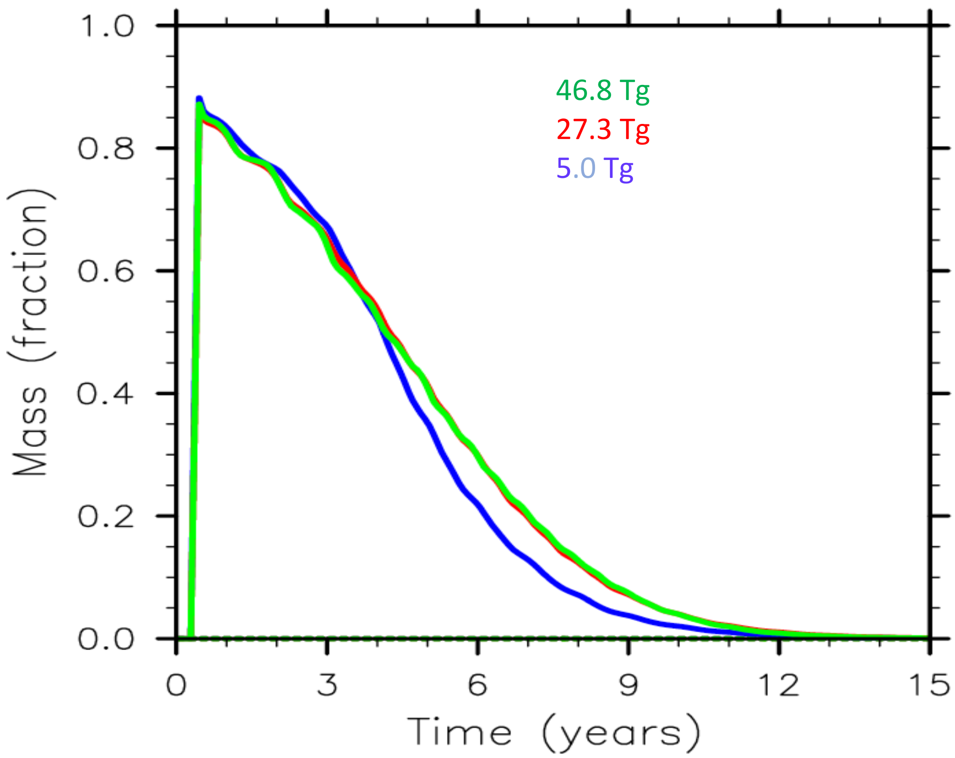

Fig. S5. Fraction of the injected smoke remaining in the atmosphere as a function of time. Note that 20% of the BC was assumed to be removed during the initial injection process, presumably as "black rain." The figure indicates that another roughly 10-15% of the BC is removed by precipitation generated by the climate model during the first few days. In total, 30-35% of the BC is removed before it has a chance to be lofted into the stratosphere.

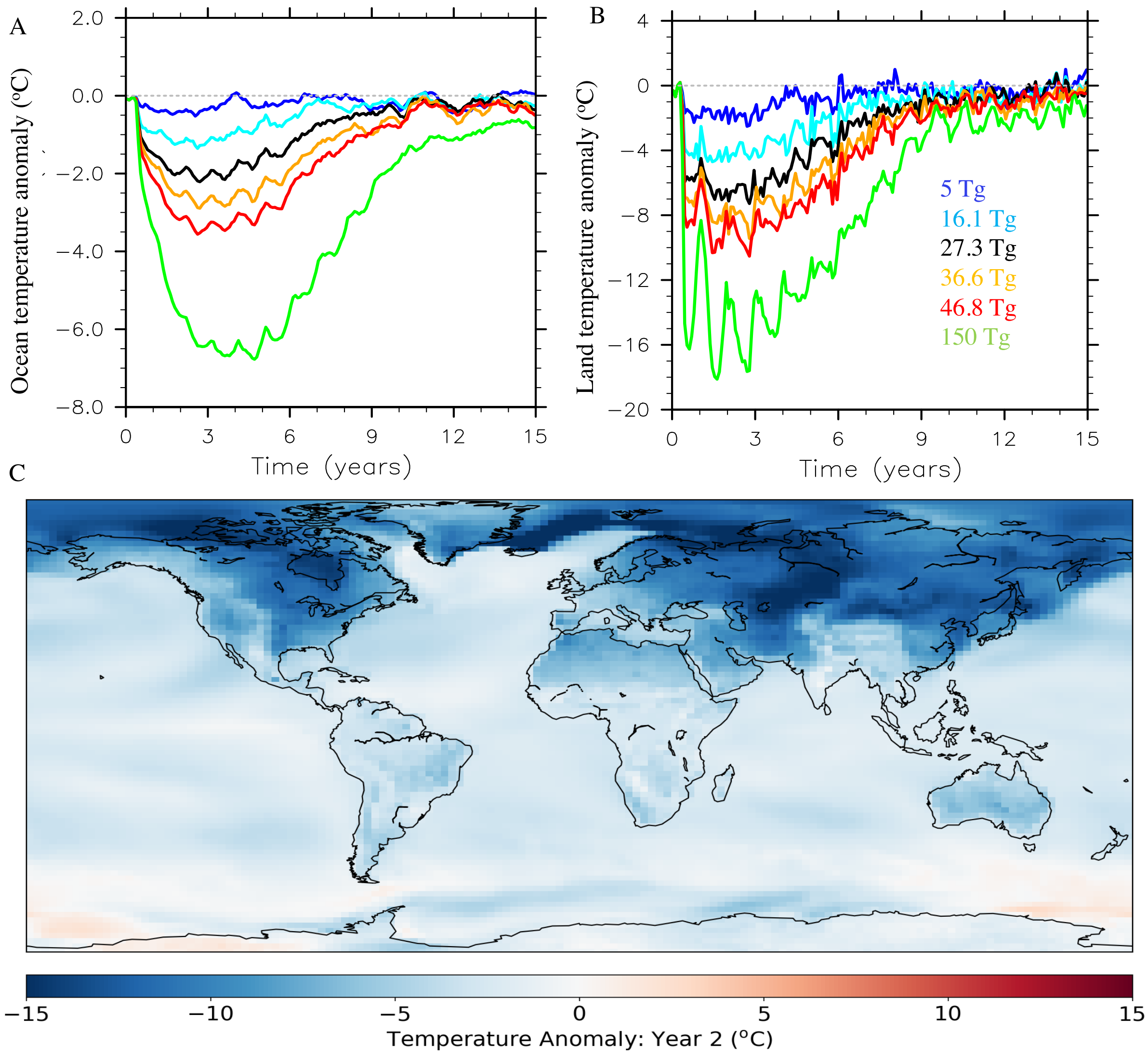

Fig. S6. Decline in ocean surface temperature (A) and land surface temperature (B) as a function of time. Color-coding designates the assumed black carbon (BC) injections. The ocean surface temperatures apply to a layer that can deepen over time to a few hundred meters as the heat deficit propagates downward. Panel C illustrates the global distribution of changes in ocean and land surface temperatures averaged over the second year following a conflict beginning in May of year one for the scenario with 50 kt weapons and a 27.3 Tg injection of BC.

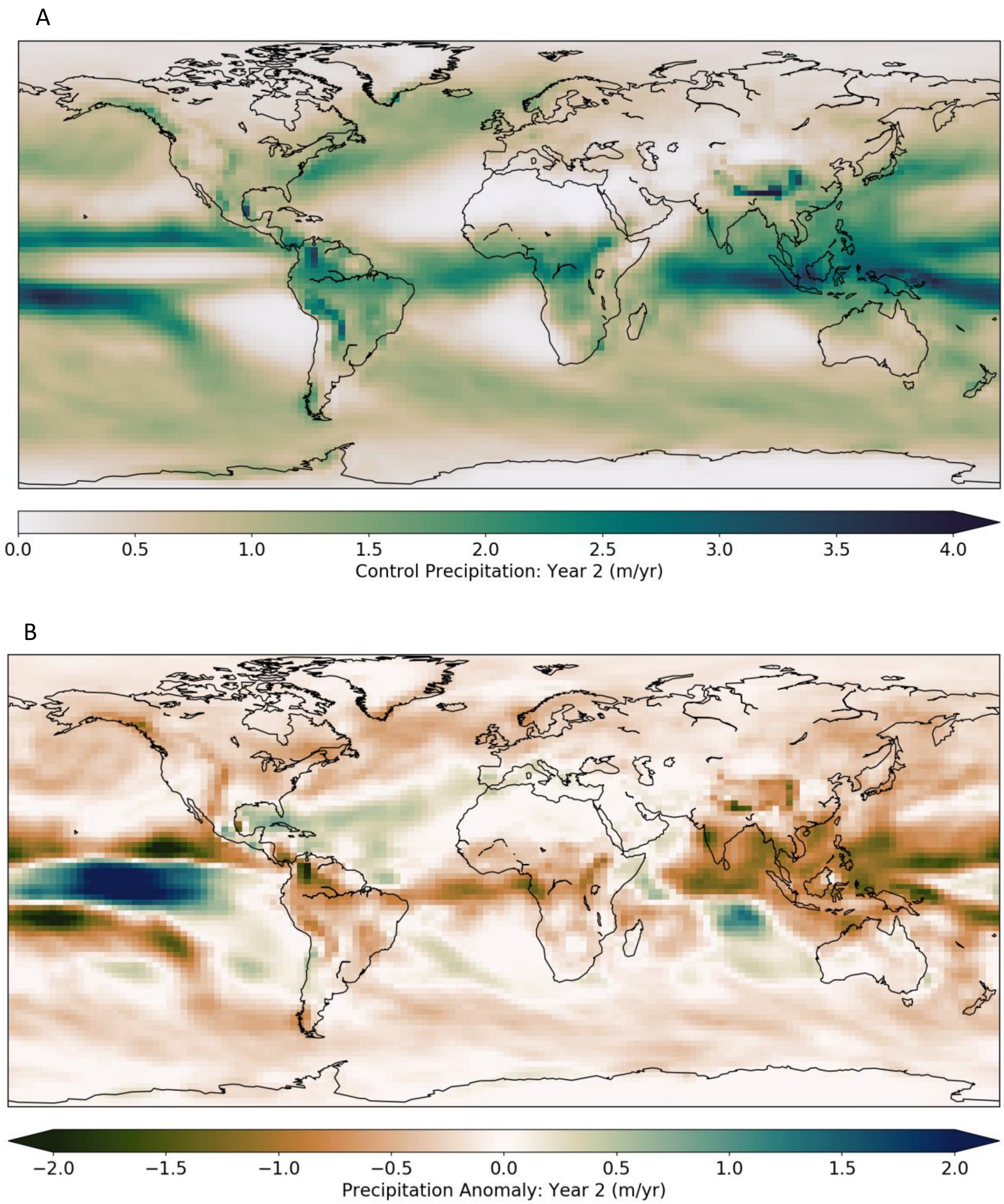

Fig. S7. Global precipitation patterns and changes following a regional nuclear war. (A) Global pattern of precipitation averaged over the second year of a control run with the climate model. (B) Change in precipitation averaged over the second year following a conflict beginning in May of year one for the scenario with 50 kt weapons and a 27.3 Tg injection of BC. Note the large declines in precipitation throughout Southeast Asia and Indonesia, tropical South America and Africa, as well as in the Midwestern U.S.

Table S1. One scenario for a war between India and Pakistan. Columns headed P and I are the number of weapons used on that day by Pakistan or India, respectively. Tactical weapons are assumed to have low yields and to be used on rural, battlefield targets. Strategic weapons have yields of 15, 50 or 100 kt depending on the scenario, and are targeted on urban areas. Totals do not include weapons that failed to detonate, or exploded on rural targets.

Day number	Number of weapons (tactical/strategic)		Targets
	P	I	
-30			Terrorist attack on Indian parliament
-2			Indian and Pakistani armies mobilized
-1			Indian army units deploy along border and cross line of control in Kashmir
0			Pakistani conventional forces respond, but are overwhelmed
1	10/0		Pakistan uses tactical weapons inside its own border and in Kashmir against tanks
2	15/0	0/20	Pakistan continues to use tactical weapons; India attacks 20 military garrisons and airfields collocated with urban areas
3	15/30	0/10	Pakistan continues to use tactical weapons; Pakistan uses ballistic and cruise missiles on garrisons in 20 Indian cities, 10 Indian naval bases and airfields in urban areas: India attacks 10 Pakistani navy, army and air force bases in urban areas
4-7	0/120	0/70	Remaining arsenals used on cities
Total	40/150	0/100	An additional 20 Pakistani and 25 Indian weapons are used on military targets in rural areas

Table S2. Fatalities and casualties and the percentage of the urban population killed or injured. Fatalities and total casualties, in millions of people, in India and Pakistan for the scenario in **Table S1** for different yields, and the percent of the urban population killed or injured.

Country	size of weapons used		
	15 kt	50 kt	100 kt
India, fatalities/ % urban	36/7	71/13	96/18
India, casualties/ % urban	58/11	106/20	138/25
Pakistan, fatalities/ % urban	16/18	26/30	31/35
Pakistan, casualties/ % urban	25/28	38/43	45/51
Total fatalities	52	97	127
Total casualties	83	144	183

Table S3. Population densities within the area ignited and estimated fuel loads. Total populations and average population densities within the area ignited by nuclear detonations of different yields, and estimated fuel loadings within those potential mass fire zones, defined as 13 km^2 for a 15-kt burst and scaling linearly with yield for larger weapon sizes.

Location, target #	Population within burned area for given yield[1]			Population density (km^{-2})/ fuel load ($g\ cm^{-2}$) for given yield		
	15 kt	50 kt	100 kt	15 kt	50 kt	100 kt
India, 1	860,000	1,600,000	3,200,000	67,000/ 73	37,000/ 41	37,000/ 41
India, 150	220,000	290,000	420,000	17,000/ 19	6,700/ 7	4,900/ 5
India, 250	160,000	210,000	290,000	13,000/ 14	4,800/ 5	3,400/ 4
Pakistan, 1	1,000,000	1,700,000	4,200,000	80,000/ 88	40,000/ 44	49,000/ 54
Pakistan, 100	110,000	100,000	140,000	8,500/ 9	2,300/ 3	1,600/ 2
Pakistan, 250	50,000	49,000	78,000	3,900/ 4	1,100/ 1	910/ 1