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PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

Climatic and Humanitarian Impacts of Nuclear War

Alan Robock

Department of Environmental Sciences
Rutgers University, New Brunswick, New Jersey USA

robock@envsci.rutgers.edu

1766-2016
RUTGERS 250
Revolutionary for 250 Years

Henry Rutgers (1745 – 1830) Painting by Henry Inman in the Old Queen's Building at Rutgers, Public Domain, https://commons.wikimedia.org/w/index.php?curid=3037089

I hereby acknowledge that the namesake of Rutgers University, Colonel Henry Rutgers, owned slaves, as did many of the early presidents of Rutgers College (now Rutgers University). Slave labor built the Rutgers campus. The land on which Rutgers sits was stolen from the Lenni Lenape natives. Rutgers benefited from the land-grant Morrill Act of 1862, which allowed New Jersey to sell land taken from western Native Americans for the benefit of Rutgers.

Committee on Enslaved and Disenfranchised Populations in Rutgers History
https://scarletandblack.rutgers.edu/findings

Alan Robock
Department of Environmental Sciences

Reviews of Geophysics distills and places in perspective previous scientific work in currently active subject areas of geophysics. Contributions evaluate overall progress in the field and cover all disciplines embraced by AGU.

Authorship is by invitation, but suggestions from readers and potential authors are welcome. If you are interested in writing an article please talk with me, or write to reviewsgeophysics@agu.org, with an abstract, outline, and analysis of recent similar review articles, to demonstrate the need for your proposed article.

Reviews of Geophysics has an impact factor of 21.5 in the 2019 Journal Citation Reports, highest in the geosciences.

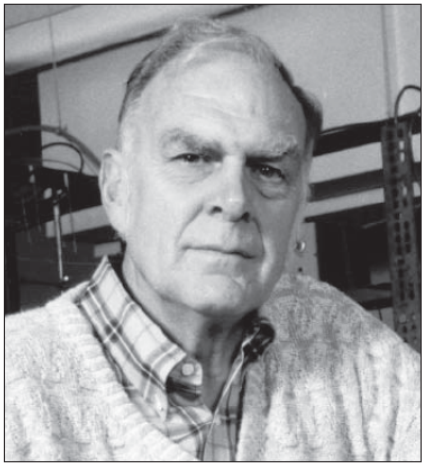
GEOPHYSICISTS

F. Sherwood “Sherry” Rowland (1927–2012)

Frank Sherwood Rowland, known to his friends and colleagues as Sherry, died at his

Prize autobiography (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/

result. Ultraviolet radiation would break down CFCs in the upper atmosphere, freeing chlorine atoms that could each catalytically destroy up to 100,000 ozone molecules. As Sherry later recalled in his autobiography, “Within three months, Mario and I realized that this was not just a scientific ques-



F. Sherwood “Sherry” Rowland

“What’s the use of having developed a science well enough to make predictions if, in the end, all we’re willing to do is stand around and wait for them to come true?”
The New Yorker, June 9, 1986.

in Chemistry with Mario Molina and Paul Crutzen for their pioneering contributions to atmospheric chemistry, particularly the formation and decomposition of stratospheric ozone. In its citation, the Nobel Committee commended them for contributing to “our salvation from a global environmental problem that could have catastrophic consequences.”

Born in Delaware, Ohio, on 28 June 1927, Sherry showed an early natural aptitude for academics and graduated from high school in 1943 at age 15. Once Sherry reached the draft age of 18, he interrupted his undergraduate studies at Ohio Wesleyan University to enlist in a Navy program to train radar operators. Sherry was also a passionate athlete, and after 14 months in service he emerged as a noncommissioned officer with a rating of Specialist (Athletics) 3rd Class.

Sherry’s research was driven by curiosity, meticulous work, and a keen ability to perceive. As a graduate student at the University of Chicago, Sherry was randomly assigned to be mentored by Willard “Bill” Libby, a future Nobel laureate who had just finished developing the carbon-14 dating technique. As Sherry later wrote in his Nobel

As Sherry later asked at a White House climate change roundtable in 1997, “Is it enough for a scientist simply to publish a paper? Isn’t it a responsibility of scientists, if you believe that you have found something that can affect the environment, isn’t it your responsibility to actually do something about it, enough so that action actually takes place? If not us, who? If not now, when?”

1. Nuclear winter theory

2. Analogs, to test the theory

3. Policy implications

4. Doing something about it

You can join the PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

Alan Robock
Department of Environmental Sciences

Rich Turco Brian Toon Tom Ackerman Alan Robock Gera Stenchikov

Fall American Geophysical Union Meeting, December 2019

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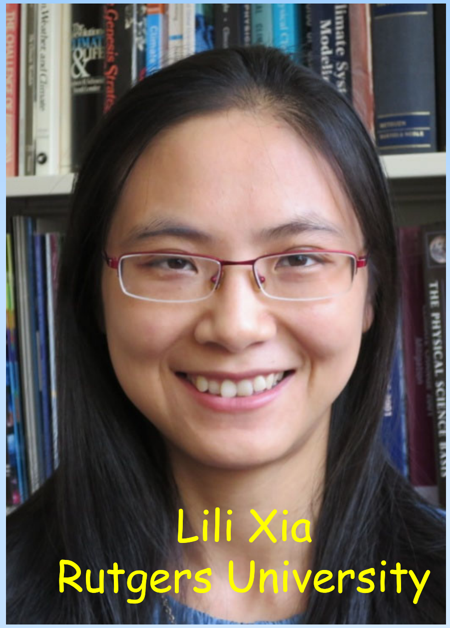

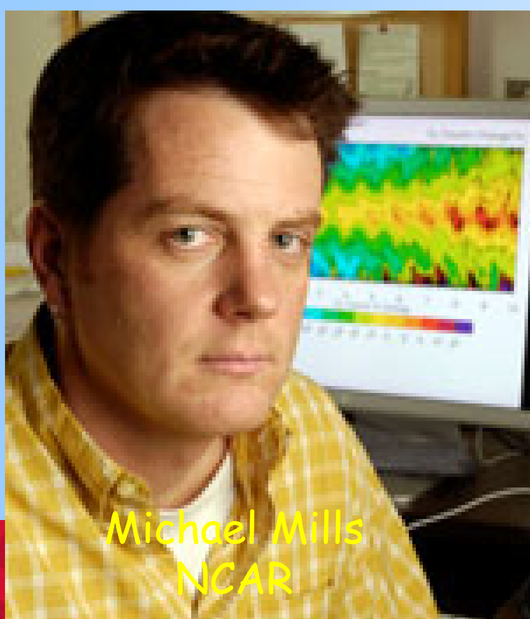

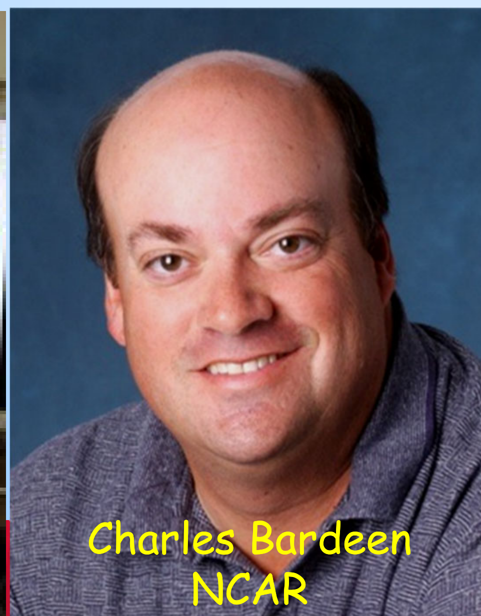

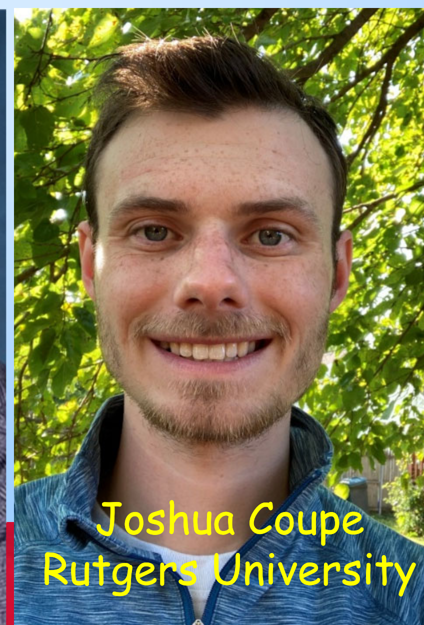

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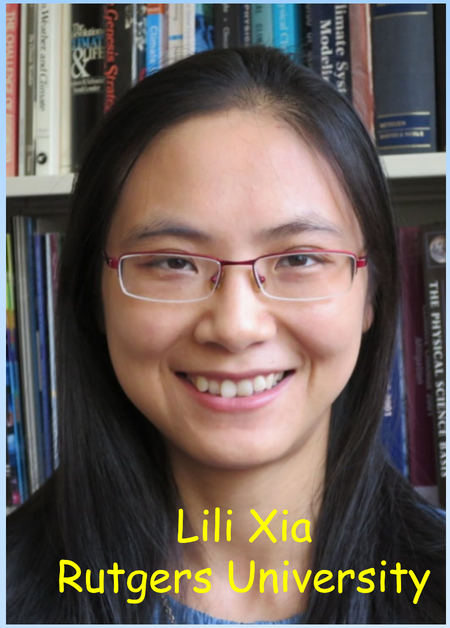

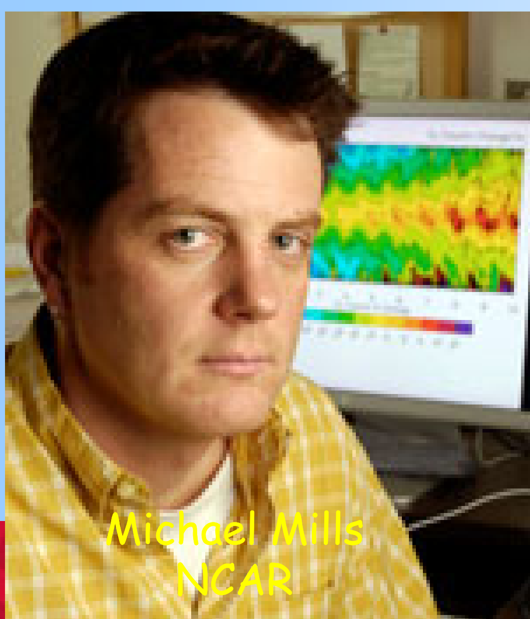

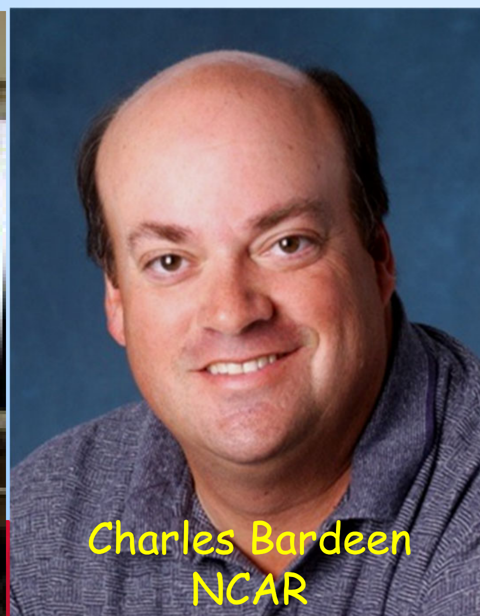

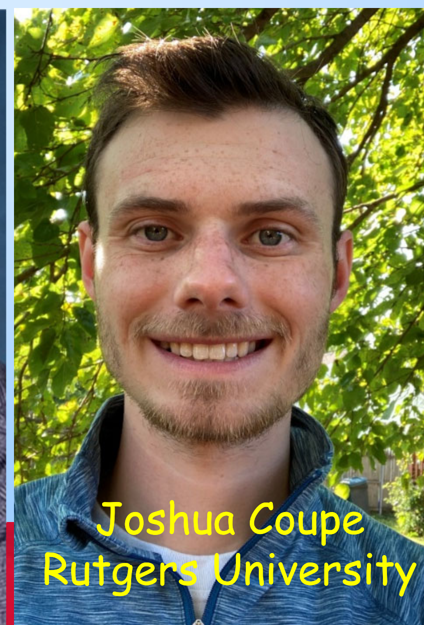

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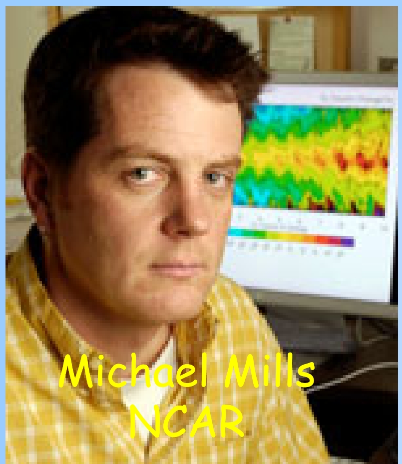

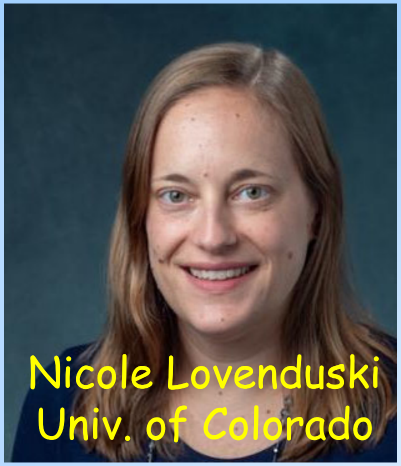

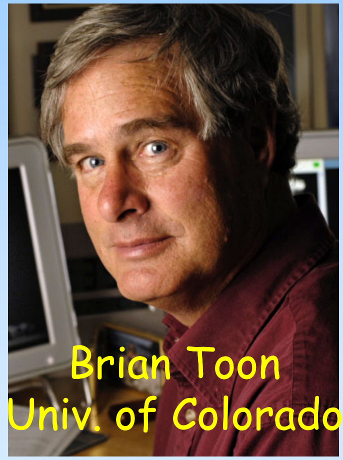

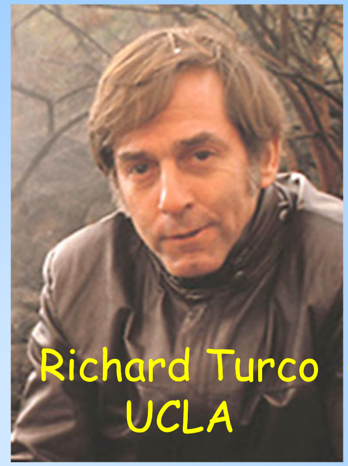

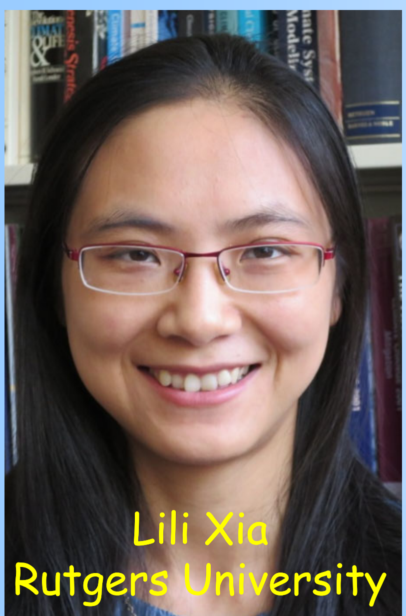

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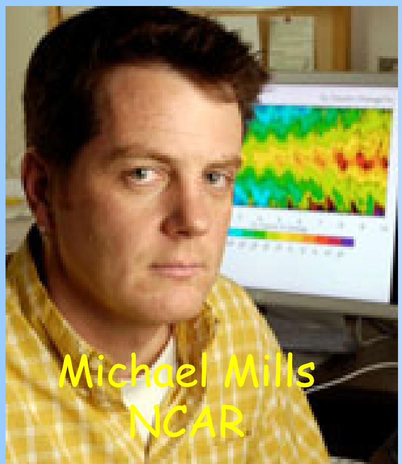

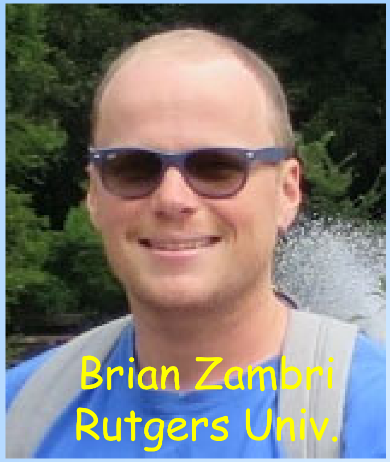

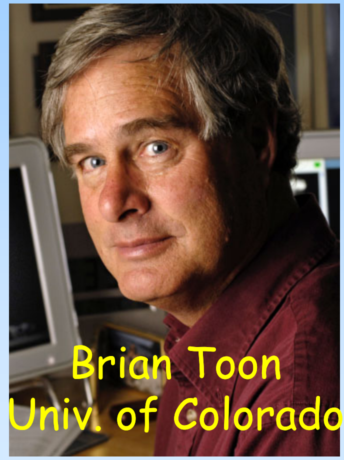

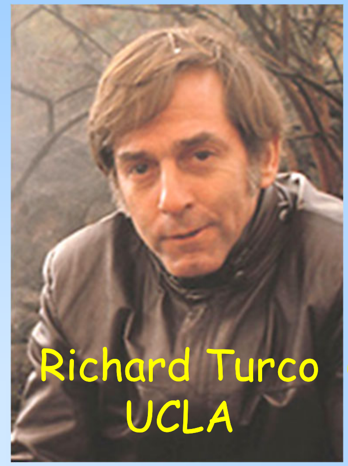

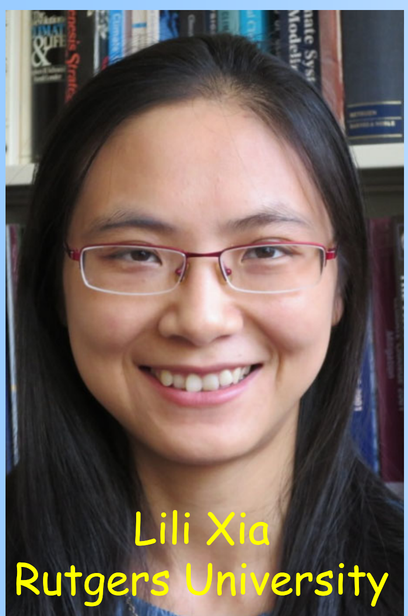

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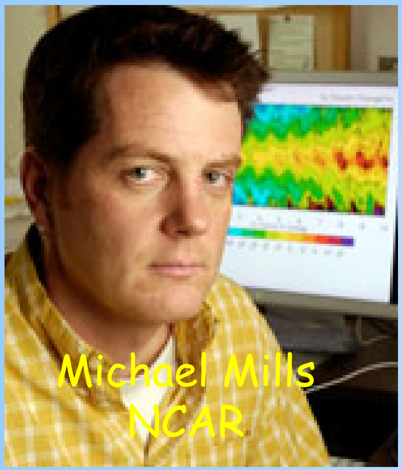

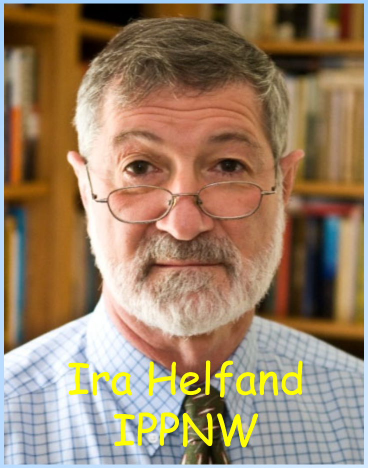

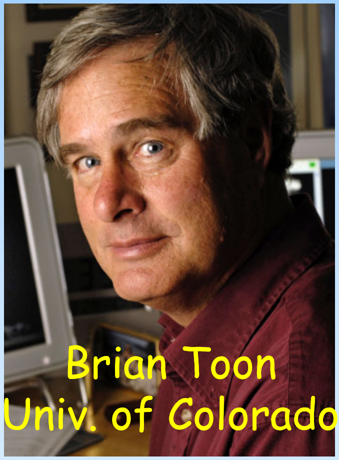

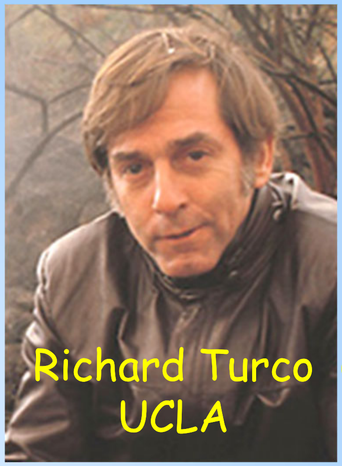

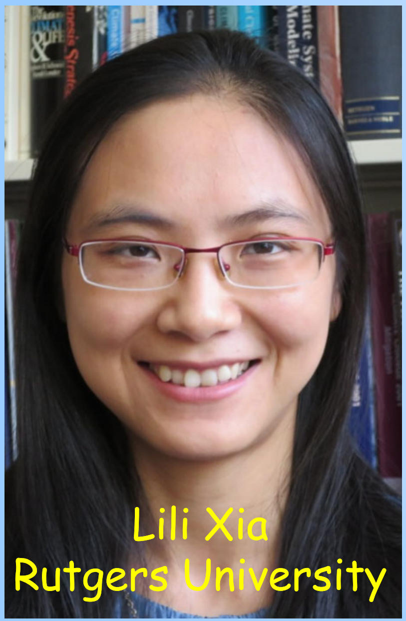

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This presentation is based on the following papers:

Coupe, Joshua, Charles G. Bardeen, Alan Robock, and Owen B. Toon, 2019: Nuclear winter responses to global nuclear war in the Whole Atmosphere Community Climate Model Version 4 and the Goddard Institute for Space Studies ModelE. *J. Geophys. Res. Atmos.*, **124**, 8522-8543, doi:10.1029/2019JD030509.

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This presentation is based on the following recent papers:

Coupe, Joshua, Samantha Stevenson, Nicole S. Lovenduski, Tyler Rohr, Cheryl S. Harrison, Alan Robock, Holly Olivarez, Charles G. Bardeen, and Owen B. Toon, 2021: Nuclear Niño response observed in simulations of nuclear war scenarios. *Communications Earth & Environment*, **2**, 18, doi:10.1038/s43247-020-00088-1.

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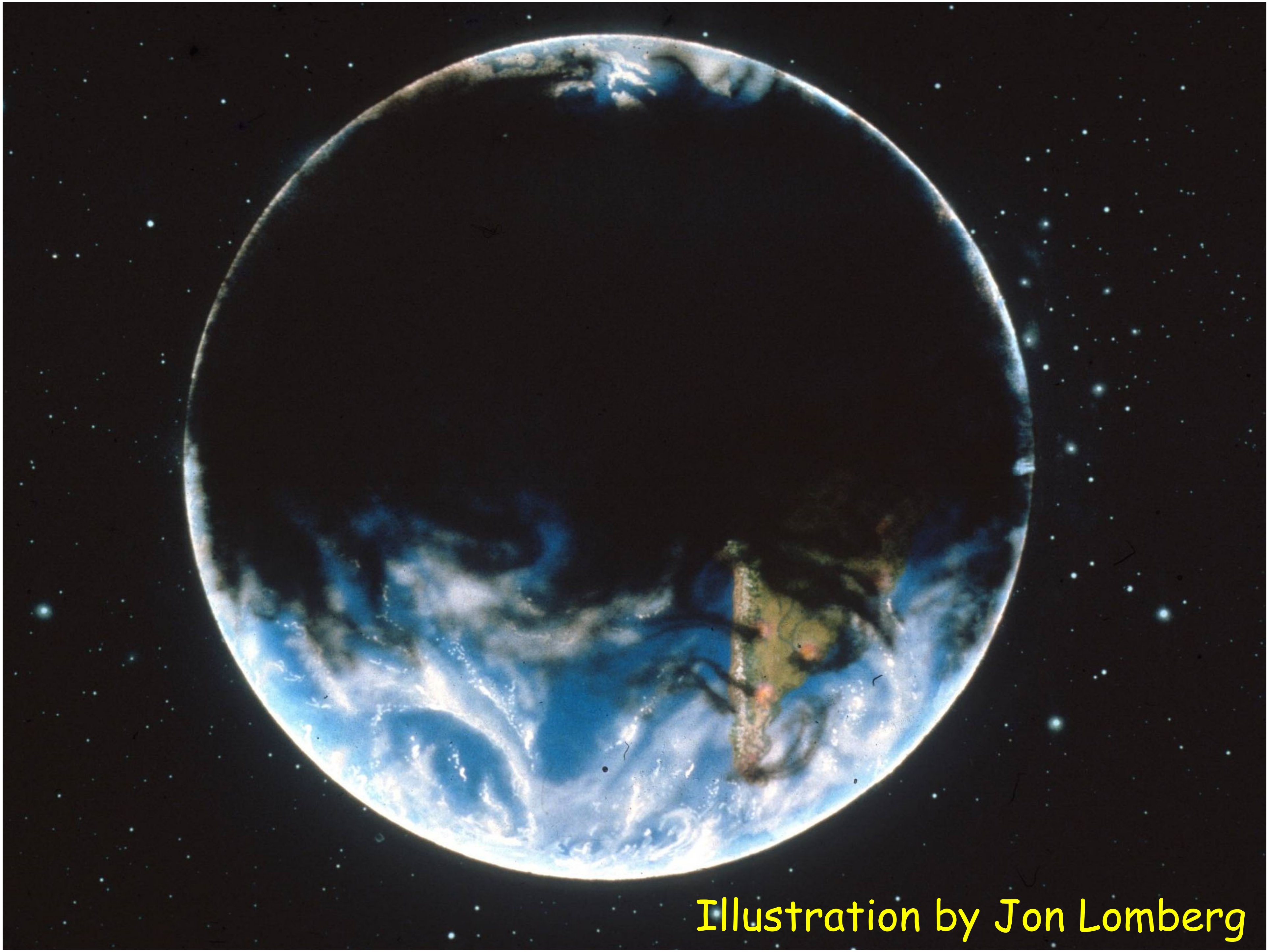
Yu, Pengfei, Owen B. Toon, Charles G. Bardeen, Yunqian Zhu, Karen H. Rosenlof, Robert W. Portmann, Troy D. Thornberry, Ru-Shan Gao, Sean M. Davis, Eric T. Wolf, Joost de Gouw, David A. Peterson, Michael D. Fromm, and Alan Robock, 2019: Black carbon lofts wildfire smoke high into the stratosphere to form a persistent plume. *Science*, **365**, 587-590, doi:10.1126/science.aax1748.

Alan Robock
Department of Environmental Sciences


Illustration by Jon Lomberg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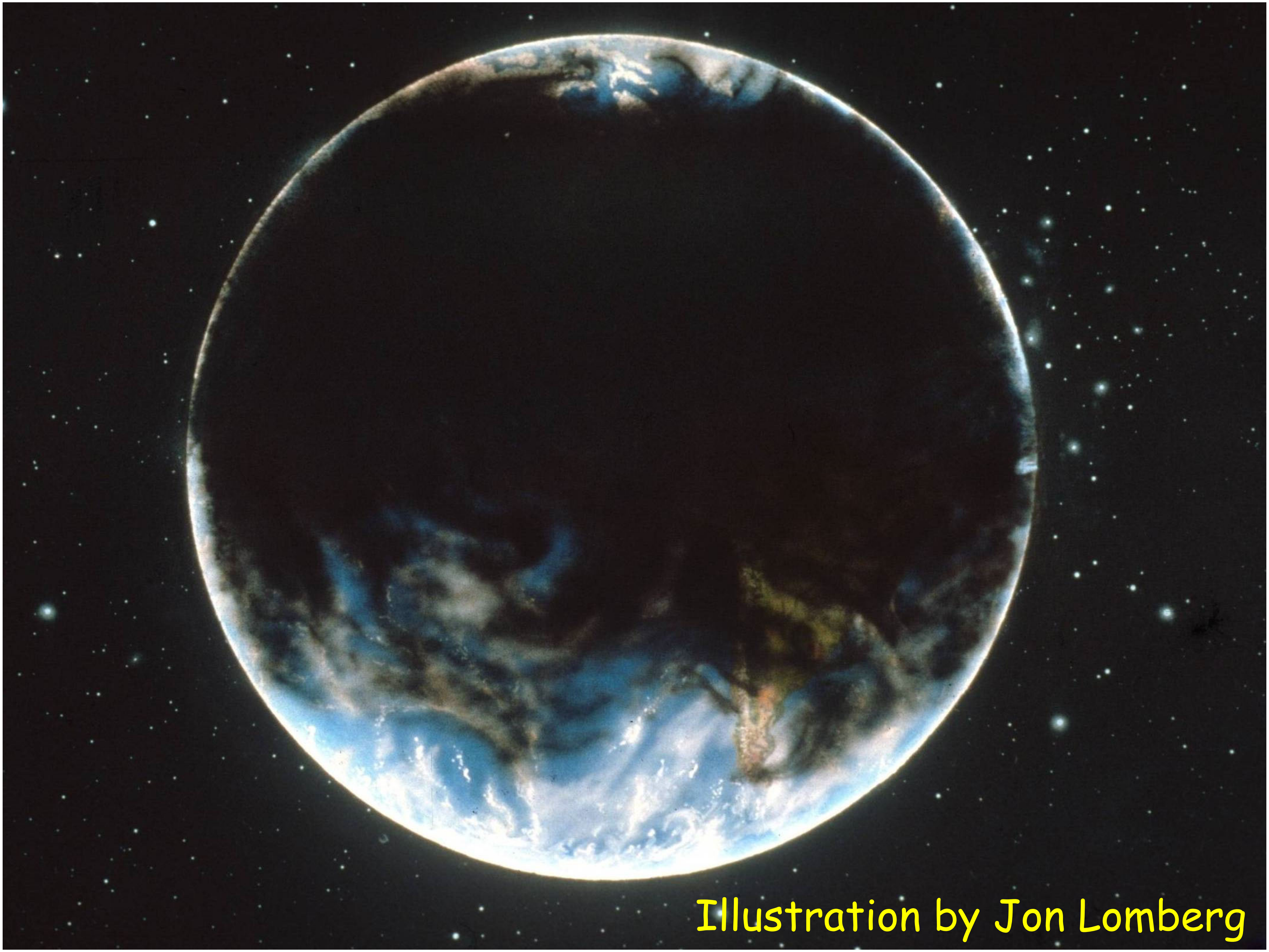
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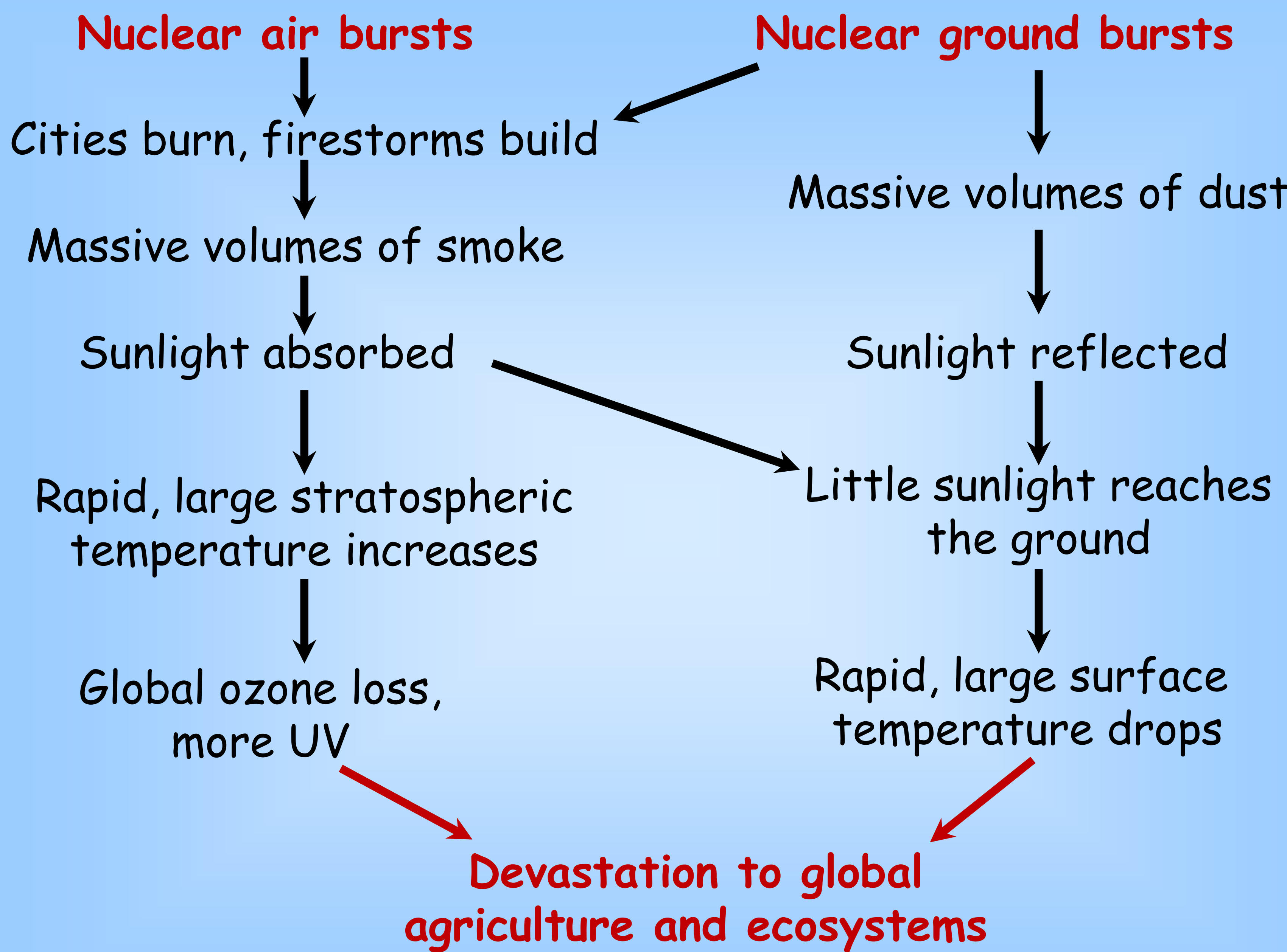
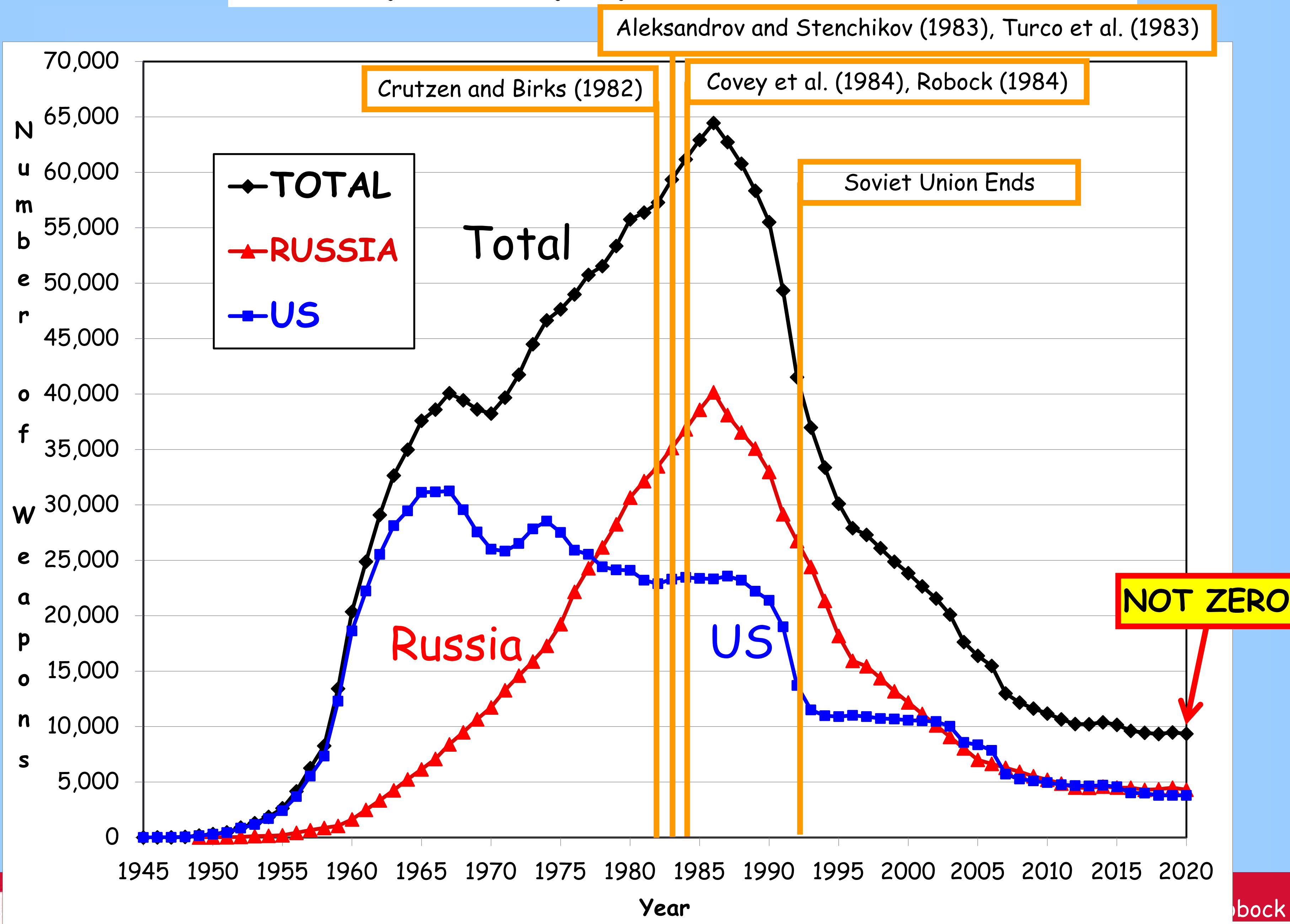


Alan Robock
Department of Environmental Sciences


Nuclear Winter
Cold, Dry, Dark, and More UV
Crops Dying and Global Famine
© 2009 Scientific American Inc

History of Deployed Nuclear Warheads



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Al Gore

Nobel Peace Prize address
Dec. 10, 2007

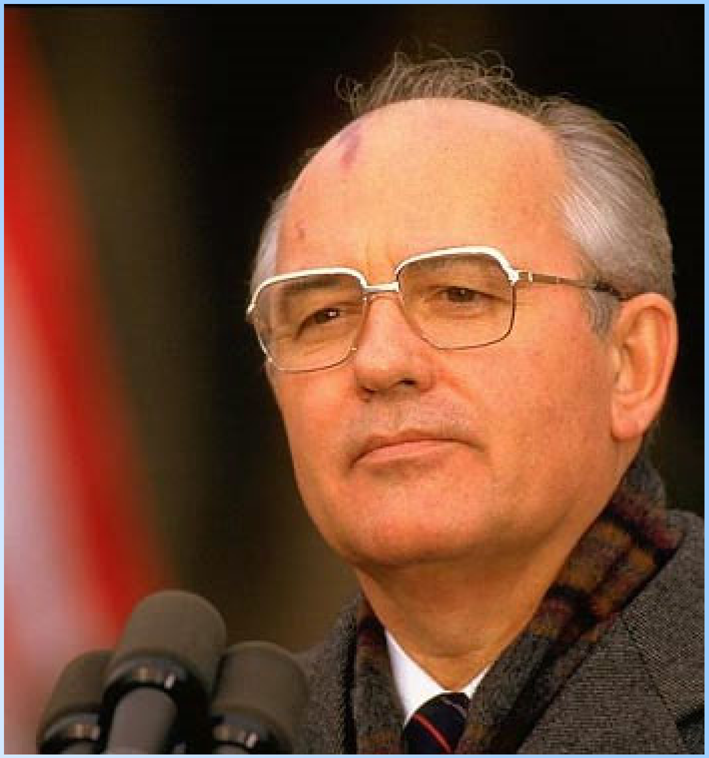
"More than two decades ago, scientists calculated that nuclear war could throw so much debris and smoke into the air that it would block life-giving sunlight from our atmosphere, causing a 'nuclear winter.' Their eloquent warnings here in Oslo helped galvanize the world's resolve to halt the nuclear arms race."

Ronald Reagan:

When asked about the effects of nuclear war in a February 12, 1985 interview in the *New York Times* said,

"A great many reputable scientists are telling us that such a war could just end up in no victory for anyone because we would wipe out the earth as we know it. And if you think back to ... natural calamities - back in the last century, in the 1800's, ... volcanoes - we saw the weather so changed that there was snow in July in many temperate countries. And they called it the year in which there was no summer. Now if one volcano can do that, what are we talking about with the whole nuclear exchange, the nuclear winter that scientists have been talking about? It's possible ..."

Mikhail Gorbachev:



"Mikhail Gorbachev explains what's rotten in Russia"
by Mark Hertsgaard
Salon.com, Sept. 7, 2000

"Models made by Russian and American scientists showed that a nuclear war would result in a nuclear winter that would be extremely destructive to all life on Earth; the knowledge of that was a great stimulus to us, to people of honor and morality, to act in that situation."

http://dir.salon.com/story/news/feature/2000/09/07/gorbachev/

Thirty-nine years after the threat of nuclear winter was discovered, we now ask:

1. Although the Cold War and its associated nuclear arms race are over, could remaining nuclear arsenals still produce nuclear winter?

2. What would be the consequences of the use of a much smaller number of nuclear weapons in a regional nuclear conflict?

Alan Robock
Department of Environmental Sciences

Thirty-nine years after the threat of nuclear winter was discovered, we now ask:

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Thirty-nine years after the threat of nuclear winter was discovered, we now ask:

1. Although the Cold War and its associated nuclear arms race are over, could remaining nuclear arsenals still produce nuclear winter? YES, AND IT WOULD LAST LONGER THAN WE THOUGHT BEFORE.

2. What would be the consequences of the use of a much smaller number of nuclear weapons in a regional nuclear conflict? NOT NUCLEAR WINTER, BUT MILLIONS DEAD FROM BLAST, RADIOACTIVITY AND FIRES, AND SEVERE IMPACTS ON GLOBAL AGRICULTURE AND FOOD AVAILABILITY FOR A DECADE.

This is also a story of new scientific results made possible through the development of more sophisticated, detailed climate models and the computers to run them on.

Initial experiments were limited by available computer time, but pushed models to include aerosols for the first time.

Now we can use sophisticated climate models, even for initial exploratory work.

Cray 1-A

IBM Blue Gene/L

Comparison of climate models used for previous and current nuclear winter simulations.

Study	Model type	Horizontal resolution (lat x lon)	Vertical levels	Seasonal cycle?/ Continuous?	Model top	Length of simulation (x # of runs)
Aleksandrov and Stenchikov [1983]	AGCM	12° x 15°	2	no	Tropopause	400 days (x 1)
Turco et al. [1983]	SCM	none	60	no	38 km	300 days (x 10)
Robock [1984]	EBM	10° x 180°	1	yes/yes	–	4 yr (x 9)
Covey et al. [1984]	AGCM	4.5° x 7.5°	9	yes/no	20 km	20 days (x 3)
Thompson [1985]	AGCM	4.5° x 7.5°	9	yes/no	20 km	20 days (x 3)
Malone et al. [1986]	AGCM	4.5° x 7.5°	20	yes/no	32 km	40 days (x 8)
Ghan et al. [1988]	AGCM	4° x 5°	2	yes/no	Tropopause	30 days (x 21)
Pittock et al. [1989]	AGCM	4.4° x 7.5°	9	yes/no	31 km	105 days (x 2)
Ghan [1991]	AGCM	4° x 5°	2	yes/yes	Tropopause	1.5 yr (x 3)
Current work	**AOGCM**	**4° x 5°**	**23**	**yes/yes**	**80 km**	**10 yr (x 8)**

AGCM = atmospheric general circulation model
SCM = single column model
EBM = energy balance model
AOGCM = atmosphere-ocean general circulation model

One megaton (MT) is the explosive power of a million tons of TNT.

$$1\ \text{MT} = 1000\ \text{kT} = 10^{6}\ \text{tons} = 10^{9}\ \text{kg} = 10^{12}\ \text{g}$$
$$= 1{,}000{,}000{,}000{,}000\ \text{g} = 1\ \text{Tg}$$

$$1\ \text{MT} = 10^{15}\ \text{calories} = 4.2 \times 10^{15}\ \text{joules}$$

Alan Robock
Department of Environmental Sciences

World Arsenals (1985)

	Warheads	MT
USA	9,800	4000
USSR	8,600	6000
Others	300	200
"Strategic"	**~19,000**	**~10,000**
USA	16,000	2000
USSR	14,000	3000
Others	600	150
"Theater"	**~30,000**	**~5,000**
Grand Total	**~50,000**	**~15,000**

Total yield of all explosive bombs used in World War II (including Hiroshima and Nagasaki) = 2-3 MT!

Total yield of all explosive bombs used in all warfare in the history of the world = 10 MT!

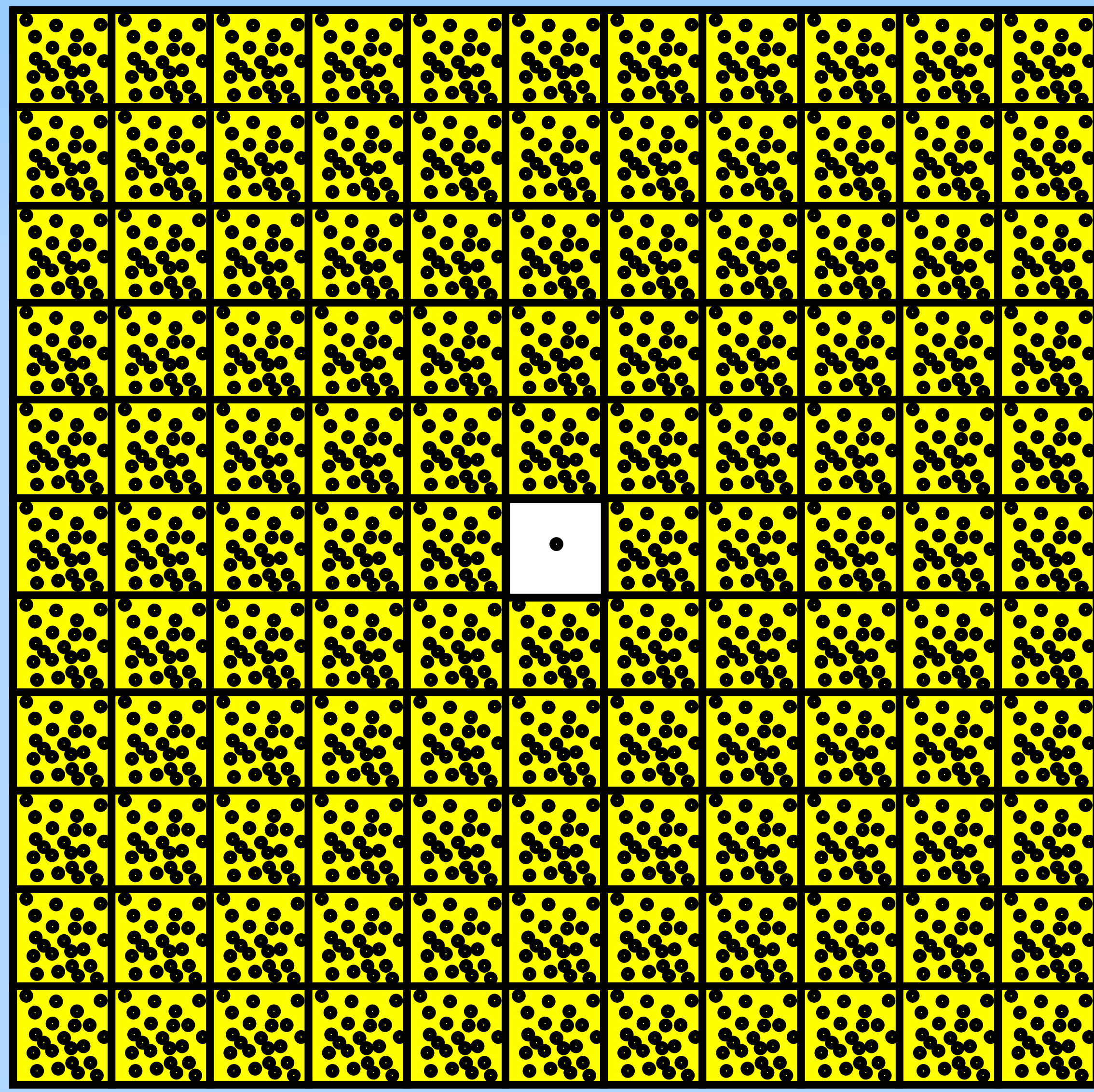
Alan Robock
Department of Environmental Sciences

Today's arsenal (2020) is about 1/3 of the 1985 arsenal. It is the equivalent of the explosive power of about

5,000,000,000,000 kg
(11,000,000,000,000 lbs)
of TNT.

If we divided this up and gave everyone on the planet his or her share, each person would have the equivalent of
more than 750 kg
(more than 1500 lbs)
of TNT.

Alan Robock
Department of Environmental Sciences



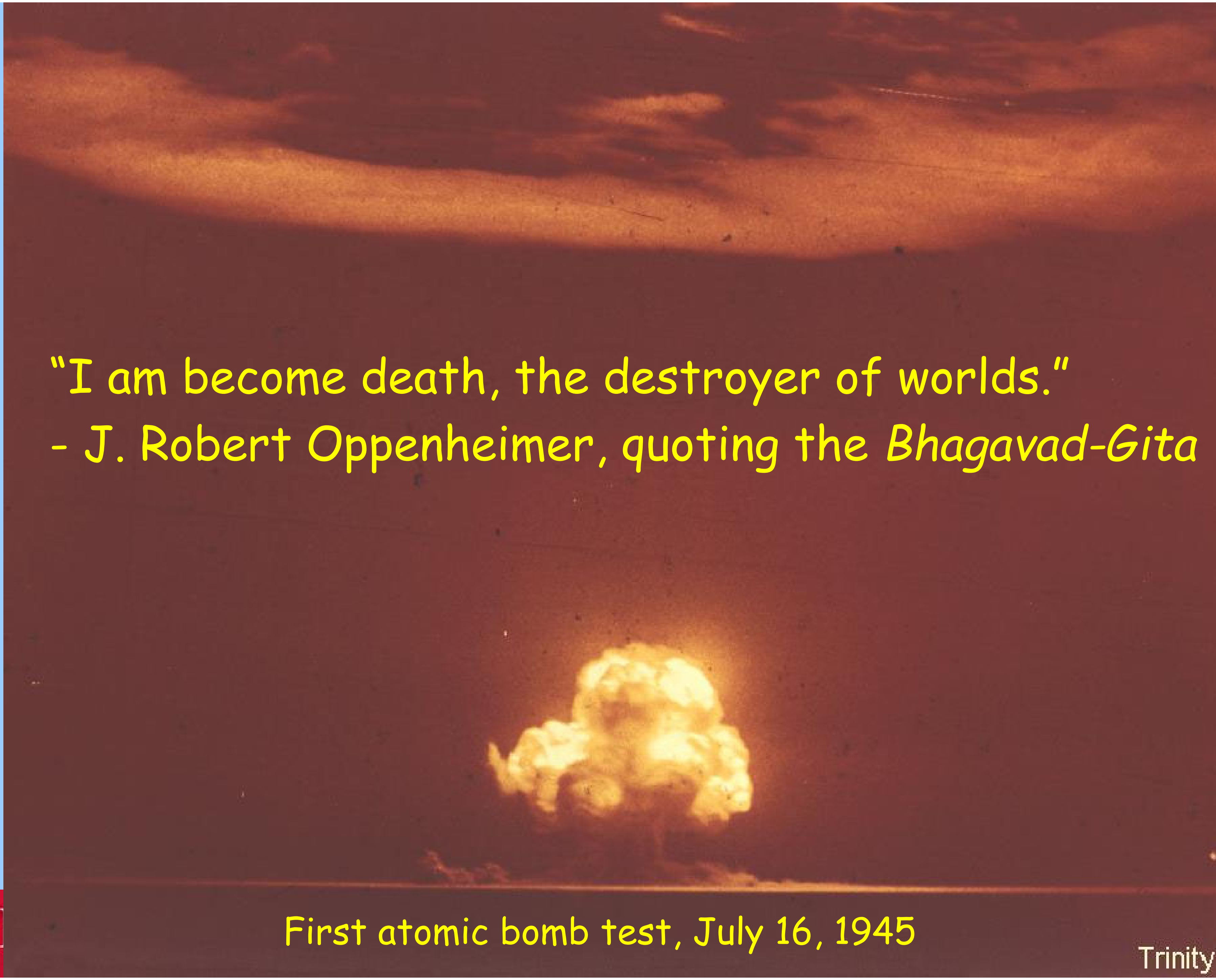
Center dot: Total firepower of WW II
The rest: Current nuclear arsenal

RUTGERS
Alan Robock
Department of Environmental Sciences

SCIENCE

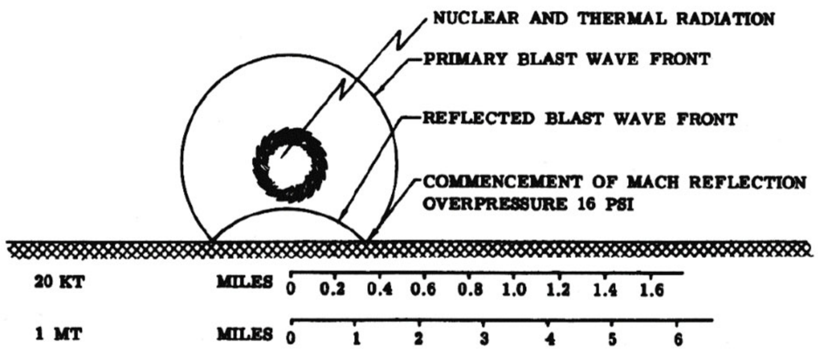
E. C. P. Armees

H-bomb being tested in the Pacific.

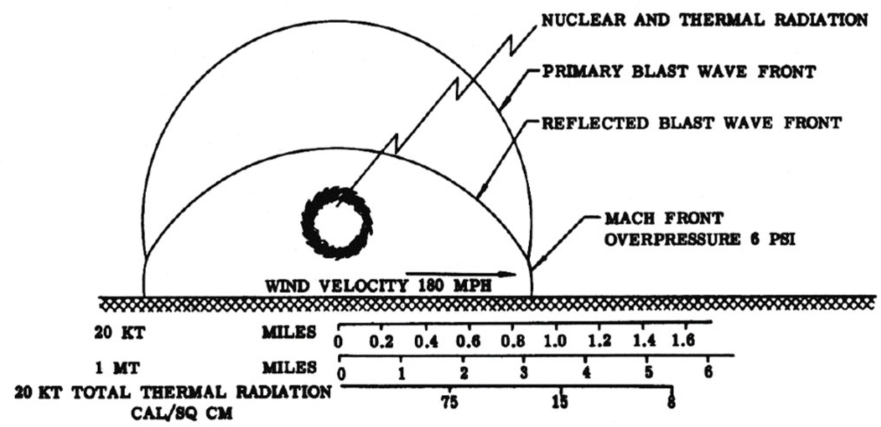


First atomic bomb test, July 16, 1945

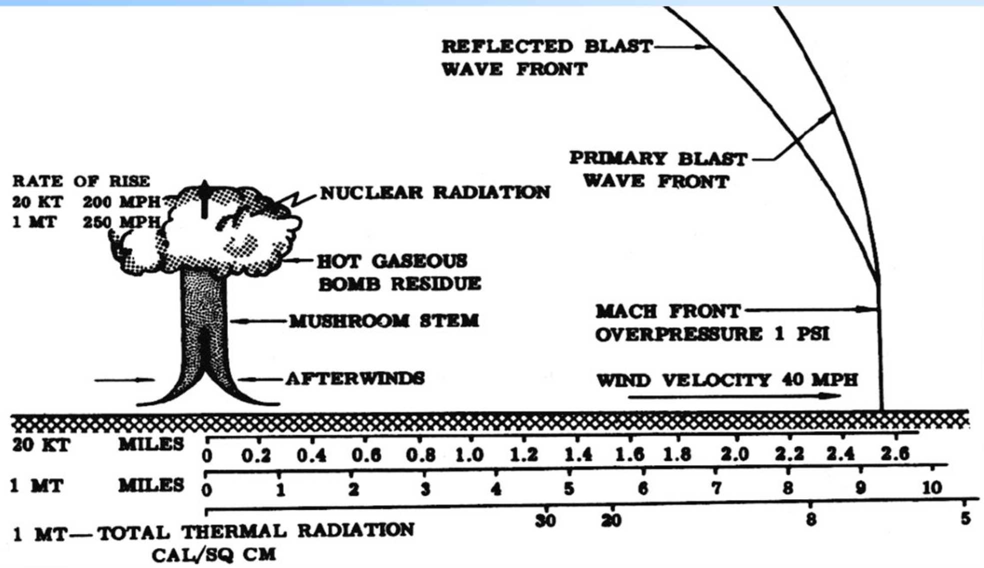
Time sequence of 20 kt airburst



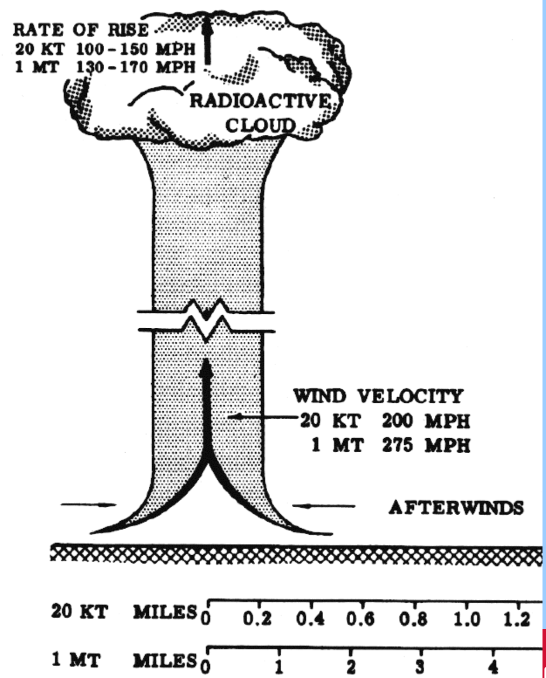
20 kt airburst, 1.25 s



20 kt airburst, 3 s



20 kt airburst, 10 s

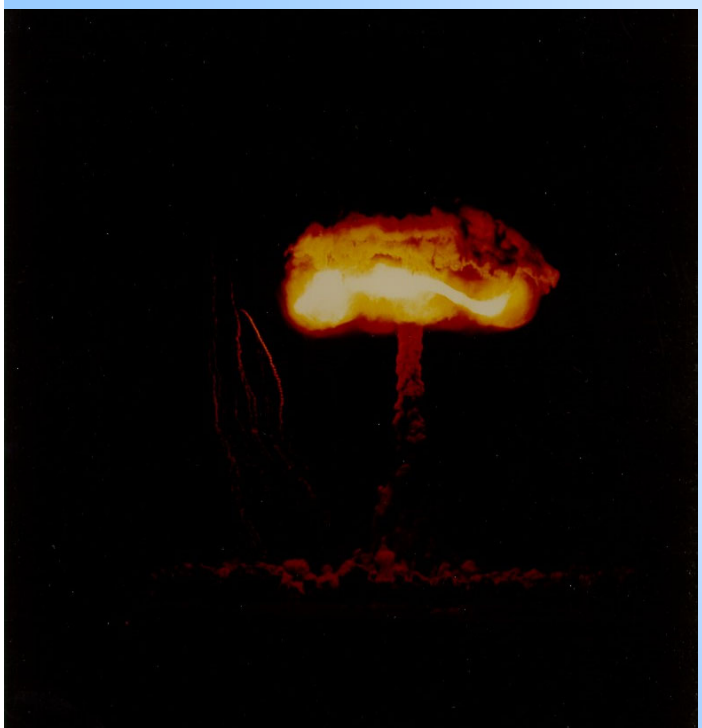


20 kt airburst, 30 s

The Effects of Nuclear Weapons, Samuel Glasstone, ed., USAEC, Washington, DC, April 1962; Revised Edition reprinted February 1964.
http://www.cddc.vt.edu/host/atomic/nukeffct/

UPSHOT-KNOTHOLE

Nevada Proving Ground - Complete destruction of House No. 1 located 3,500 feet from ground zero, by the March 17, 1953 atom blast at Yucca Flat. The time from the first to last picture was 2 1/3 seconds. The camera was completely enclosed in a 2-inch lead sheath as a protection against radiation. The only source of light was that from the bomb.



Photos courtesy of National Nuclear Security Administration / Nevada Site Office.
http://www.nv.doe.gov/library/photos/

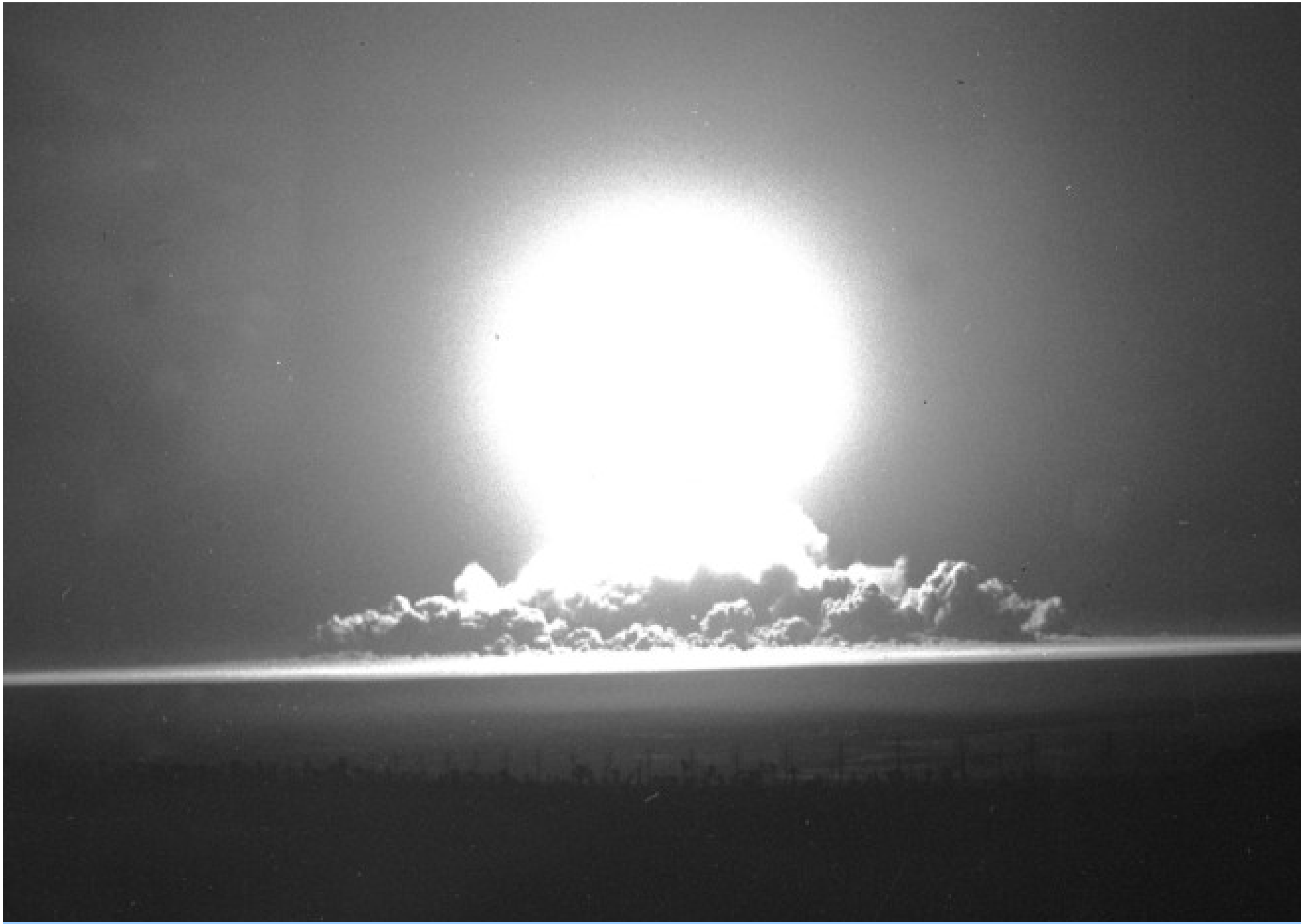


Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

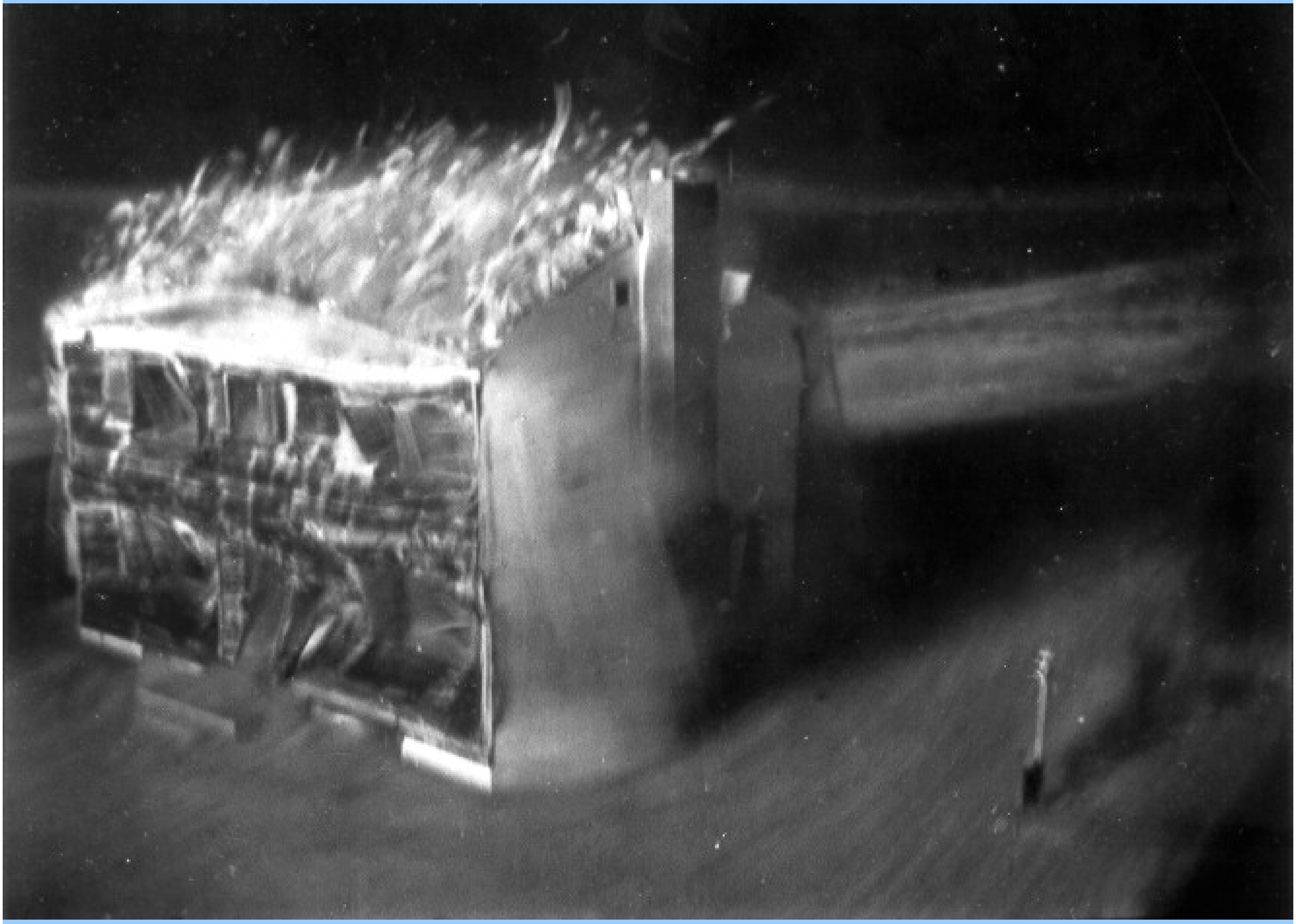


Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

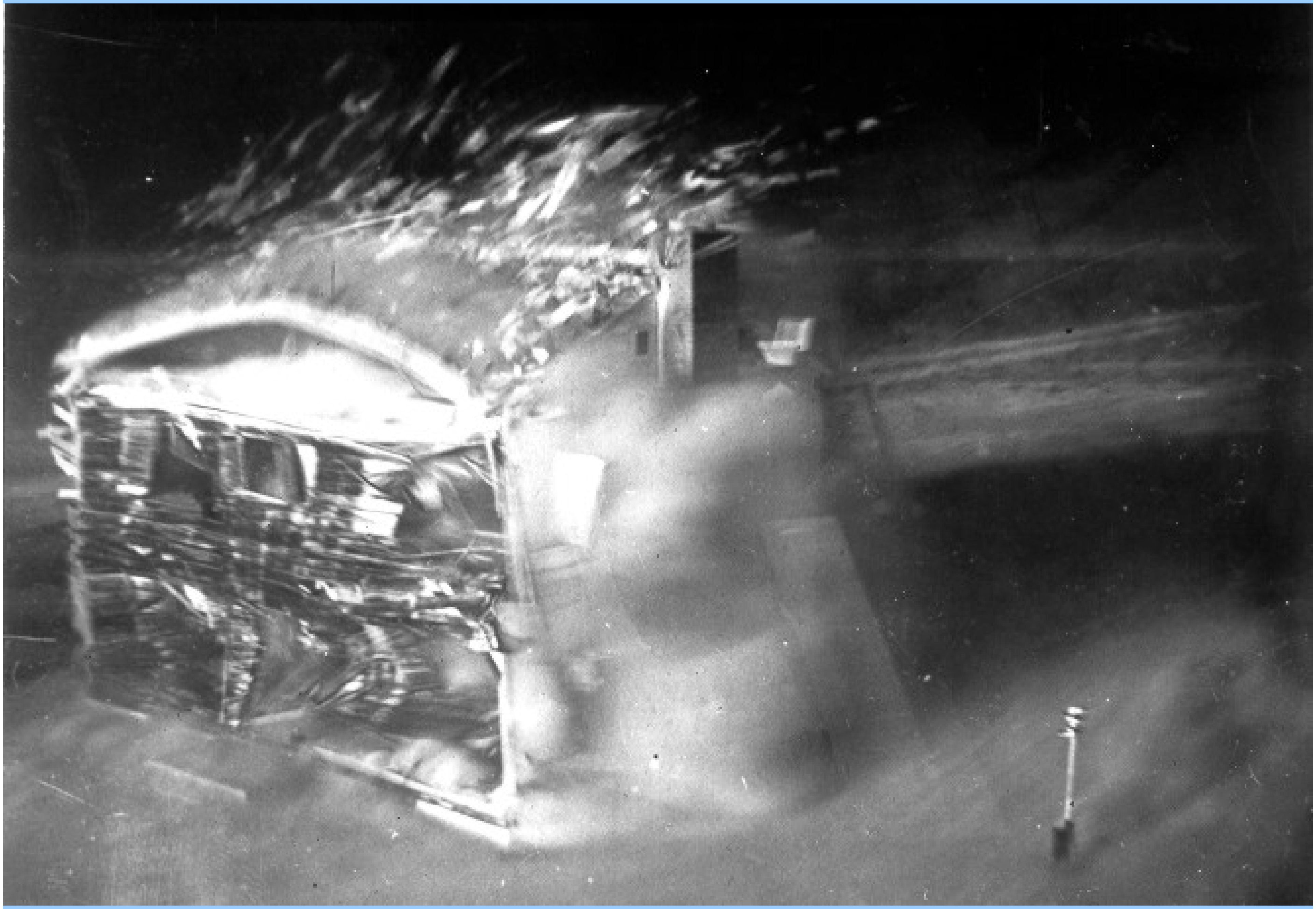


Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

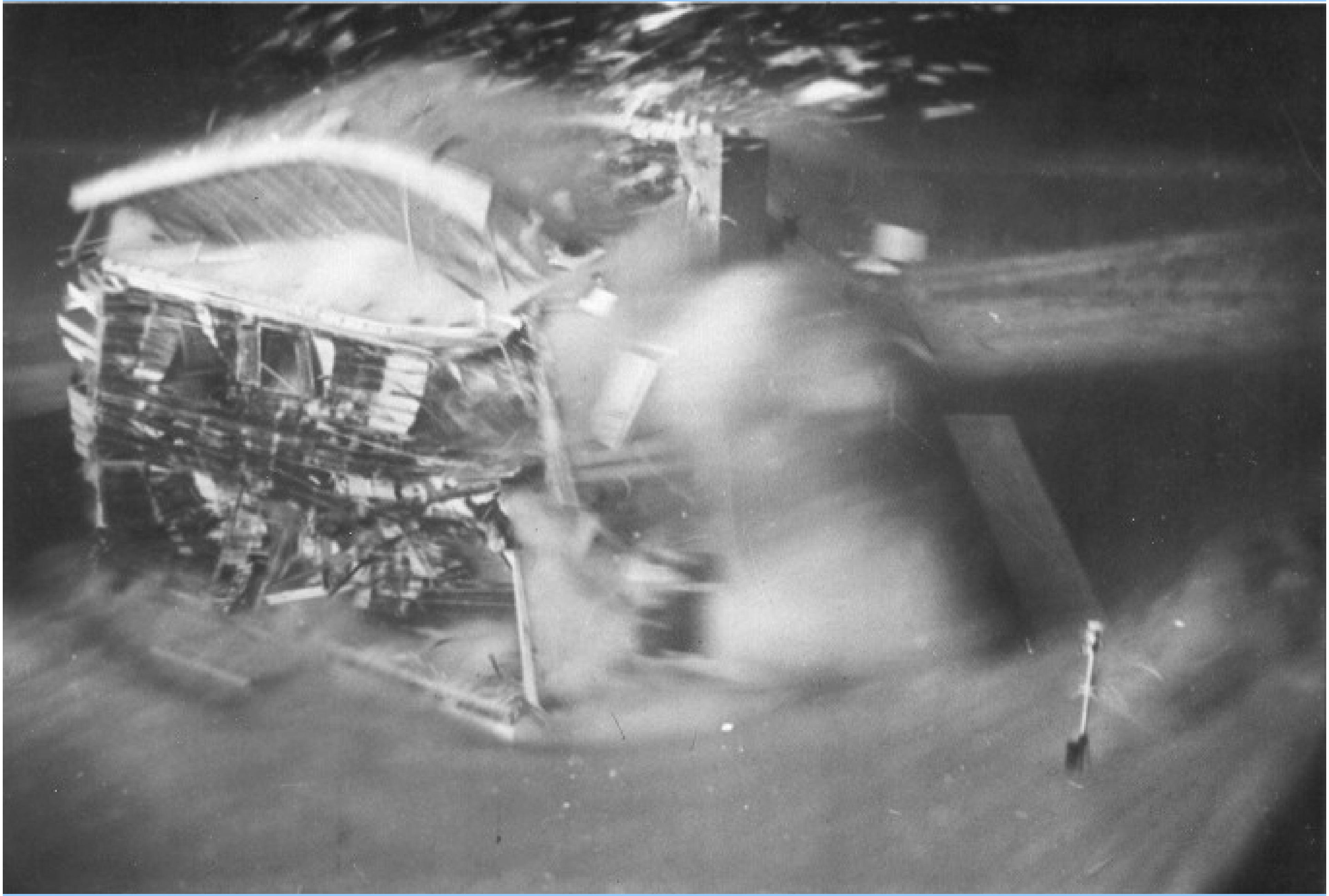


Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

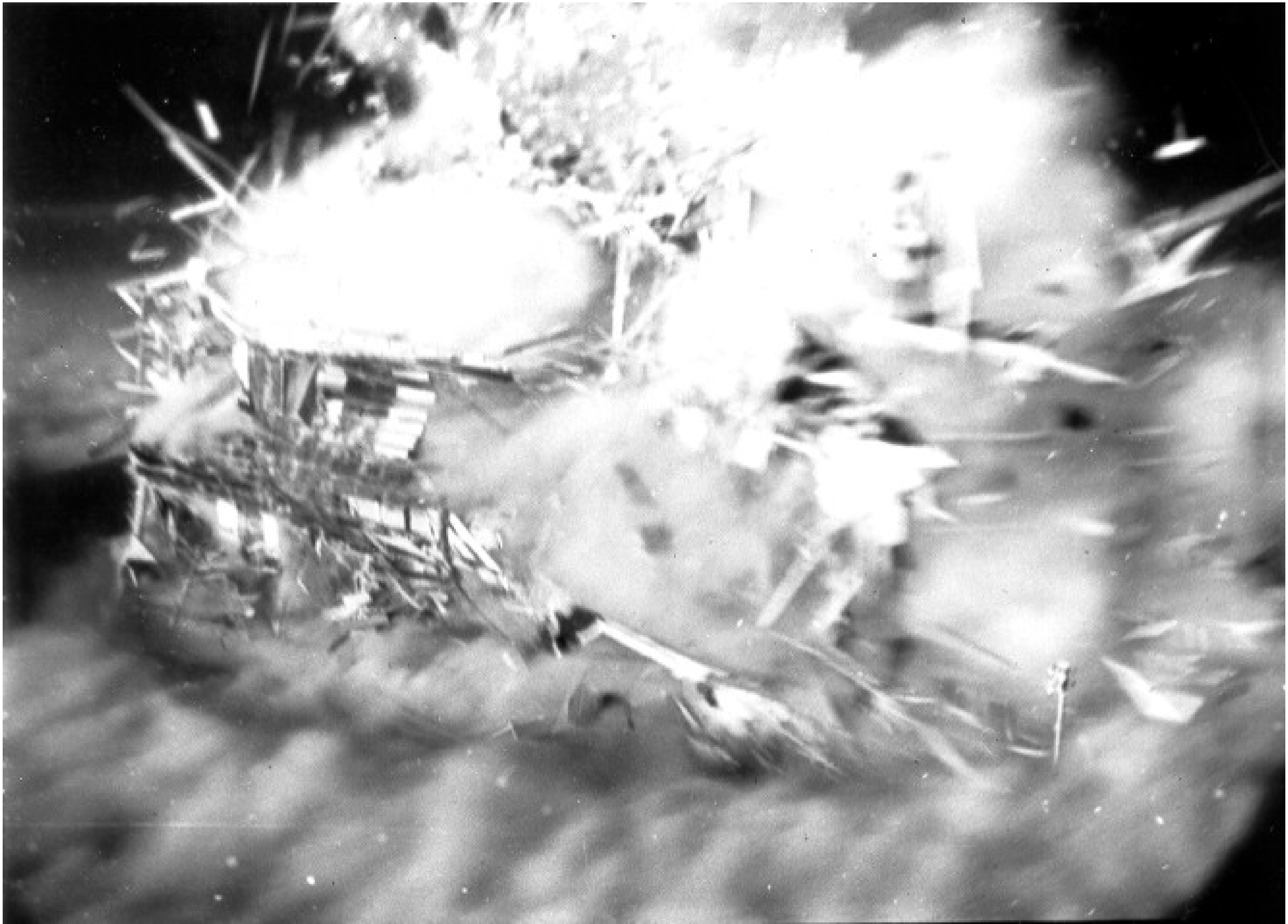


Photo courtesy of National Nuclear Security Administration / Nevada Site Office.

Scenes from the 1992 Gulf War

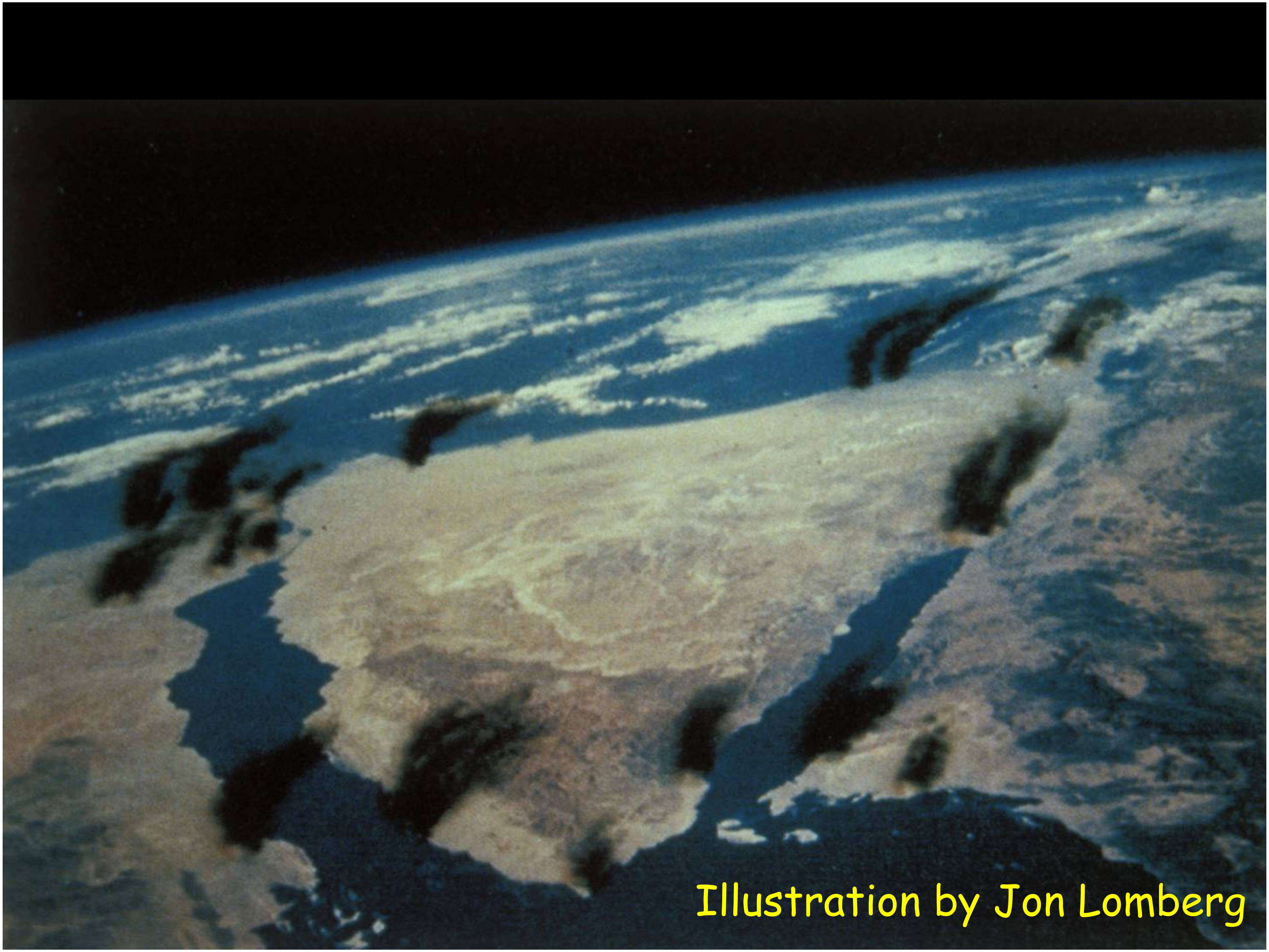
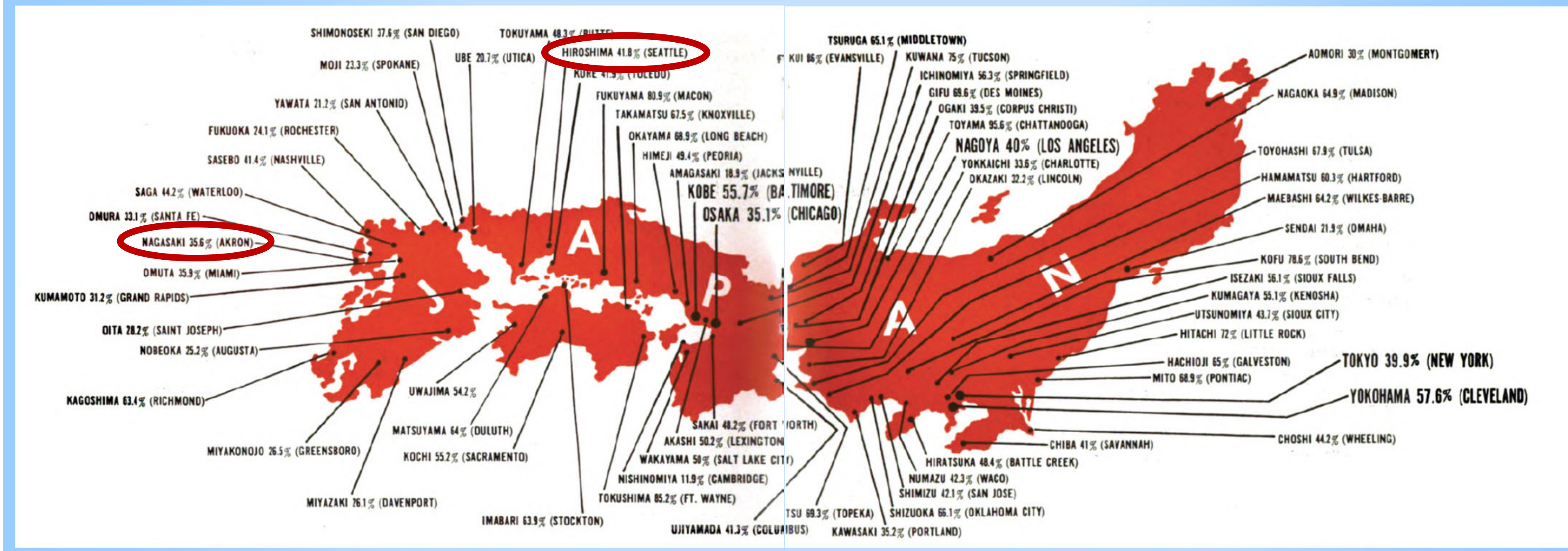


Illustration by Jon Lomberg

Principal Japanese cities firebombed by the US Army Air Force during the summer of 1945, with percent of each city destroyed. (In parentheses - US cities of same size.)



Third report of the Commanding General of the Army Air Forces to the Secretary of War, 12 November 1945.

Alan Robock
Department of Environmental Sciences

Hiroshima

August 6, 1945

A 15 kT bomb killed 150,000 people

Note: 15 kT = 0.015 MT = 1/1,000,000 of the 1985 world arsenal

= 3/1,000,000 of the current world arsenal

While current weapons are mostly more powerful than the initial one, if one Hiroshima-sized bomb were dropped every *two hours* from the end of World War II to today, it would still not use up the current arsenal.

Alan Robock
Department of Environmental Sciences

World War II
Aviation

Boeing B-29 Superfortress
Enola Gay

COPILOT
106
copilot.si.edu

Boeing's B-29 Superfortress was the most sophisticated propeller-driven bomber of World War II, and the first bomber to house its crew in pressurized compartments. Although designed to fight in the European theater, the B-29 found its niche on the other side of the globe. In the Pacific, B-29s delivered a variety of aerial weapons: conventional bombs, incendiary bombs, mines, and two nuclear weapons.

On August 6, 1945, this Martin-built B-29-45-MO dropped the first atomic weapon used in combat on Hiroshima, Japan. Three days later, *Bockscar* (on display at the U.S. Air Force Museum near Dayton, Ohio) dropped a second atomic bomb on Nagasaki, Japan. *Enola Gay* flew as the advance weather reconnaissance aircraft that day. A third B-29, *The Great Artiste,* flew as an observation aircraft on both missions.

Transferred from the U.S. Air Force

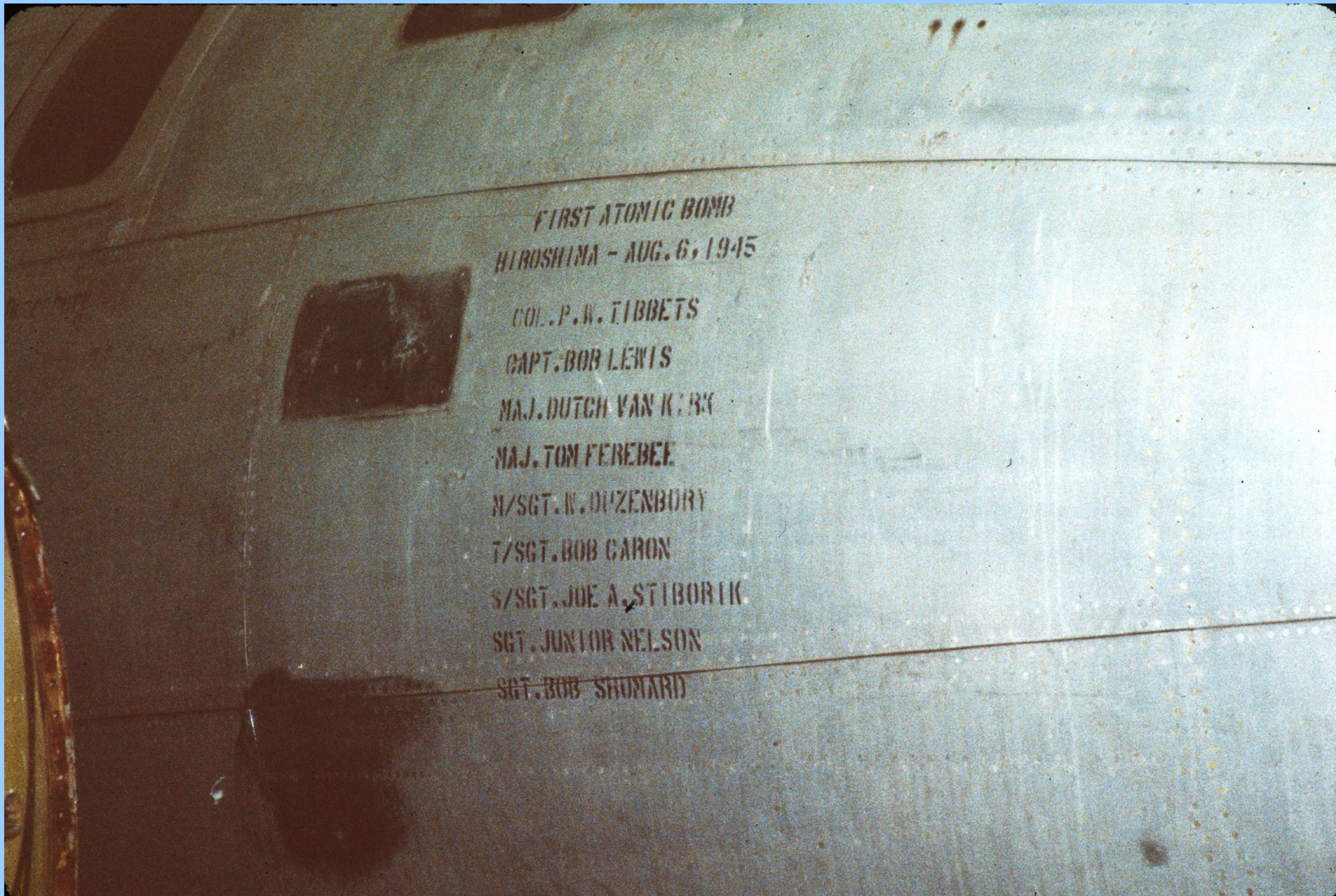
Wingspan:	43 m (141 ft 3 in)
Length:	30.2 m (99 ft)
Height:	9 m (27 ft 9 in)
Weight, empty:	32,580 kg (71,826 lb)
Weight, gross:	63,504 kg (140,000 lb)
Top speed:	546 km/h (339 mph)
Engines:	4 Wright R-3350-57 Cyclone turbo-supercharged radials, 2,200 hp
Crew:	12 (Hiroshima mission)
Armament:	two .50 caliber machine guns
Ordnance:	"Little Boy" atomic bomb
Manufacturer:	Martin Co., Omaha, Nebr., 1945

A19500100000

Funding in support of the completion of the restoration of the Enola Gay *generously provided by The Alvin L. Gray Family*

RUTGERS

Alan Robock
Department of Environmental Sciences



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Department of Environmental Sciences


ENOLA
GAY
82

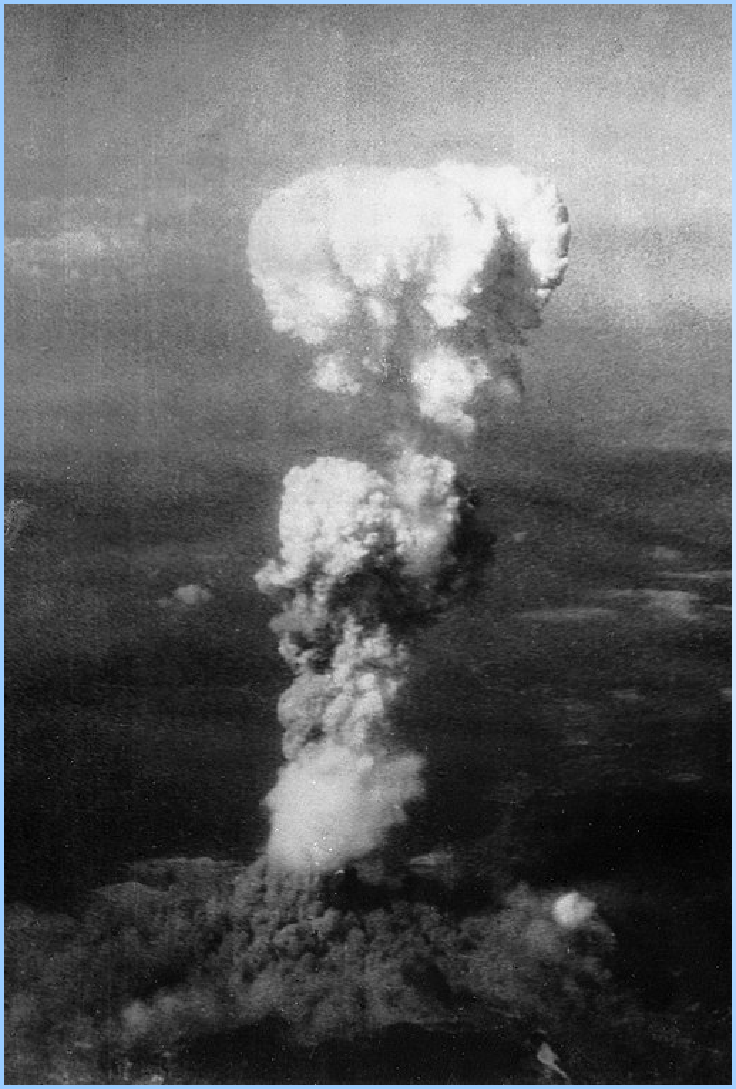

37
R
82
ENOLA GAY


ENOLA GAY
82


CUT THRU GLASS
FOR EMERGENCY
RESCUE
NO SMOKING WITHIN
100 FT.

Illustration by Mark Stevenson/Stocktrek

Mushroom cloud, minutes after the bombing, taken by Bob Caron, tail gunner of the Enola Gay



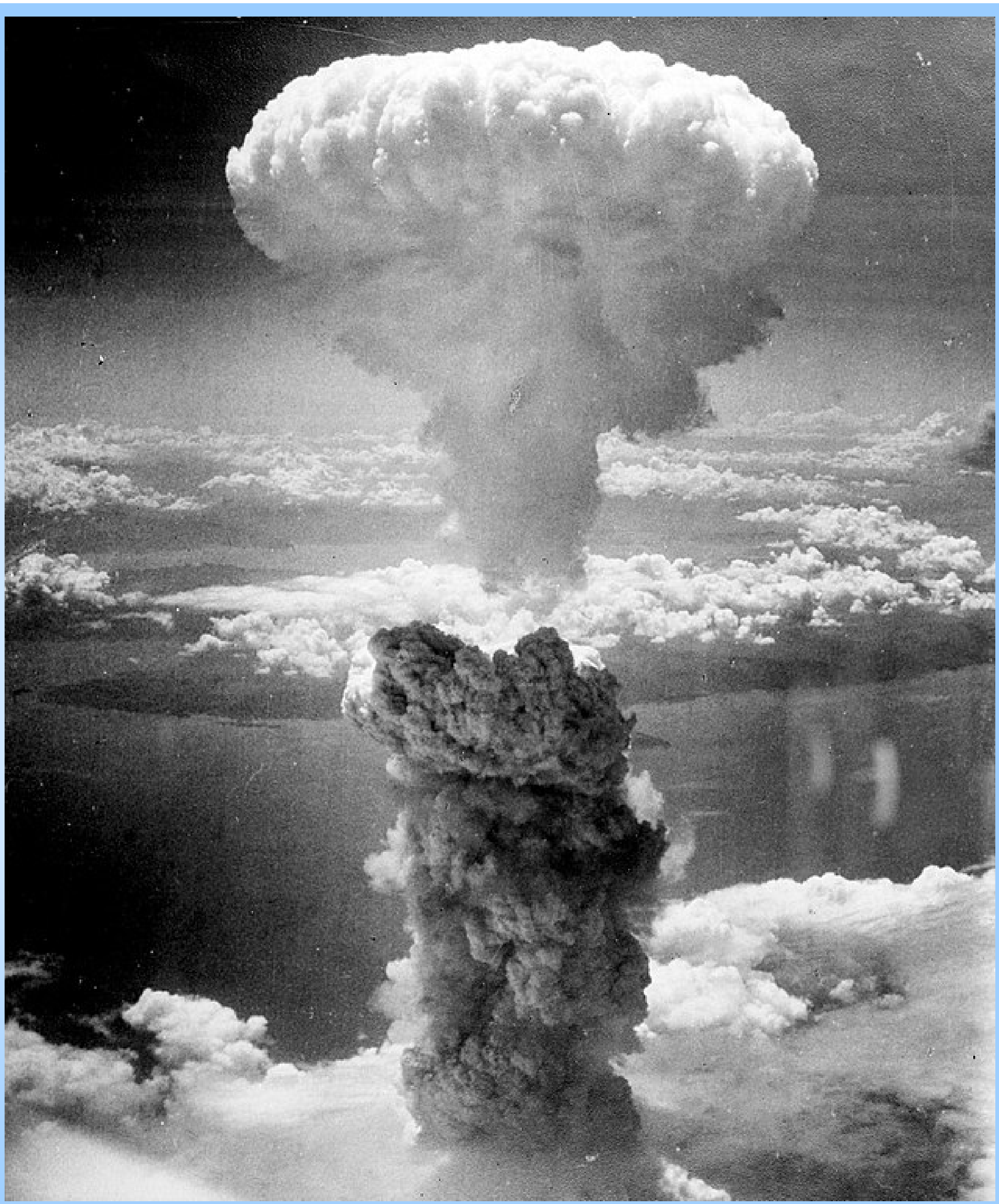
Pyrocumulonimbus smoke plume more than 3 hours after attack

Alan Robock
Environmental Sciences

Nagasaki

Aug. 9, 1945

11:02 am




The Urakami hypocenter area seen from the air
Looking from north to south.
The entire district was reduced to a burned wasteland.
The area slightly to the left of center is the hypocenter.

THE STORY OF AN EYEWITNESS

By Jack London

Collier's, the National Weekly

May 5, 1906

Within an hour after the earthquake shock the smoke of San Francisco's burning was a lurid tower visible a hundred miles away. And for three days and nights this lurid tower swayed in the sky, reddening the sun, darkening the day, and filling the land with smoke.

... I watched the vast conflagration from out on the bay. It was dead calm. Not a flicker of wind stirred. Yet from every side wind was pouring in upon the doomed city. East, west, north, and south, strong winds were blowing upon the doomed city. The heated air rising made an enormous suck. Thus did the fire of itself build its own colossal chimney through the atmosphere. Day and night this dead calm continued, and yet, near the flames, the wind was often half a gale, so mighty was the suck.

This photograph, taken from a series of kites five weeks after the great earthquake of April 18, 1906, shows the devastation brought on the city of San Francisco by the quake and subsequent fire. (photo courtesy of Harry Myers)

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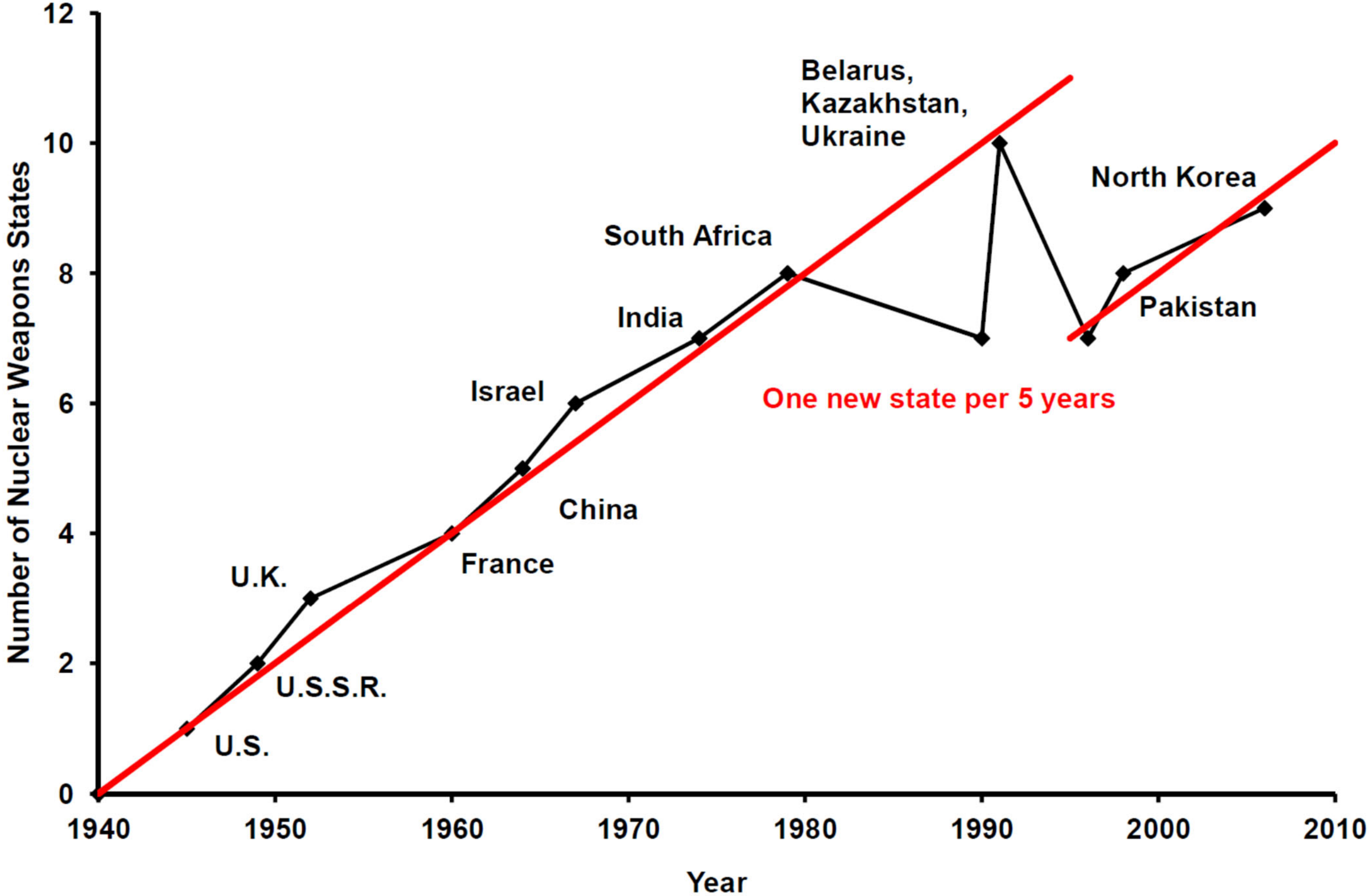
Alan Robock
Department of Environmental Sciences



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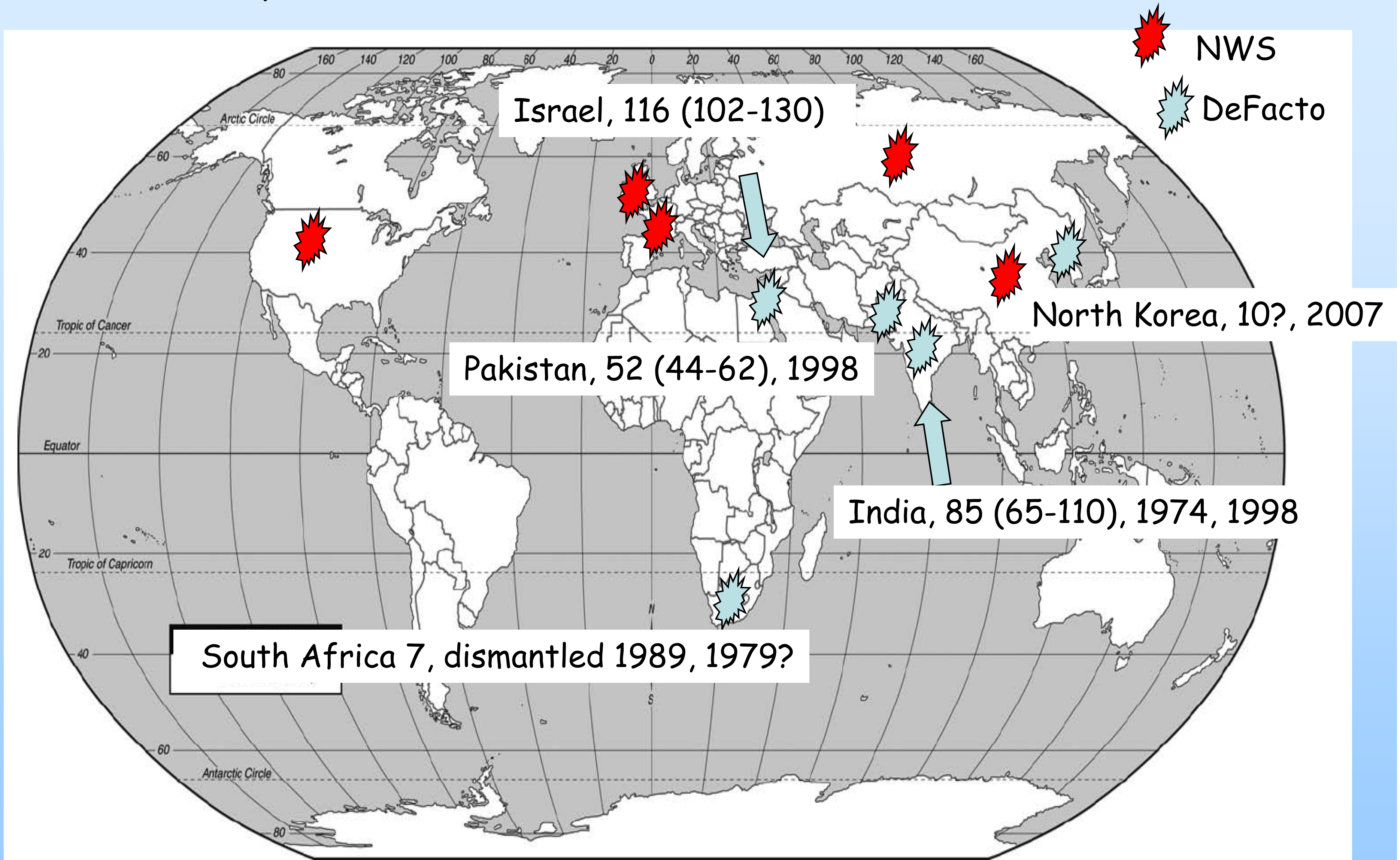
Department of Environmental Sciences

Even small nuclear states can have many warheads
[number of weapons, when first tested]



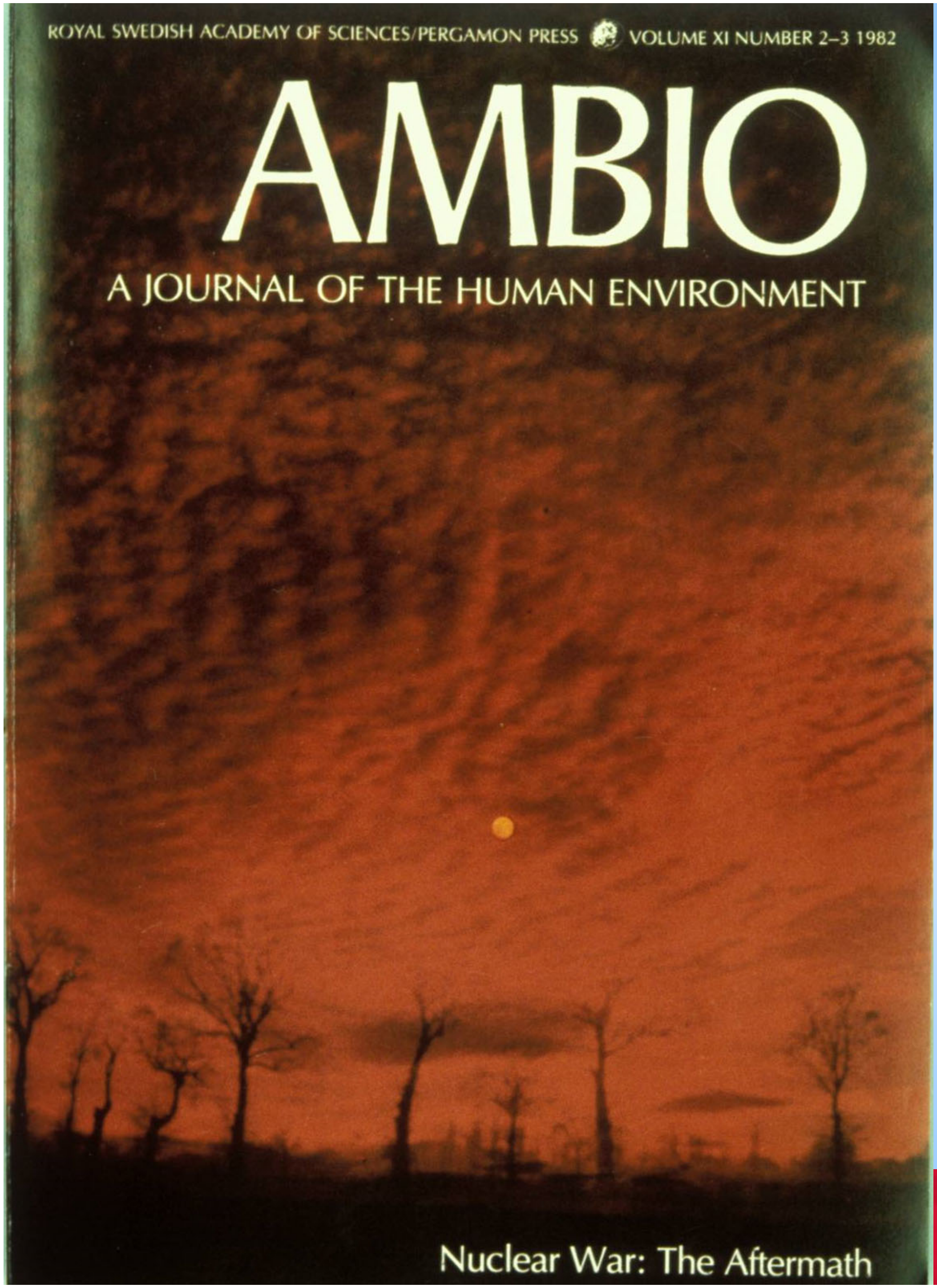
Alan Robock
Department of Environmental Sciences

2011 Nuclear Arsenals

Country	No. of weapons
Russia	11,000
United States	8,500
France	300
China	240
Britain	225
Israel	80
India	80-100
Pakistan	90-110
North Korea	10?

http://www.fas.org/programs/ssp/nukes/nuclearweapons/nukestatus.html

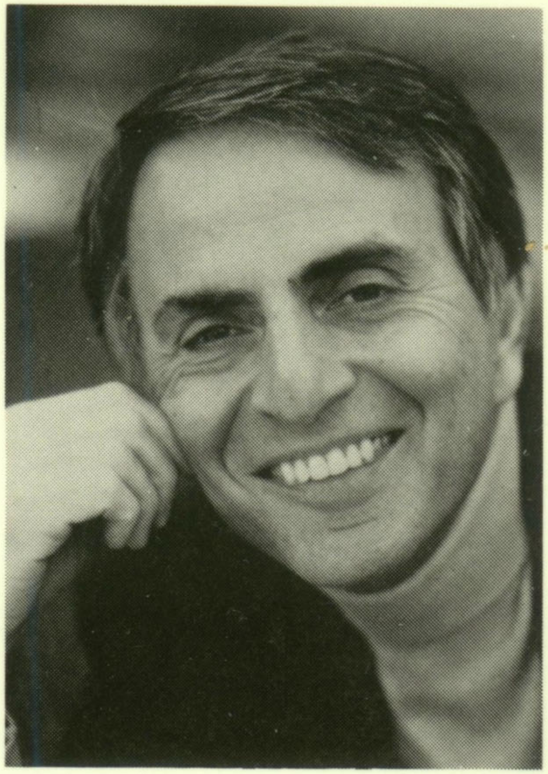
25 additional countries possess sufficient nuclear explosive materials that could allow them to construct more weapons, some in a relatively short period of time. The world could construct 100,000 more weapons with current material stockpiles. The totals for the United States and Russia do not include ~6,500 warheads awaiting dismantlement.



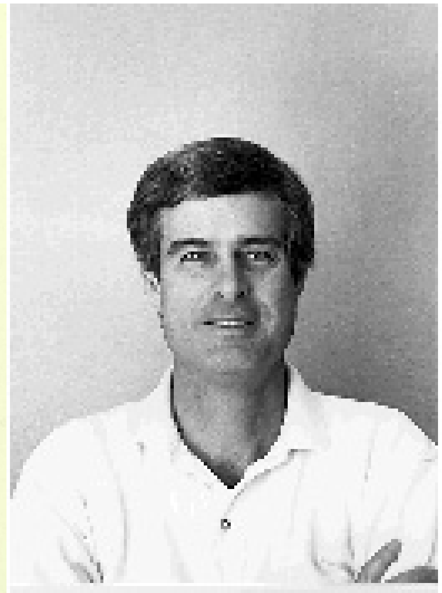
Paul Crutzen and **John Birks** discussed the effects of a nuclear holocaust on ozone.

They were the first to point out that there would be massive fires, and that the smoke from these fires could change climate.

CARL SAGAN



BRIAN TOON



TOM ACKERMAN

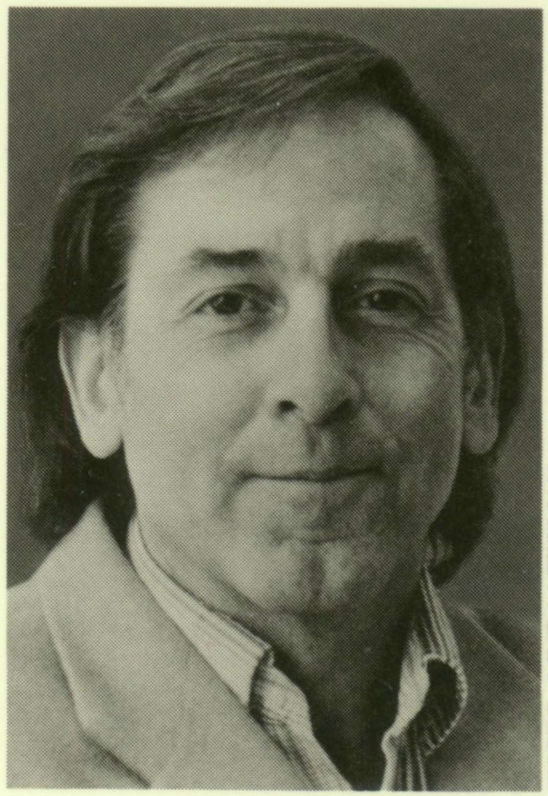


PHOTO: LINDA NEWMAN

RICHARD TURCO

JIM POLLACK

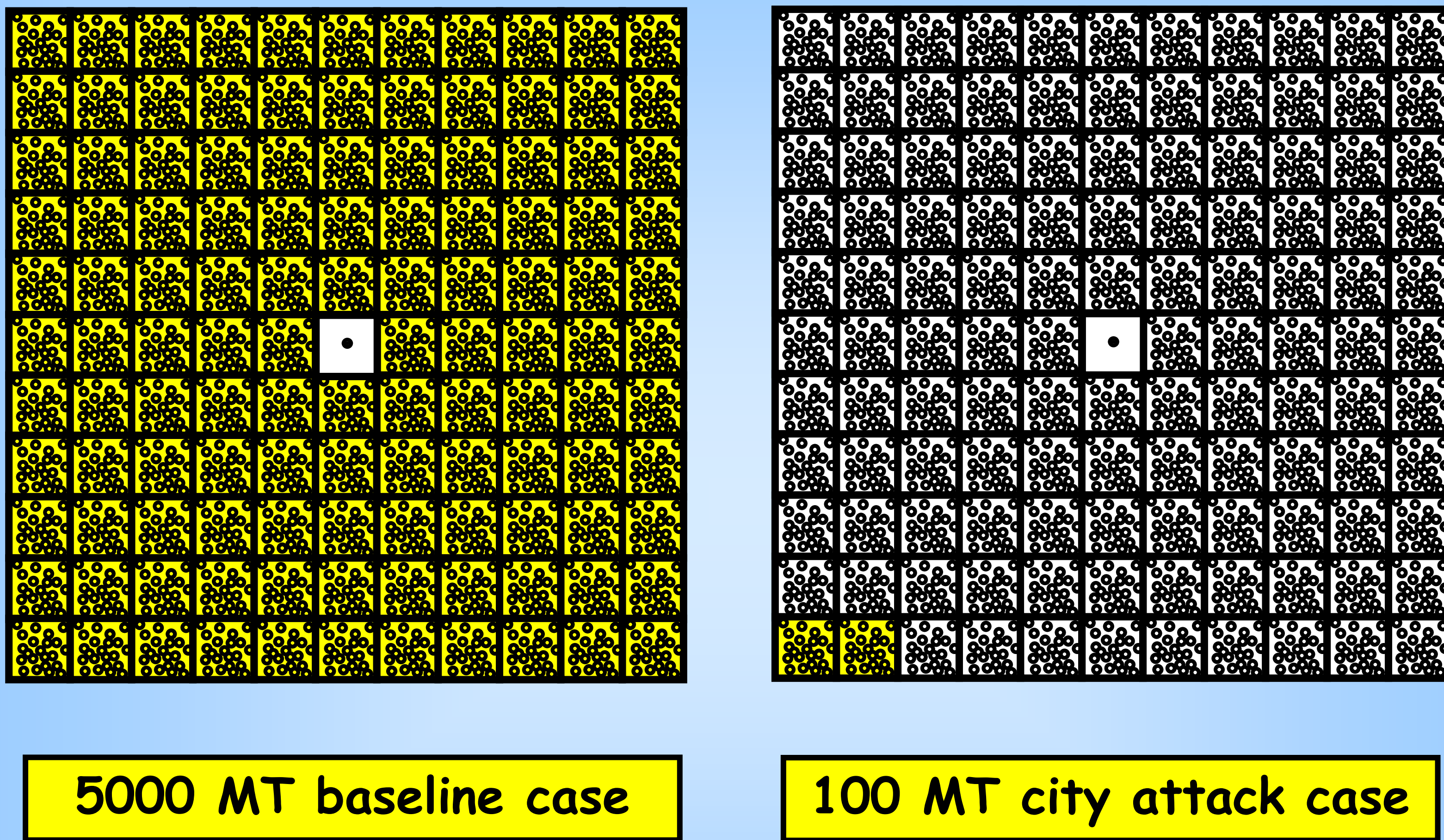
TTAPS

Richard **T**urco, Brian **T**oon, Tom **A**ckerman, Jim **P**ollack, and Carl **S**agan, 1983: Nuclear winter: Global consequences of multiple nuclear explosions, *Science*, **222**, 1283-1292.

The famous **TTAPS** paper – one of the two first climate model simulations of nuclear winter.

Gave **Nuclear Winter** its name.

Used a single column radiative-convective climate model which represented the entire Northern Hemisphere by one column and calculate the vertical distribution of temperature change for annual average radiation out to 300 days.



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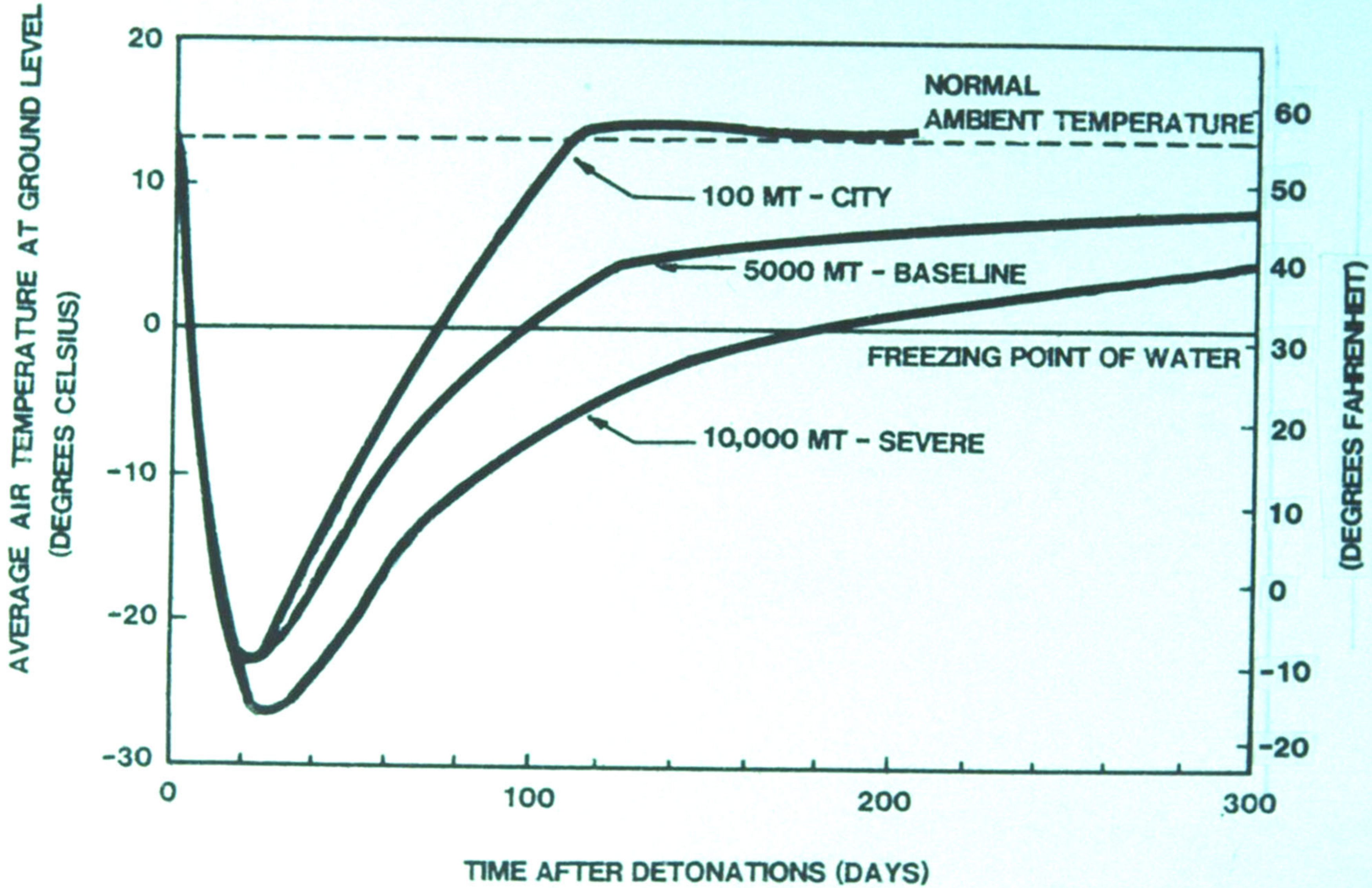

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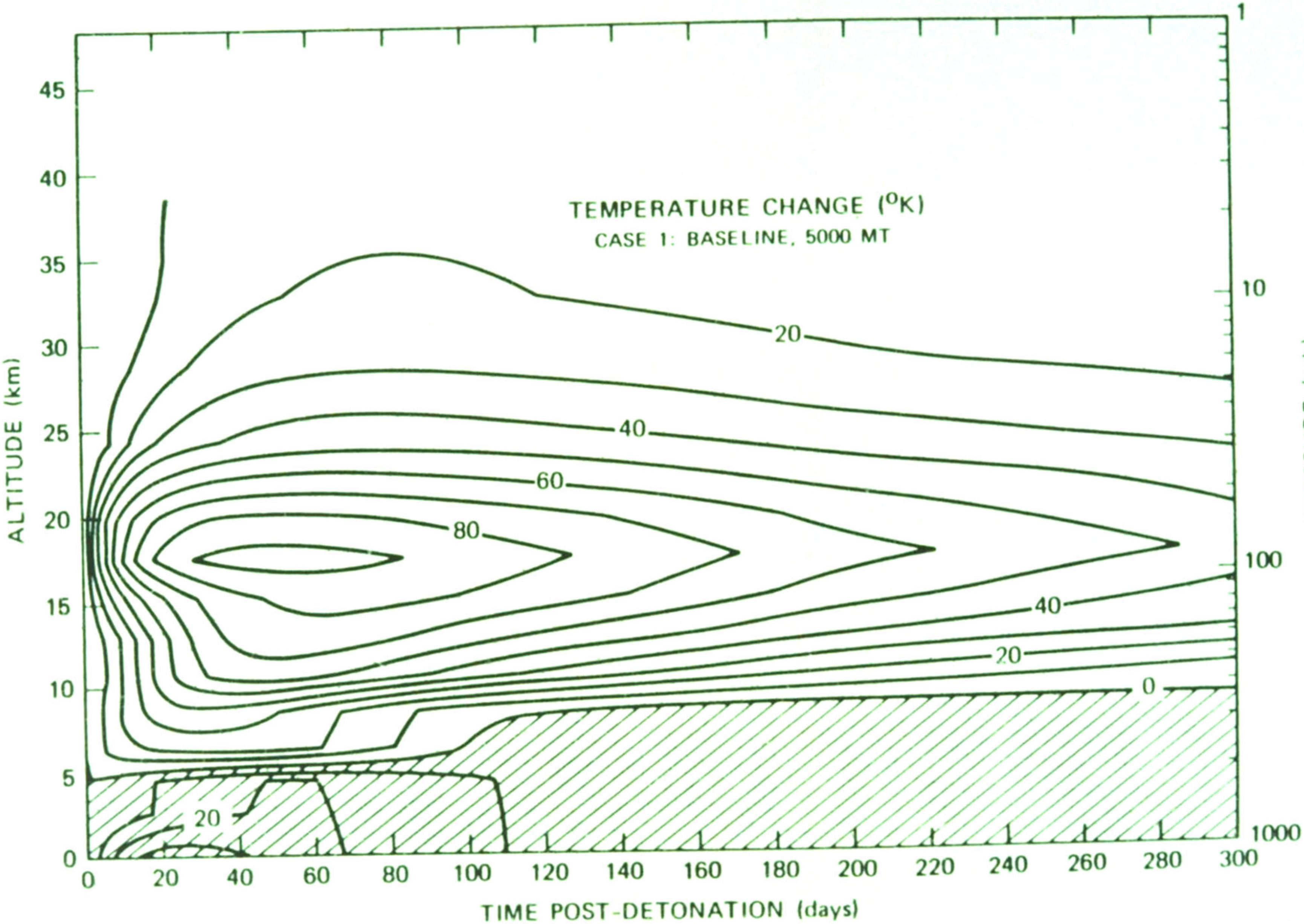
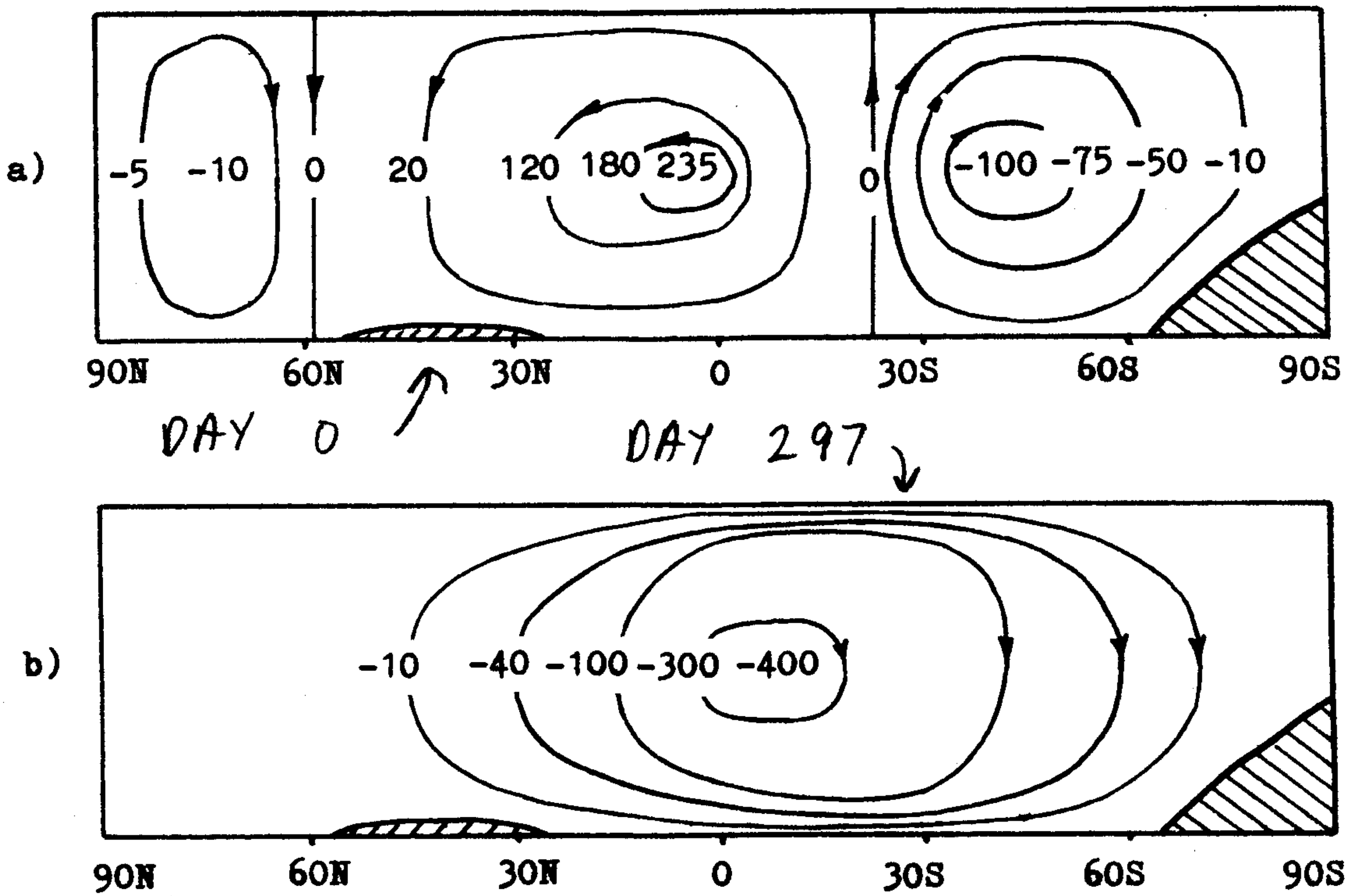

TEMPERATURE CHANGE (°K)
CASE 1: BASELINE, 5000 MT
ALTITUDE (km)
PRESSURE (mb)
TIME POST-DETONATION (days)
0
5
10
15
20
25
30
35
40
45
1
10
100
1000
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300

Vladimir V. **Aleksandrov** and Georgiy L. **Stenchikov**, 1983: On the modelling of the climatic consequences of the nuclear war. *Proc. Applied Math.*, Computing Centre, USSR Academy of Sciences, Moscow, 21 pp.

First published model simulation of nuclear winter.

First three-dimensional simulation using a general circulation model (GCM) – simulated 400 days with annual average radiation.

Used two-level Mintz-Arakawa GCM, with 12°x15° lat-lon grid.



Streamfunction of zonally averaged mass flux [10^{12} g s^{-1}]

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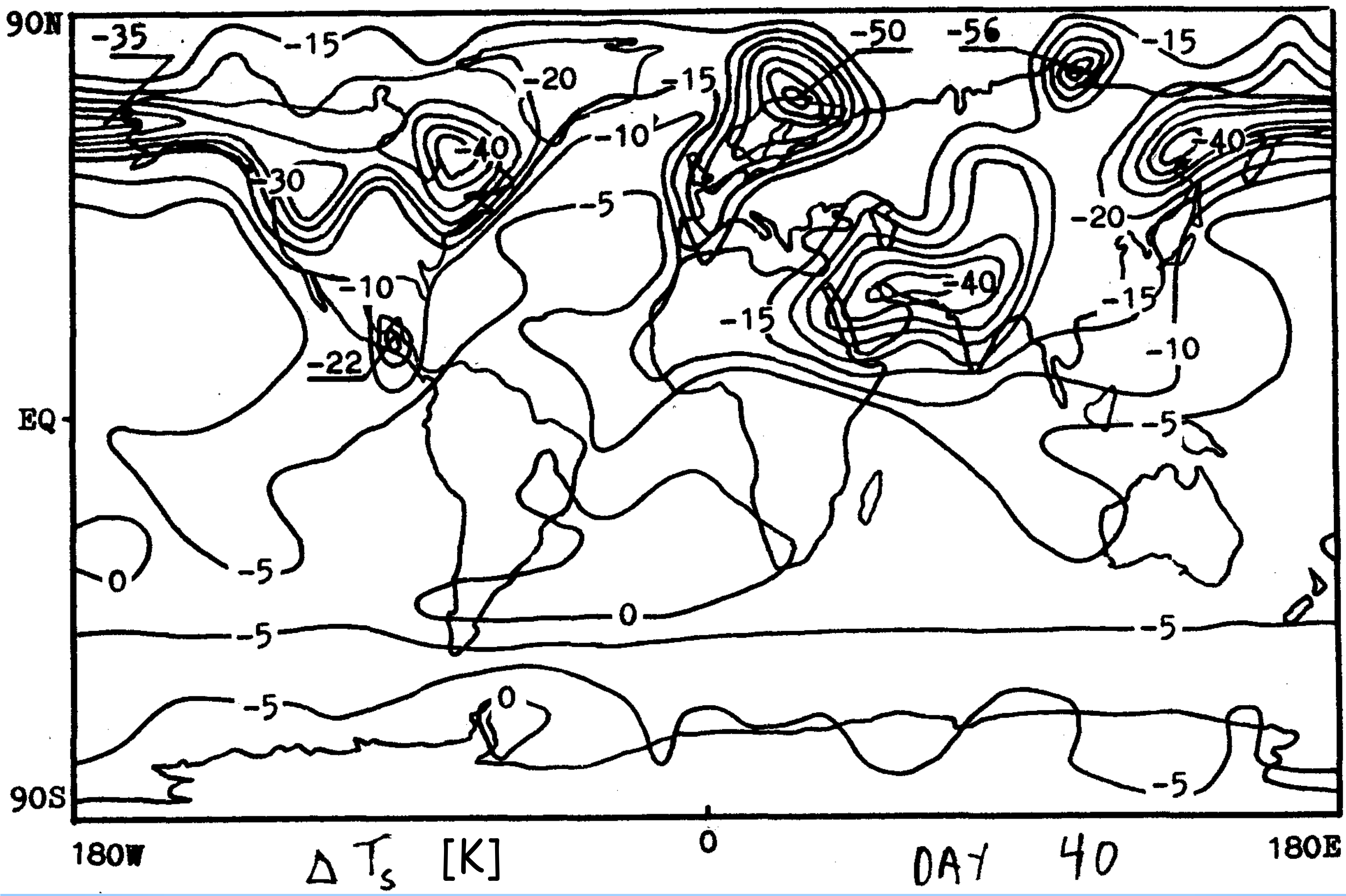
Department of Environmental Sciences



RUTGERS
Alan Robock
Department of Environmental Sciences

Curt **Covey**, Steve **Schneider**, and Starley **Thompson**, 1984: Global atmospheric effects of massive smoke injections from nuclear war: Results from general circulation model simulations. *Nature*, **308**, 21-25.

Used NCAR GCM to simulate the temperature effects for 20 days for winter, spring, and summer conditions.

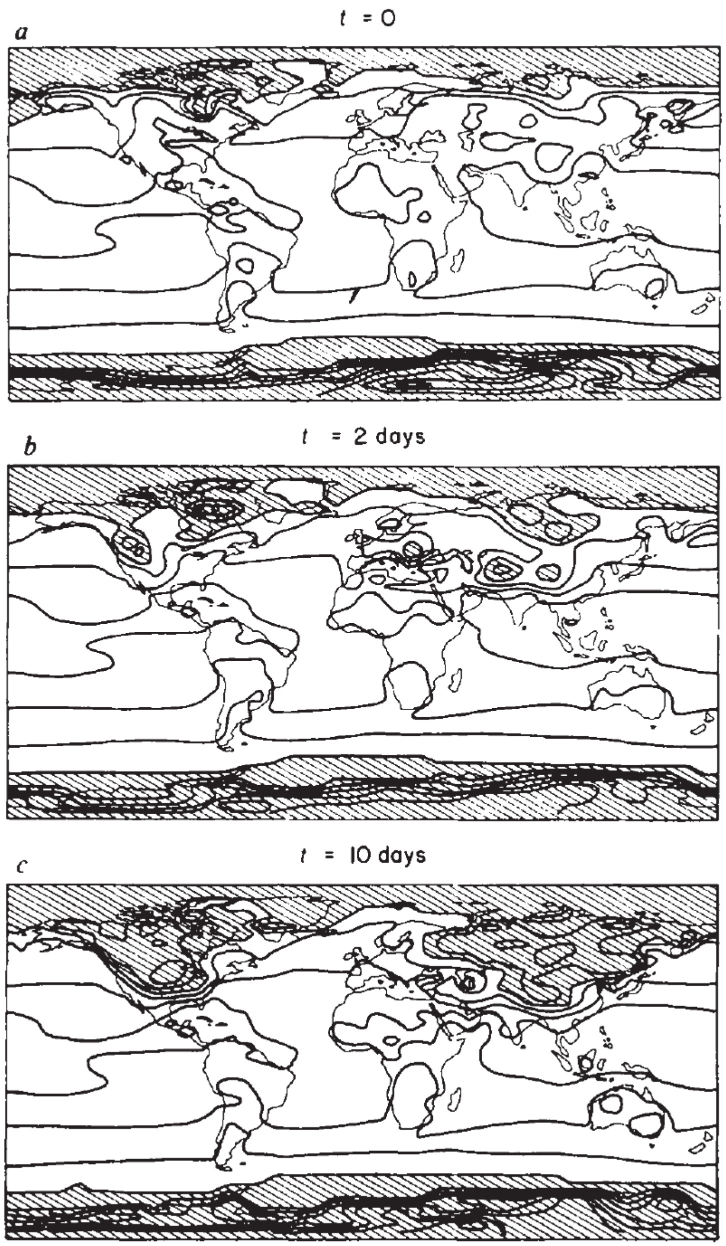


Fig. 3 Surface temperature (T) at three selected instants of time: $t = 0$ is the time at which smoke was added to the atmosphere in the summer case. Temperature contours are drawn for every 10 K. Areas with $T < 270$ K (that is, well below freezing) are shaded. The warmest contour value in the tropics is 300 K.

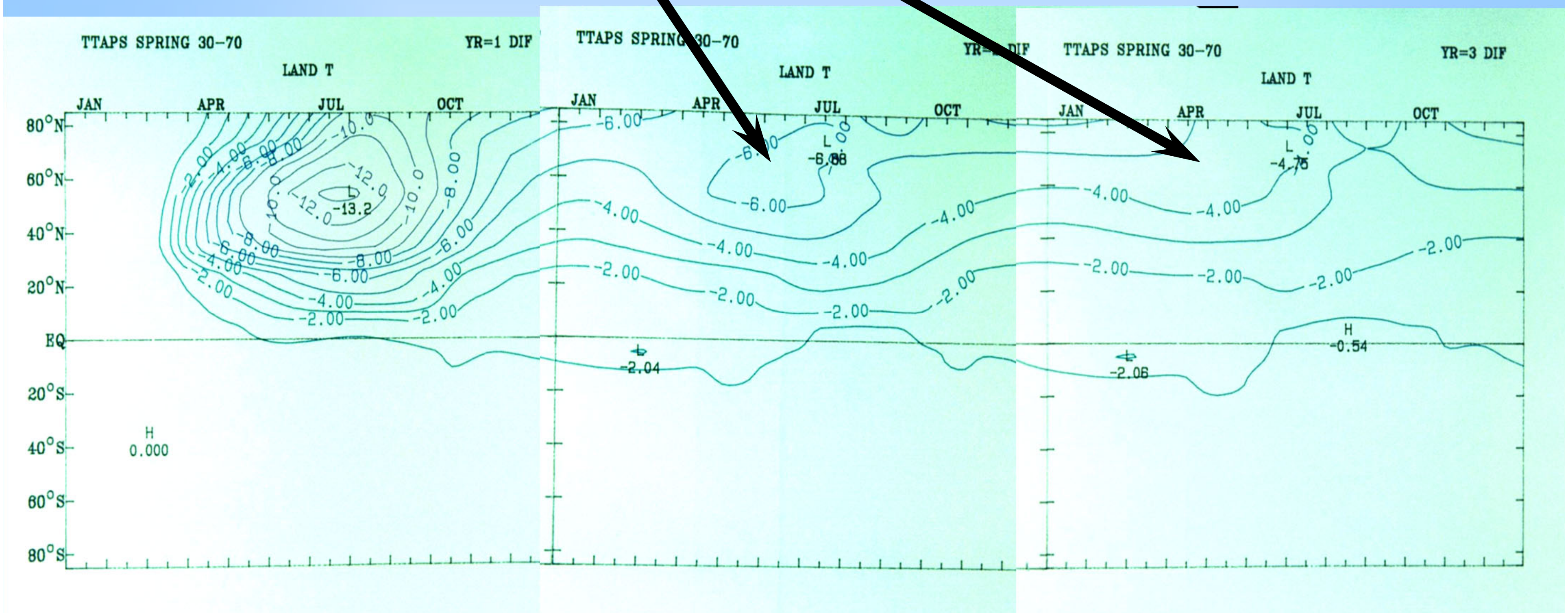
RUTGERS

Robock, Alan, 1984: Snow and ice feedbacks prolong effects of nuclear winter. *Nature*, **310**, 667-670.

Used an energy balance climate model and showed that snow and ice feedbacks prolong the surface temperature effects for several years.

Did simulations for nuclear holocaust starting in all four seasons.

Snow-albedo feedback



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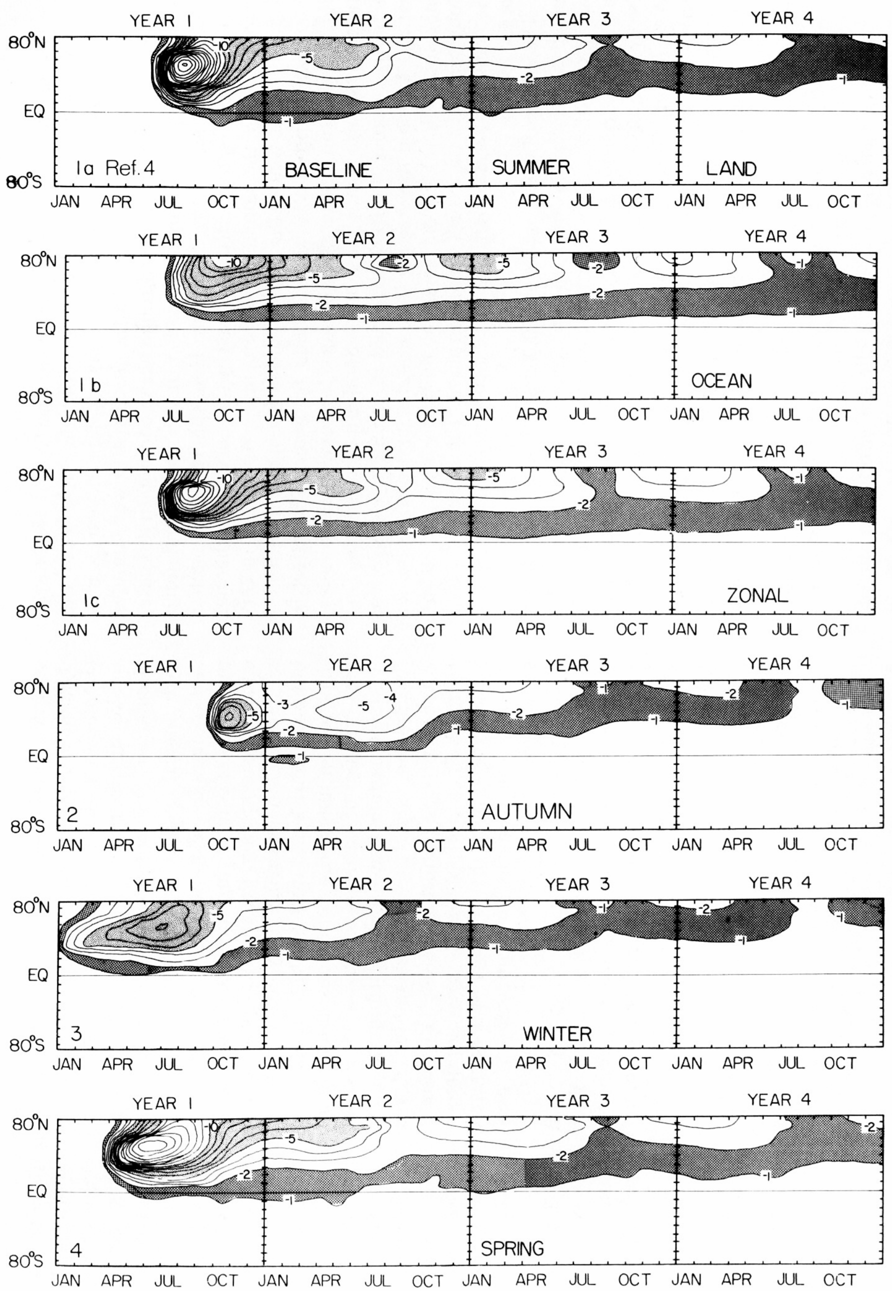


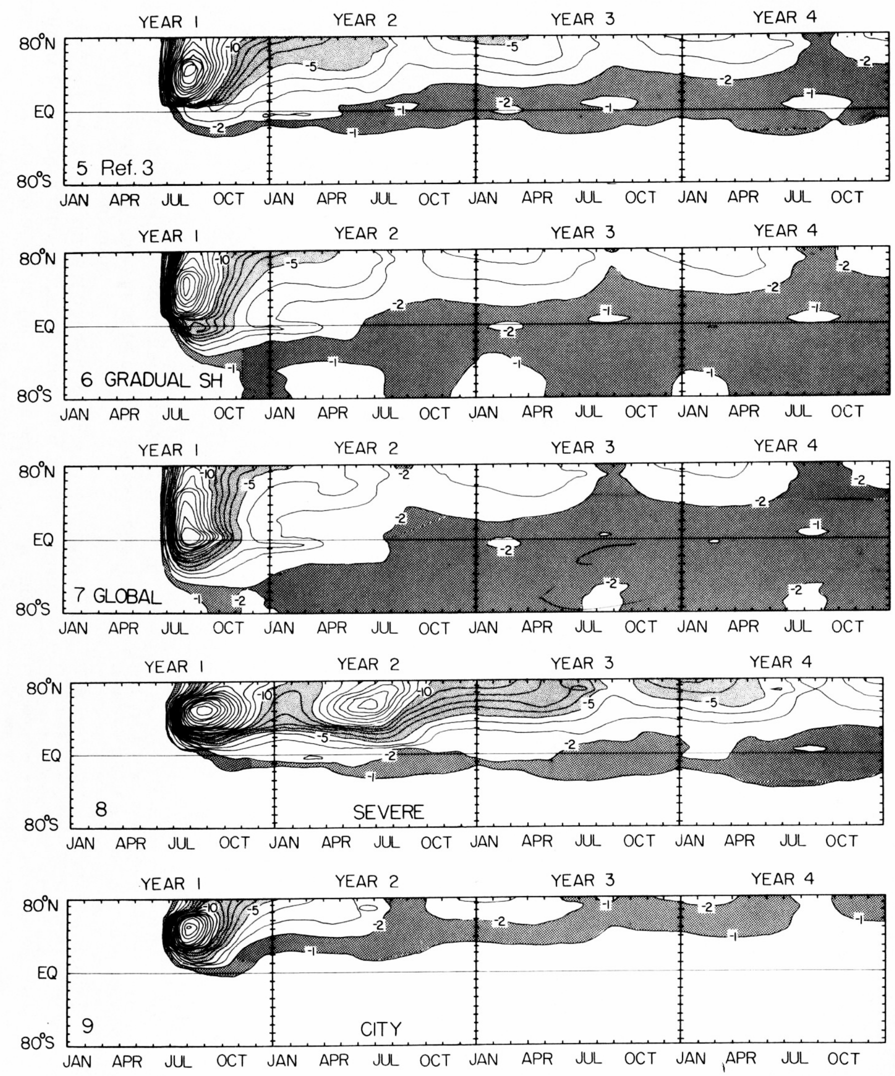
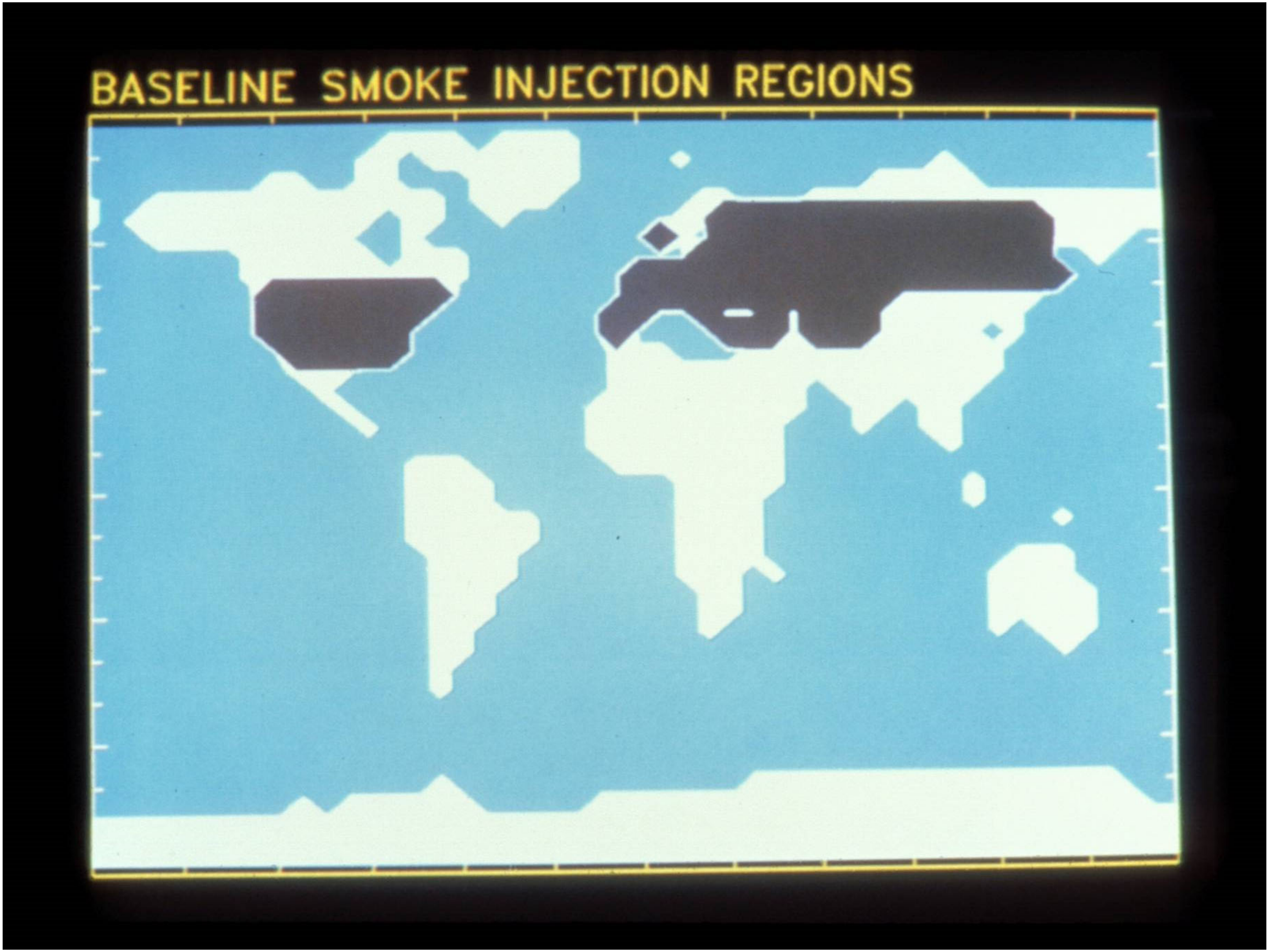
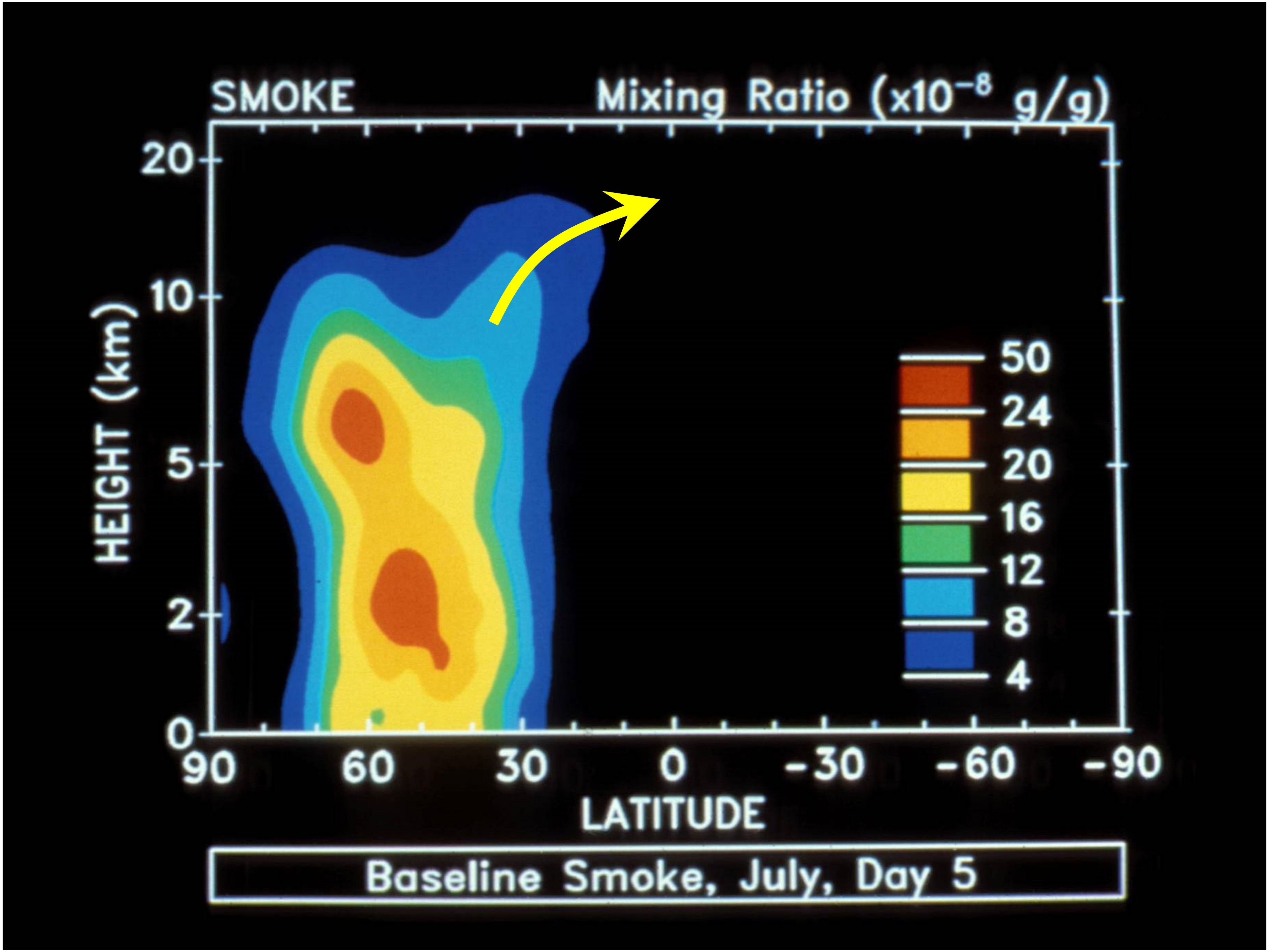


Fig. 1 Temperature change (nuclear war experiments minus unperturbed climate) as function of latitude and time for the runs listed in Table 2. Contours are every 1 °C starting at −1 °C. Temperature drops between −1 °C and −2 °C, and between −5 °C and −10 °C, are shaded.

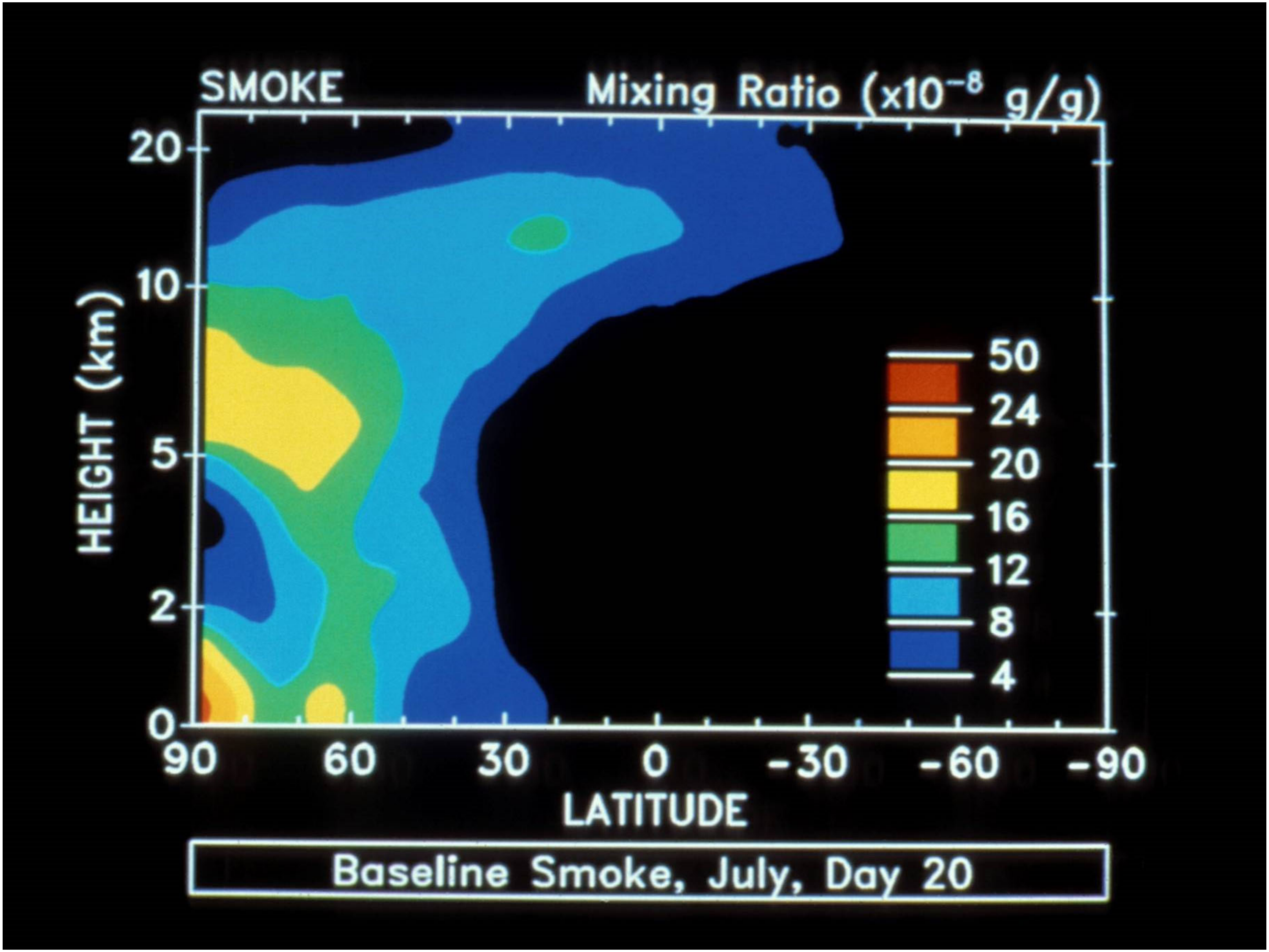
Thompson, Starley L., 1985: Global interactive transport simulations of nuclear war smoke, *Nature*, **317**, 35-39.

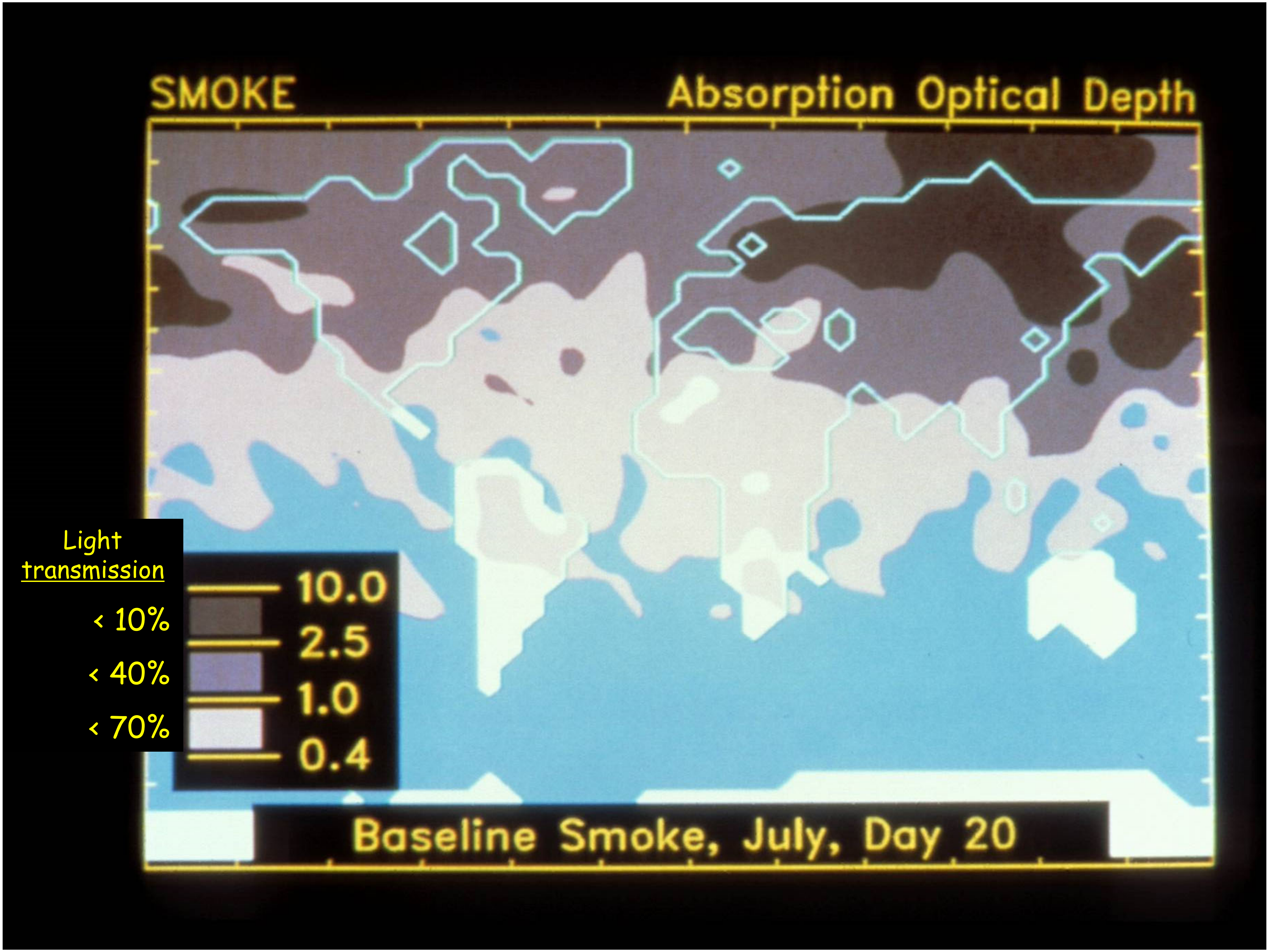
Used NCAR GCM to simulate the temperature effects for 20 days for winter, spring, and summer conditions.

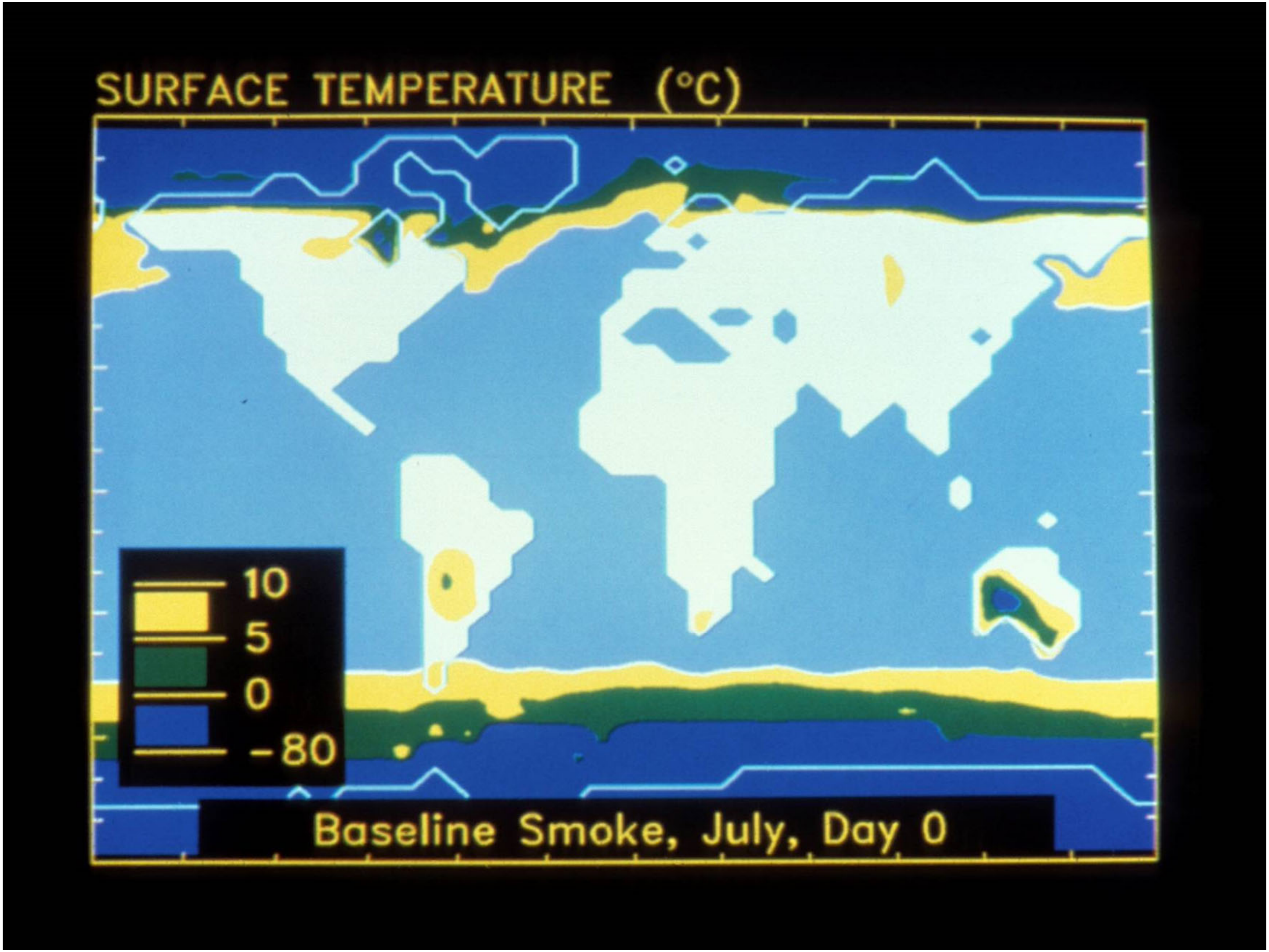

BASELINE SMOKE INJECTION REGIONS

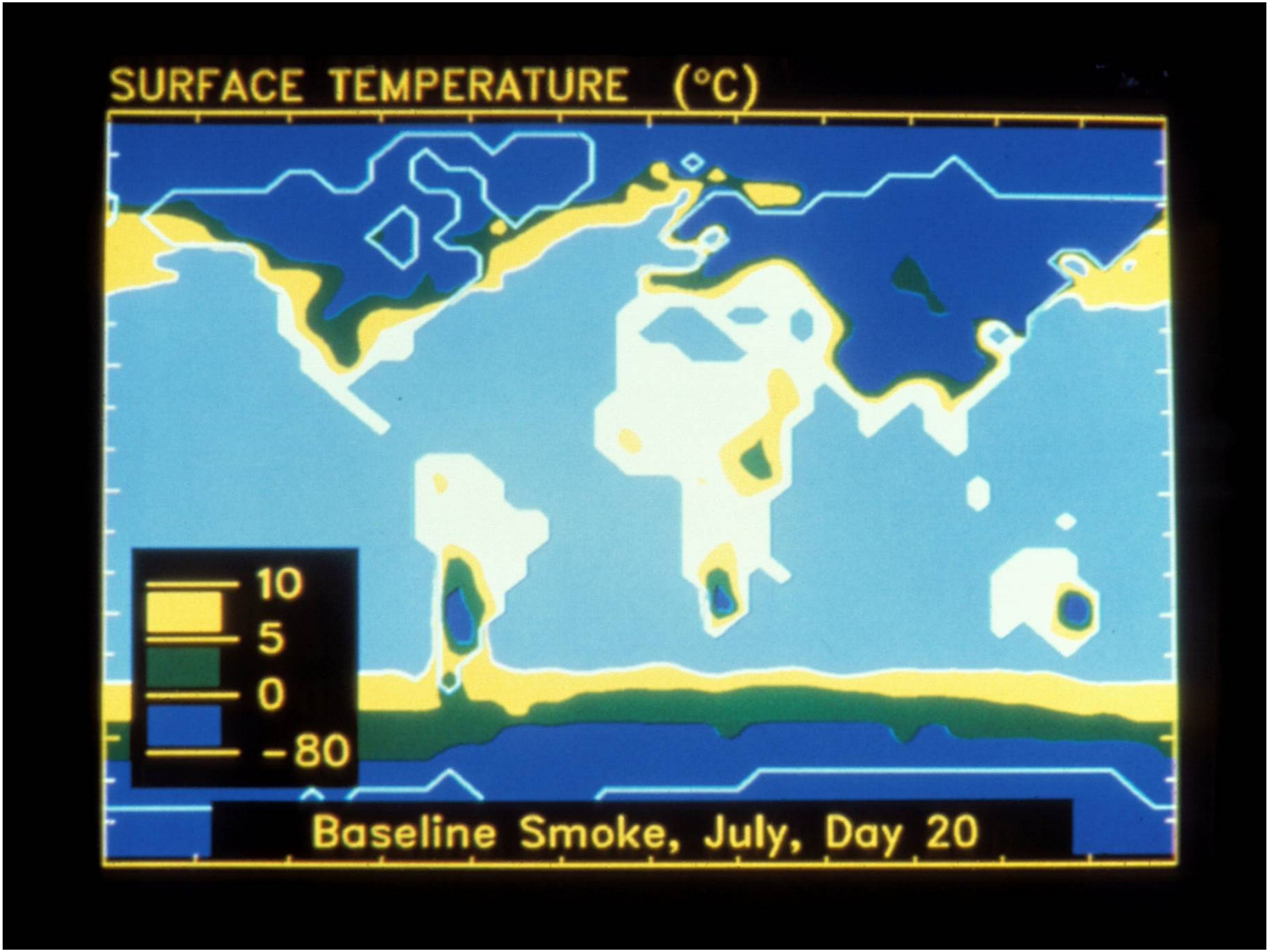


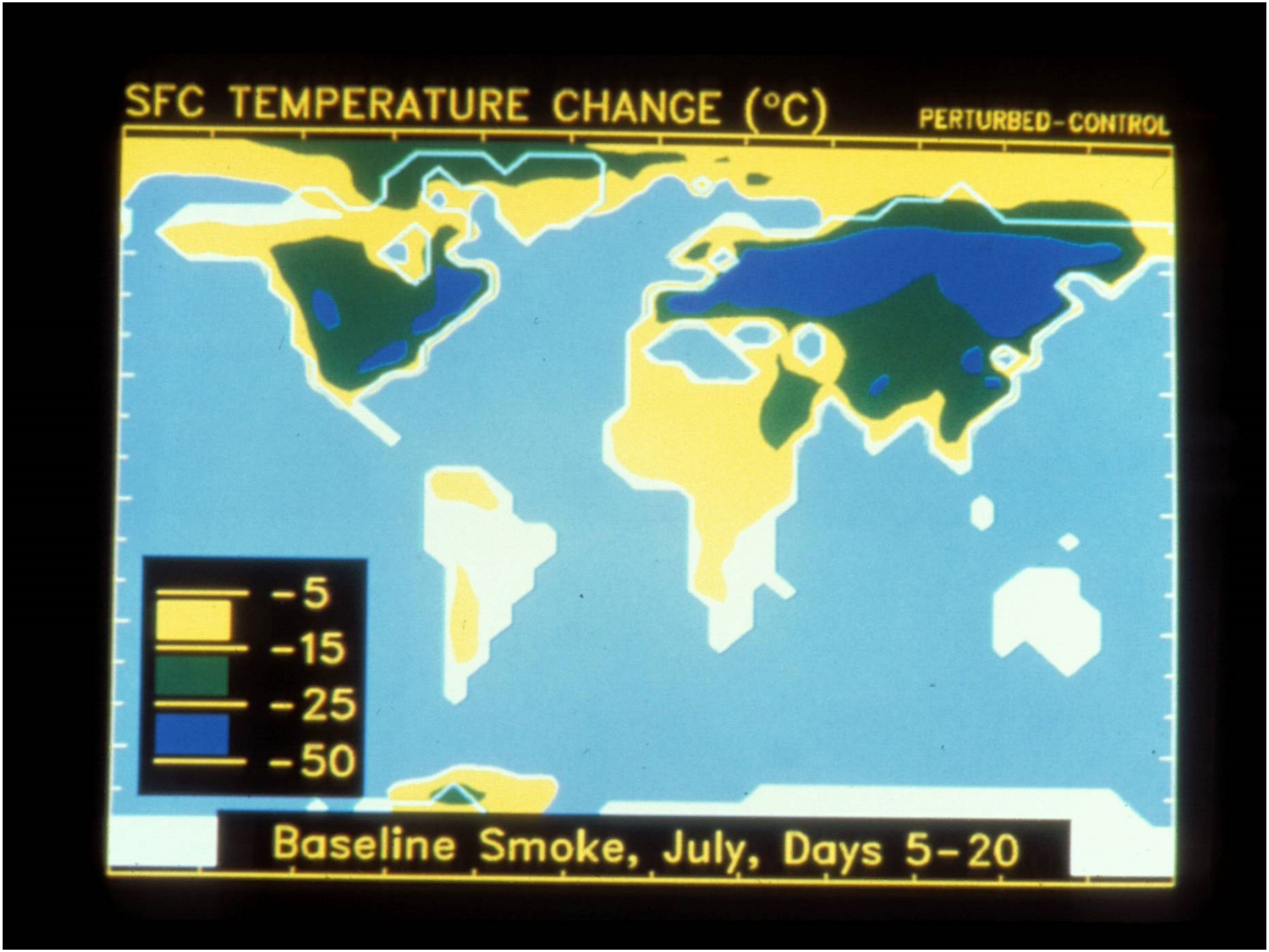
SMOKE
Mixing Ratio ($\times10^{-8}$ g/g)
HEIGHT (km)
20
10
5
2
0
90
60
30
0
-30
-60
-90
LATITUDE
50
24
20
16
12
8
4
Baseline Smoke, July, Day 5


SMOKE
Mixing Ratio (x10^{-8} g/g)
HEIGHT (km)
20
10
5
2
0
50
24
20
16
12
8
4
90
60
30
0
-30
-60
-90
LATITUDE
Baseline Smoke, July, Day 20


SMOKE
Absorption Optical Depth
Light transmission
< 10%
< 40%
< 70%
10.0
2.5
1.0
0.4
Baseline Smoke, July, Day 20


SURFACE TEMPERATURE (°C)
10
5
0
-80
Baseline Smoke, July, Day 0


SURFACE TEMPERATURE (°C)
10
5
0
-80
Baseline Smoke, July, Day 20


SFC TEMPERATURE CHANGE (°C)
PERTURBED-CONTROL
-5
-15
-25
-50
Baseline Smoke, July, Days 5-20

New NCAR Simulations

Thompson, S. L., and S. H. Schneider, 1986: Nuclear winter reappraised, *Foreign Affairs*, **64**, 981-1005.

- "moderately black" smoke
- included infrared effects of smoke
- "about three-fourths of the smoke is removed from the model's atmosphere over the course of 30 days" because it was placed in the surface to 7 km layer

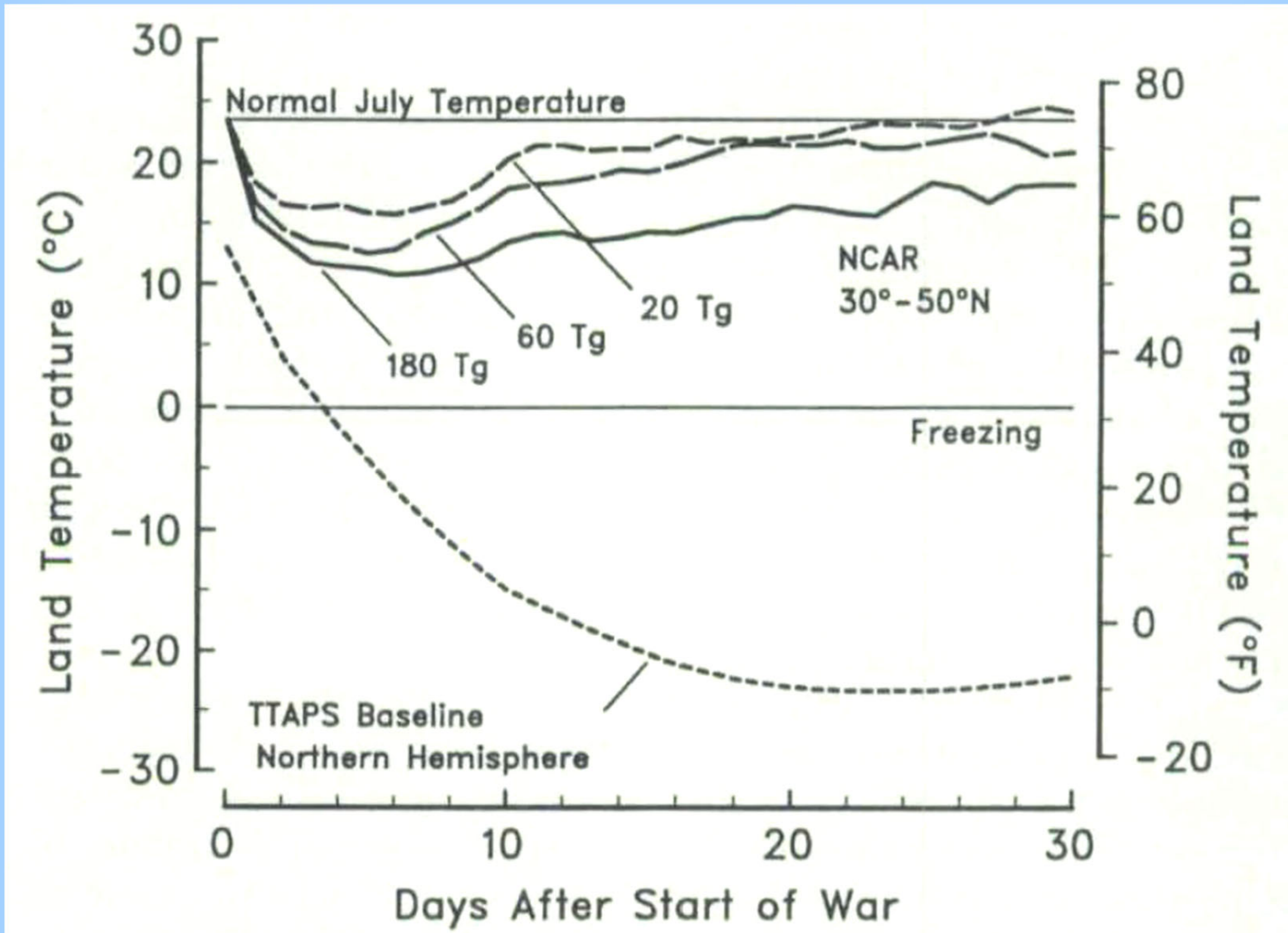
-no diurnal cycle

-specified constant sea surface temperatures

Steve Schneider, *Science as a Contact Sport* (2009), p. 102, summarizing a discussion with Walter Orr Roberts about discussing their climate modeling results:

"But I wasn't going to use that phrase 'nuclear fall' because I was media savvy enough to know that it would be used to attack Carl, conveniently ignoring the fact that a nuclear fall would be a disaster, too."

“These temperature changes more closely describe a nuclear ‘fall’ than a nuclear winter.”



RUTGERS

Thompson, S. L., and S. H. Schneider, 1986: Nuclear winter reappraised, *Foreign Affairs*, 64, 981-1005.

Alan Robock
Department of Environmental Sciences

Thompson, S. L., and S. H. Schneider, 1986: Nuclear winter reappraised, *Foreign Affairs*, **64**, 981-1005.

"... it can be misleading to interpret the curves on the figures without taking into account geographic and weather variability as well. Indeed, for certain biological impacts it would be sufficient to have only a few hours of temperature below some critical level-e.g., subfreezing for wheat, or 10-15°C (50-59°F) for rice."

"... it is still quite plausible that climatic disturbances, radioactive fallout, ozone depletions and the interruption of basic societal services, when taken together, could threaten more people globally than would the direct effects of explosions in a large nuclear war."

Schneider, Stephen H., and Starley L. Thompson, 1988: Simulating the climatic effects of nuclear war, *Nature*, **333**, 221-227.

"Because autumn is the time that the growing season ends in the mid-latitudes of the northern hemisphere and the summer monsoons fade in Asia and northern Africa, we are willing to continue to use our 'nuclear fall' metaphor as an appropriate shorthand label for the magnitude and biological implications of the results from present models given presently accepted baseline estimates by smoke production."

Turco, R. P., O. B. Toon, T. P. Ackerman, J. B. Pollack, and C. Sagan, 1990: Climate and smoke: An appraisal of nuclear winter, *Science*, **247**, 166-176.

"Serious new environmental problems associated with soot injection have been identified, including disruption of monsoon precipitation and severe depletion of the stratospheric ozone layer in the Northern Hemisphere. The basic physics of nuclear winter has been reaffirmed through several authoritative international technical assessments and numerous individual scientific investigations."

Turco, R. P., O. B. Toon, T. P. Ackerman, J. B. Pollack, and C. Sagan, **1990**: Climate and smoke: An appraisal of nuclear winter, *Science*, **247**, 166-176.

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Why do we still remember that nuclear winter was disproven and that the results would be nuclear fall?

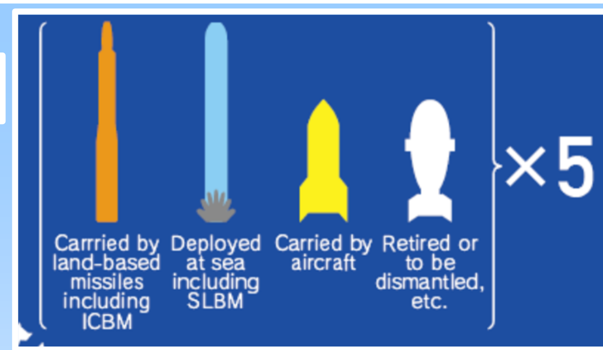
The World's Nuclear Warheads Count June 2020

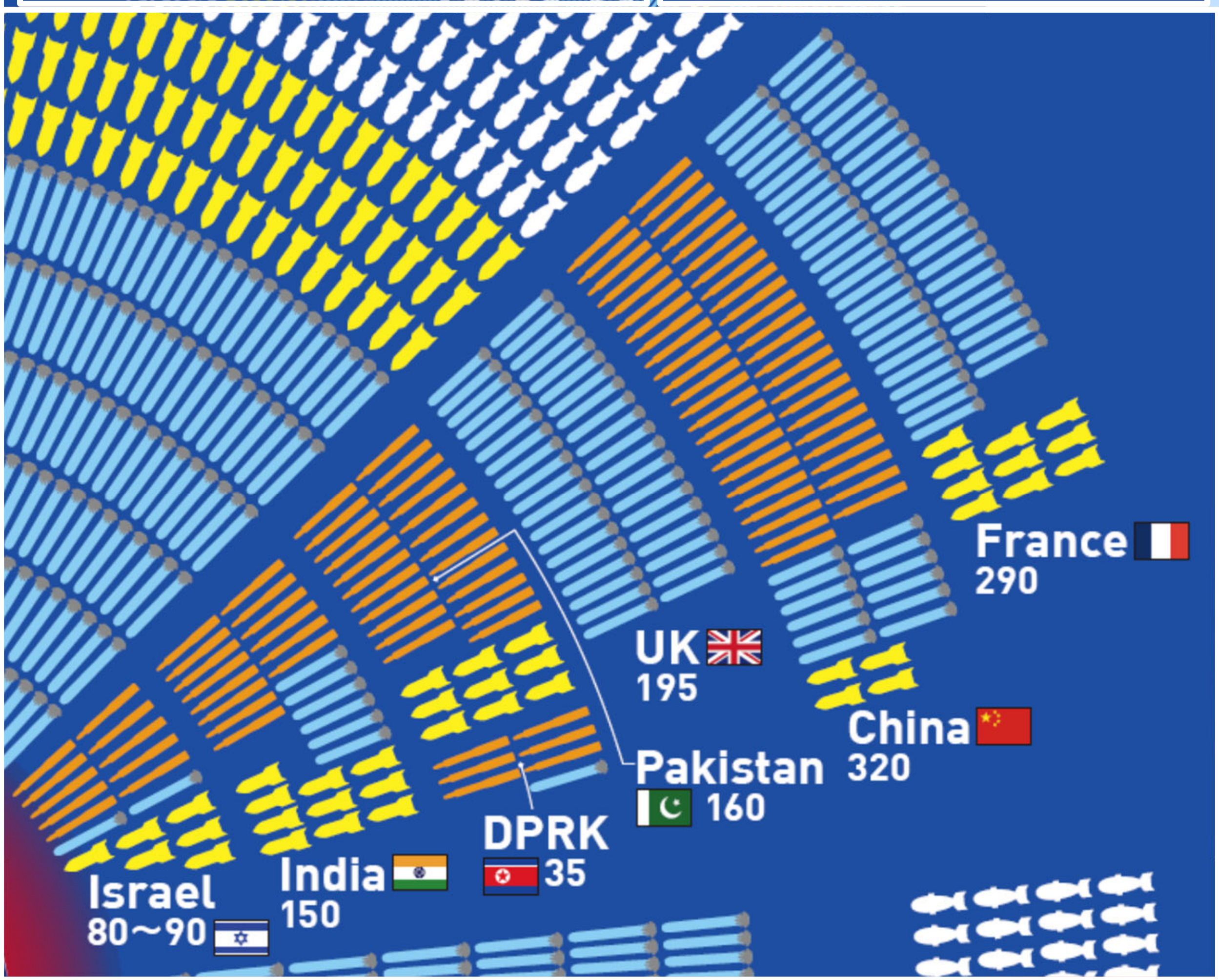
Russia 6,370

Carried by land-based missiles including ICBM	1,606
Deployed at sea including SLBM	1,620
Carried by aircraft	1,080
Retired or to be dismantled, etc.	2,060

US 5,800

Carried by land-based missiles including ICBM	800
Deployed at sea including SLBM	1,920
Carried by aircraft	1,080
Retired or to be dismantled, etc.	2,385





France 290

Deployed at sea including SLBM	240
Carried by aircraft	50

China 320

Carried by land-based missiles including ICBM	240
Deployed at sea including SLBM	60
Carried by aircraft	20

UK 195

Deployed at sea including SLBM	195

Israel 80～90

Carried by land-based missiles including ICBM	50
Deployed at sea including SLBM	10
Carried by aircraft	30

Pakistan 160

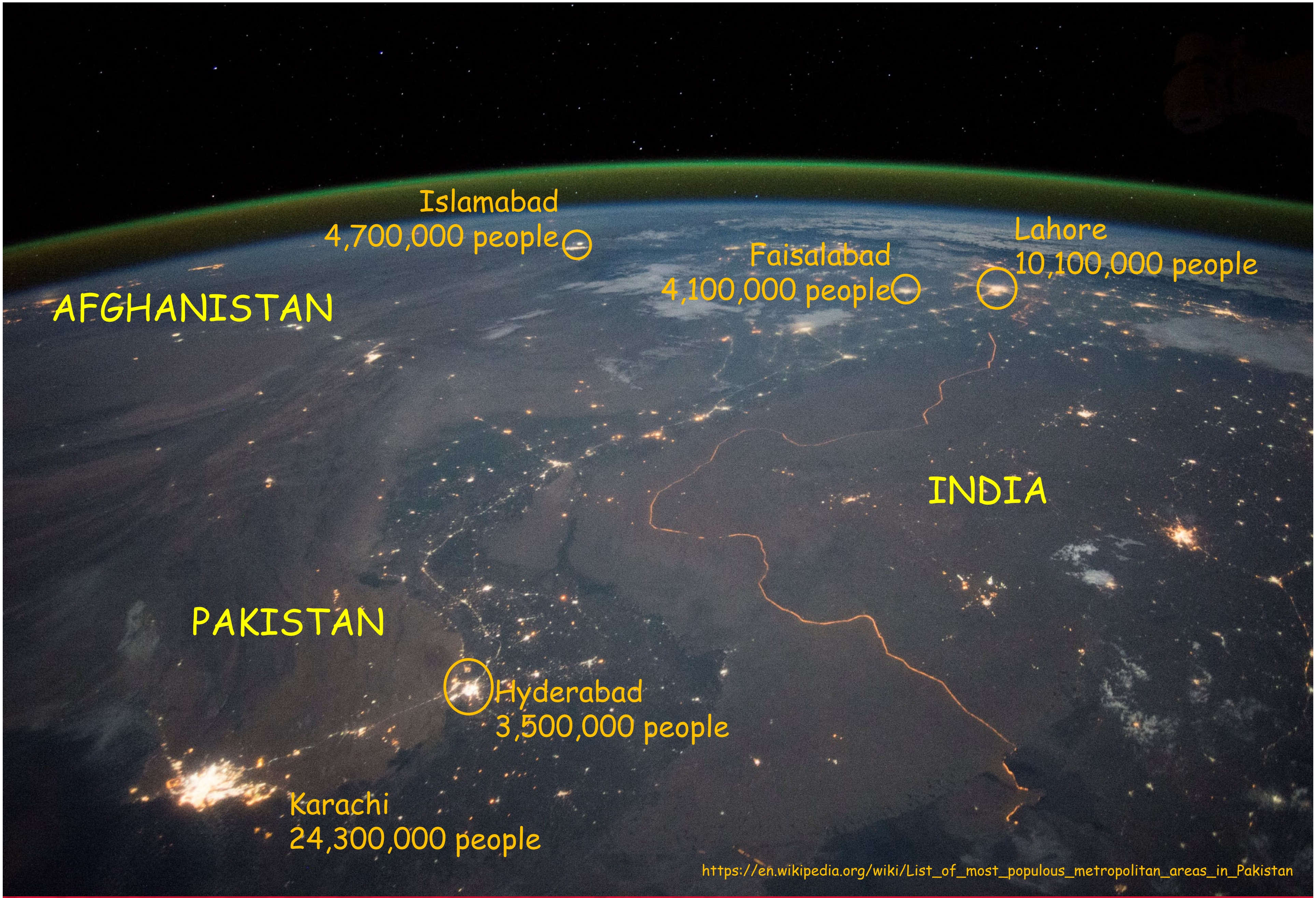
Carried by land-based missiles including ICBM	118
Carried by aircraft	42

India 150

Carried by land-based missiles including ICBM	70
Deployed at sea including SLBM	30
Carried by aircraft	48

DPRK 35

Carried by land-based missiles including ICBM	?
Deployed at sea including SLBM	?



RUTGERS

https://earthobservatory.nasa.gov/IOTD/view.php?id=86725

September 23, 2015

Alan Robock
Department of Environmental Sciences

What if India and Pakistan had a nuclear war?

Imagine a skirmish in Kashmir escalating, due to poor communication, misunderstanding, panic, and fear.

http://upload.wikimedia.org/wikipedia/commons/0/0e/Kashmir_map.jpg

Alan Robock
Department of Environmental Sciences

A unique service for Marriott Astana

Sunday, August 24, 2014

The International

Marriott hotel

Media Group HotelNewspapers

Four killed on India-Pakistan border on August 23, 2014

Four killed in India-Pakistan border fire

Srinagar, India - Four people were killed when nuclear-armed rivals India and Pakistan traded heavy fire across their border early Saturday, with each country accusing the other of "unprovoked" military action.

"Two civilians were killed" and four people injured, including a paramilitary soldier, on the Indian side of the international frontier when Pakistani forces opened fire, Indian police inspector-general Rajesh Kumar said.

On the other side of the frontier, two Pakistani civilians - a woman and a 60-year-old man - "were martyred" by Indian fire, a senior Pakistani military official said.

ASIA PACIFIC

The New York Times

Fighting Intensifies Between India and Pakistan on Kashmir Line of Control

By HARI KUMAR and SALMAN MASOOD NOV. 23, 2016

19 killed on India-Pakistan border on November 23, 2016

NEW DELHI — S ... Wednesday on the de facto border b ... shmir region, killing nine civili ... Army promised retribution for w ... its soldiers.

Pakistan said Indian troops fired on a bus in the Neelam Valley on Pakistan's side of the Line of Control in the disputed Kashmir region, killing the nine passengers and seriously wounding nine others. The Indian military also fired on rescue workers in an ambulance trying to reach the wounded, Pakistan said.

In other violence reported on Wednesday, the Indian military also killed three Pakistani soldiers, including a captain, Pakistan said, and Pakistani forces retaliated, killing seven Indian soldiers.

The New York Times

Militants Attack Indian Army Base in Nagrota, Inflaming Tensions With Pakistan

By GEETA ANAND and HARI KUMAR NOV. 29, 2016

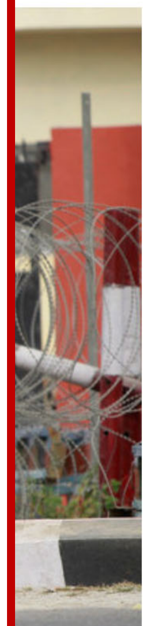
NEW DELHI — Tensions between India and Pakistan were raised again on Tuesday, when a group of heavily armed militants disguised as police officers attacked an Indian Army unit in the northern state of Jammu and Kashmir, killing seven soldiers, the Indian government said in a statement.

The assault began early Tuesday in the officers' dining hall at Nagrota, about two miles from the army's regional headquarters for the country's northernmost state, which has been at the center of a nearly 70-year dispute with neighboring Pakistan.

After killing four soldiers there, the militants moved on to two other buildings, where they held hostage a group of 16 soldiers and relatives, including "two ladies and two children," the statement said.

All of the hostages were rescued, the government said, but an officer and two soldiers were killed in the operation, along with three militants.

Also on Tuesday, Indian security forces in Jammu and Kashmir reported killing three heavily armed militants after a battle near the town of Ramgarh, on the Pakistani border, that lasted several hours. Dinesh Kumar Upadhyaya, inspector general of the Jammu frontier area for the Border Security Force, said the militants were armed with AK-47s, wore suicide belts and hurled about a dozen grenades before being killed.



The New York Times

Cross-Border Clashes in Kashmir Leave 7 Soldiers Dead

By SALMAN MASOOD DEC. 26, 2017

The funeral of a suspected Pakistan-based militant, who according to the local news media was killed in a gun battle with Indian security forces, in Kashmir on Tuesday. Danish Ismail/Reuters

ISLAMABAD, Pakistan — Three Pakistani soldiers have been killed by Indian fire in the disputed Kashmir border region, officials said on Tuesday, after several Indian troops were killed by Pakistani gunfire nearby over the weekend.

The back-to-back deaths added to the latest round of military clashes between Pakistan and India across the Line of Control, and further dashed any faint hopes that the two estranged nations could soon normalize relations.

7 killed on India-Pakistan border on December 26, 2017

…illed and one was injured Monday evening, …ribed as an "unprovoked" cease-fire …Chikri Sector of Poonch District.

…d Tuesday that the soldiers were killed after …who were provided cover by fire from Indian …Chikri. A spokesman for the ministry said that Pakistan had lodged a diplomatic protest.

Previously, the Indian Army said four Indian soldiers, including an army major, had been killed after Pakistani troops opened fire in the Rajauri District of the Indian-controlled part of Kashmir.

Despite a 2003 cease-fire agreement, fire between the two militaries has become a frequent occurrence in Kashmir, the picturesque Himalayan region the two nations have fought over since they both declared independence from Britain in 1947. Both countries claim Kashmir in its entirety, and they have fought several wars over it.

RUTGERS

Alan Robock
Department of Environmental Sciences

Kashmir Suffers From the Worst Attack There in 30 Years

By Sameer Yasir and Maria Abi-Habib

Feb. 14, 2019

AWANTIPORA, Kashmir — A vehicle filled with explosives rammed into a convoy of Indian paramilitary forces on a busy highway in the Indian-controlled part of Kashmir on Thursday, killing at least 40 soldiers, local officials said, in the worst attack in the disputed region in three decades.

Kashmir Militants Kill Again as Trouble Grows Between India and Pakistan

Flames and smoke billow
militants and Indian secu
Monday. Dar Yasin/Associ

By Jeffrey Gettleman and Sameer Yasir

Feb. 18, 2019

NEW DELHI — Militants in Kashmir struck again on Monday, killing an Indian Army major and at least three other soldiers just days after orchestrating a devastating bombing that left dozens of Indian security forces dead.

Fears are now rising that Kashmir, a disputed region that lies between India and its regional rival, Pakistan, could be sliding into an especially deadly phase again.


NEW YORK POST
Page Six.
LATE CITY FINAL
OFFICIAL: Bin Laden dead
GOT HIM!
Vengeance at last!
US nails the bastard
PAGES 2, 3, 4, 5, 6, 7, 8 & 9

Osama bin Laden, the founder and head of the Islamist militant group al-Qaeda, was killed in Pakistan on May 2, 2011, shortly after 1:00 am PKT (20:00 UTC, May 1) by U.S. Navy SEAL Team Six.

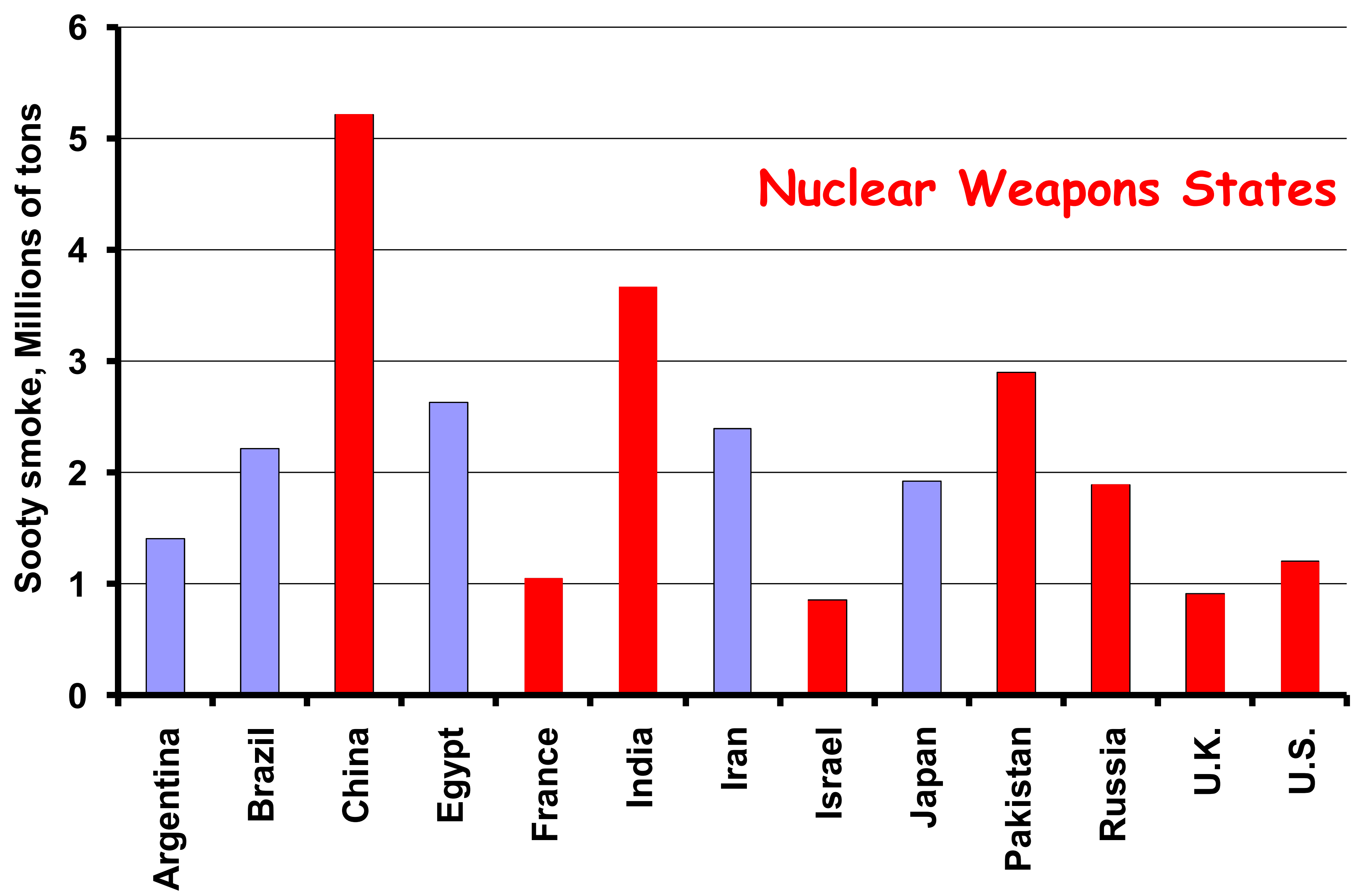
Did this raid risk the possibility of a Pakistan-India nuclear war?

RUTGERS

http://media.syracuse.com/news/photo/2011/05/nypost-bin-ladenjpg-aebfa5e81bd7d1d2.jpg

Alan Robock
Department of Environmental Sciences

Sooty smoke generation from 50, 15 kT weapons



What would be the consequences of a regional nuclear war using 100 15-kT (Hiroshima-size) weapons?

This would be only 0.03% of the current world arsenal.

Scenario: Weapons dropped on the 50 targets in each country that would produce the maximum smoke.

20,000,000 people would die from direct effects, half of the total fatalities from all of World War II.

Portions of megacities attacked with nuclear devices or exposed to fallout of long-lived isotopes would likely be abandoned indefinitely.

5 million tons of smoke injected into the upper atmosphere, accounting for fuel loading, emission factors and rainout.

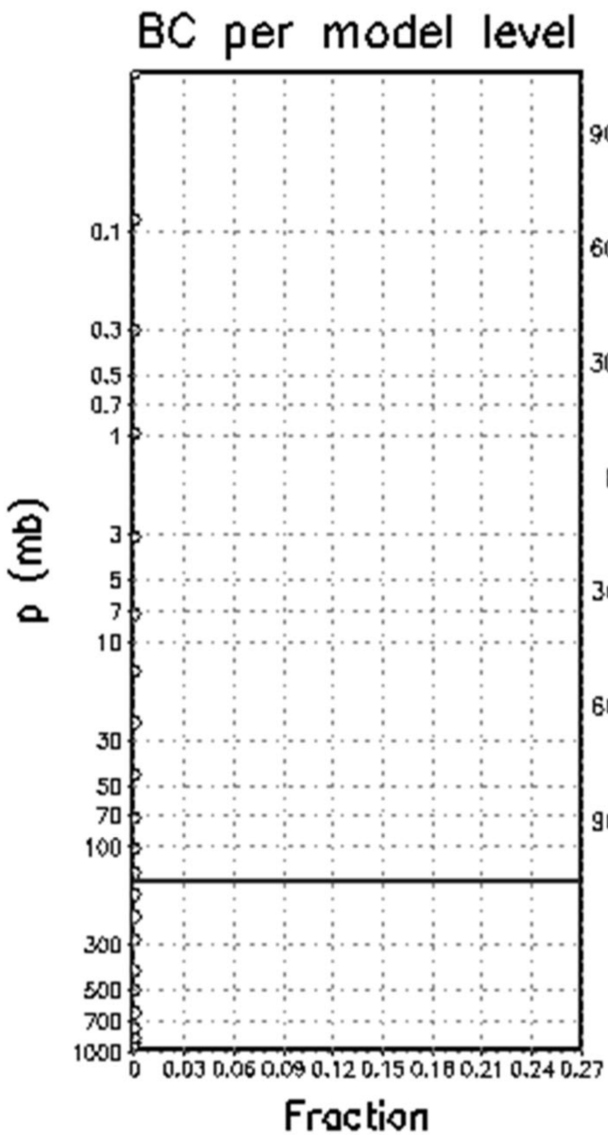
Robock, Alan, Luke Oman, Georgiy L. Stenchikov, Owen B. Toon, Charles Bardeen, and Richard P. Turco, 2007: Climatic consequences of regional nuclear conflicts. *Atm. Chem. Phys.*, **7**, 2003-2012.

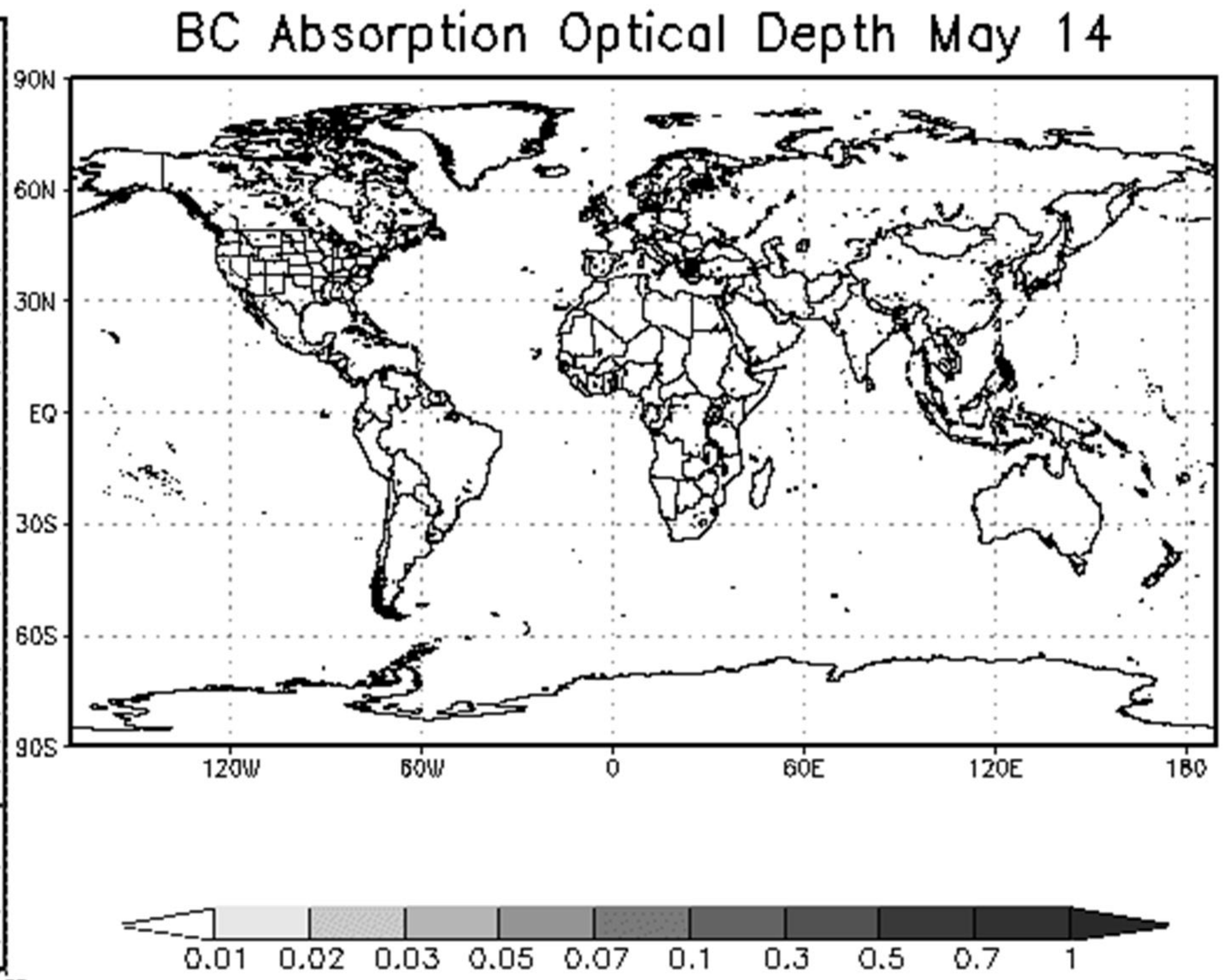
What would be the consequences of a regional nuclear war using 100 15-kT (Hiroshima-size) weapons?

We use the NASA GISS ModelE atmosphere-ocean general circulation model.

- 4°x5° lat-lon horizontal resolution
- 23 vertical levels including stratosphere and mesosphere, extending 0-80 km, 13 layers in ocean
- 5 Tg of smoke into the 300-150 mb layer (upper troposphere) at 30°N, 70°E on May 15
- 30-yr control run
- 3-member ensemble for 10 yr

Robock, Alan, Luke Oman, Georgiy L. Stenchikov, Owen B. Toon, Charles Bardeen, and Richard P. Turco, 2007: Climatic consequences of regional nuclear conflicts. *Atm. Chem. Phys.*, **7**, 2003-2012.

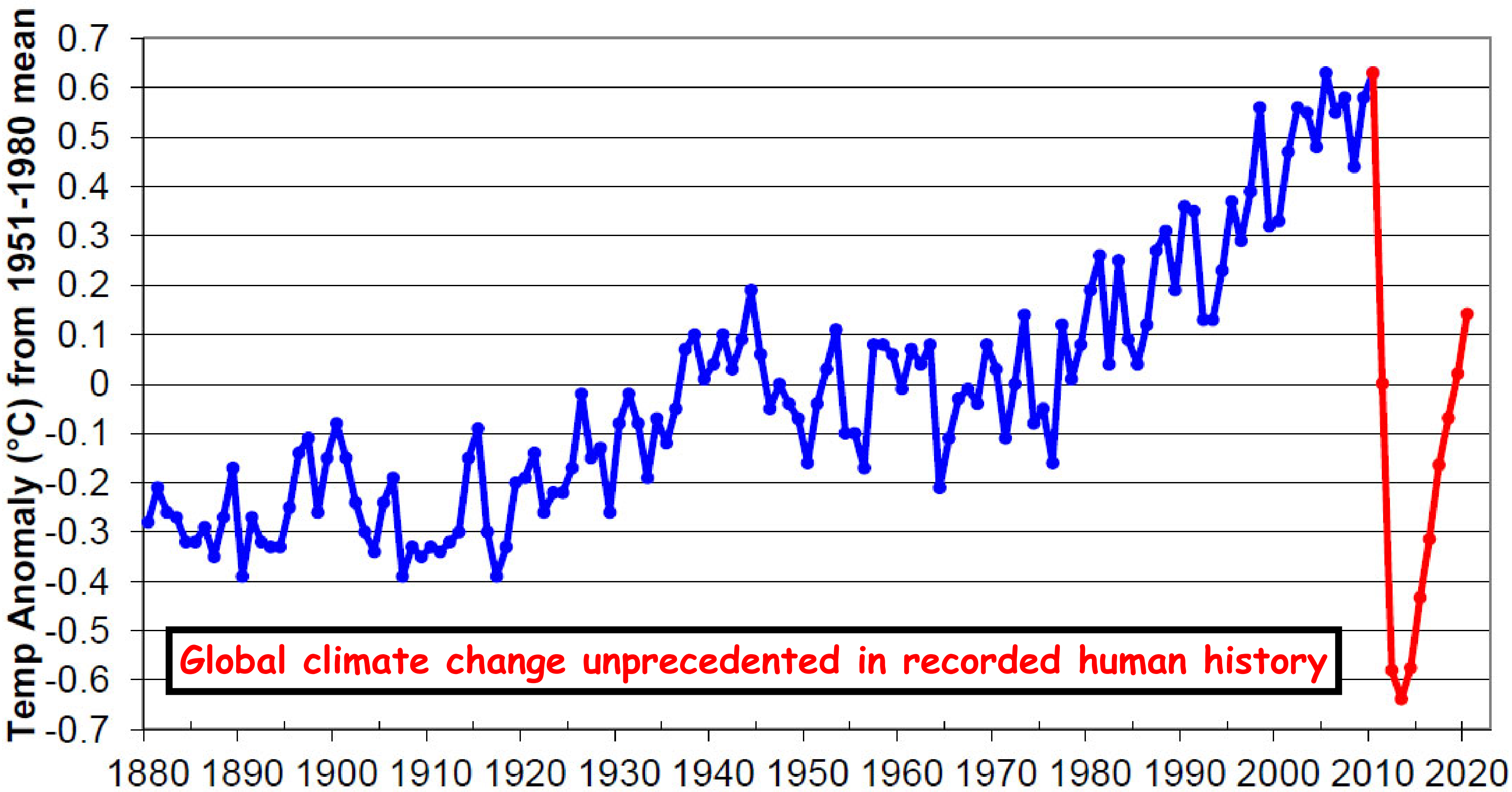




Robock et al., 2007a

Daily smoke loading from one ensemble member.
Absorption optical depth of 0.1 means that 90% of radiation reaches the surface.

GISS Global Average Temperature Anomaly
+ 5 Tg smoke in 2011



Robock et al., 2007a

Two other climate models have now simulated the impacts of 5 million tons of smoke injected into the upper atmosphere from fires from nuclear attacks.

Stenke, Andrea, et al., 2013: Climate and chemistry effects of a regional scale nuclear conflict, *Atmos. Chem. Phys.*, **13**, 9713-9729, doi:10.5194/acp-13-9713-2013.

Mills, Michael J., Owen B. Toon, Julia Lee-Taylor, and Alan Robock, 2014: Multi-decadal global cooling and unprecedented ozone loss following a regional nuclear conflict. *Earth's Future*, **2**, 161-176, doi:10.1002/2013EF000205.

<u>All three find global cooling for more than a decade, unprecedented in recorded human history.</u>

(This is from "only" 100 15-kt bombs,
much less than 1% of the global nuclear arsenal.)

Stenke, Andrea, et al., 2013: Climate and chemistry effects of a regional scale nuclear conflict, *Atmos. Chem. Phys.*, **13**, 9713-9729, doi:10.5194/acp-13-9713-2013.

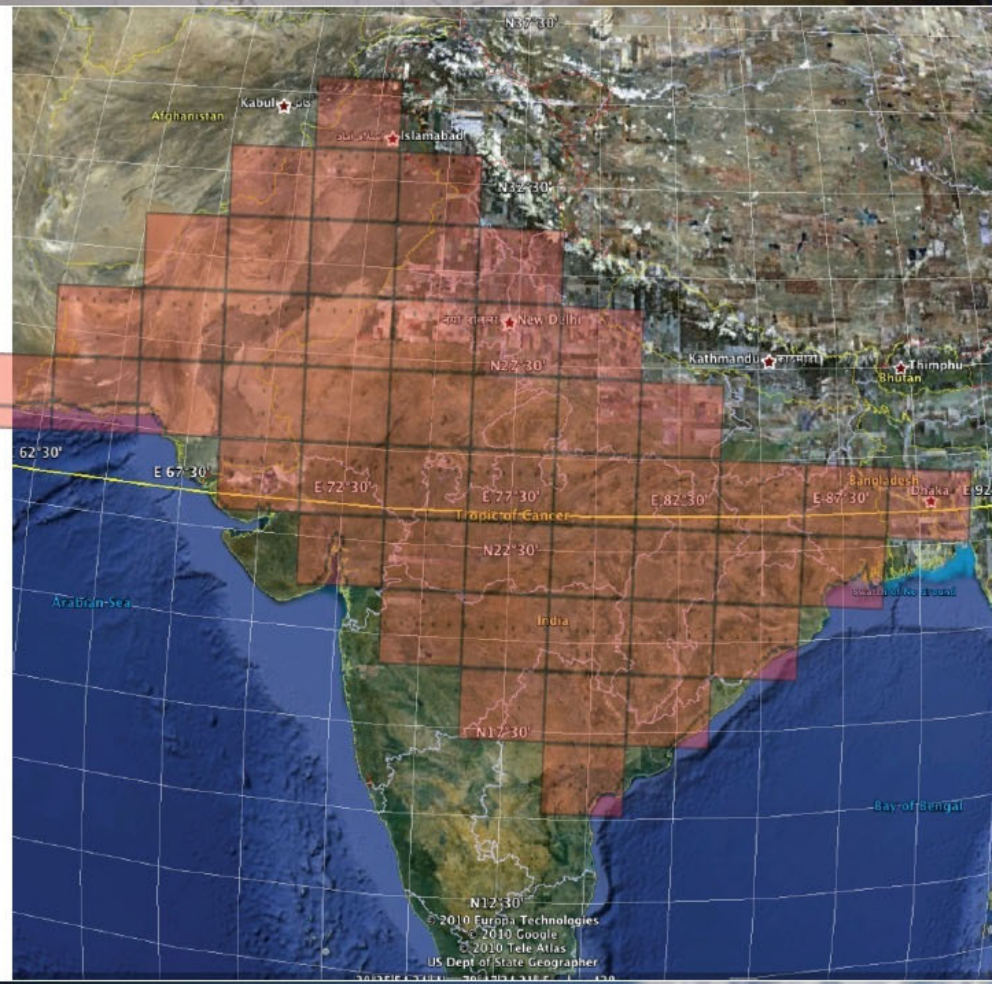
Used Solar Climate Ozone Links (SOCOL3) GCM

39 levels up to 0.01 mb (80 km)
T42 (2.8°x2.8° latitude-longitude)
50-m mixed layer ocean, q-flux

Forced by a range of soot loadings 1-12 Tg, and two soot particle radii, 50 or 100 nm.

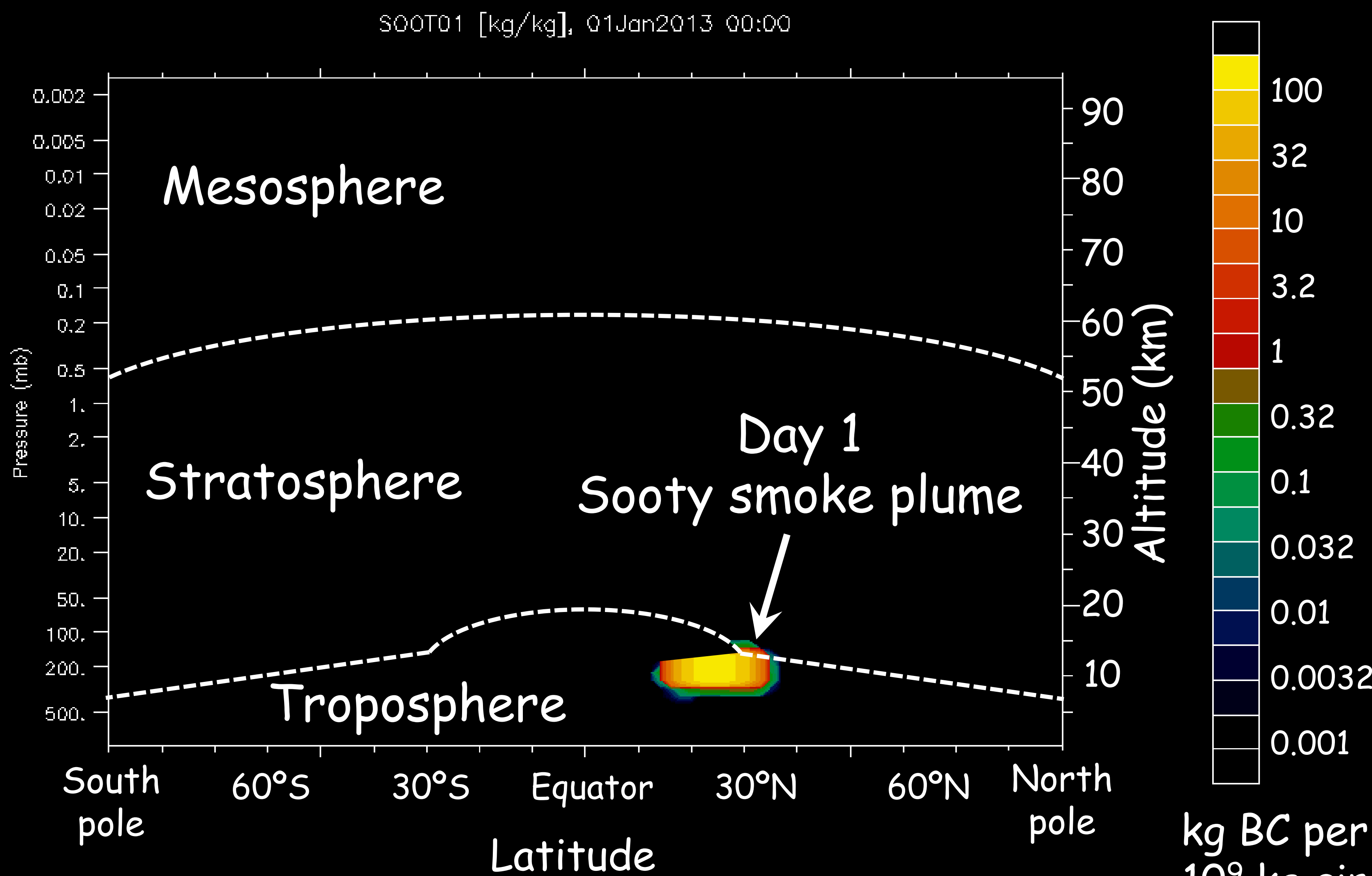
Mills, Michael J., Owen B. Toon, Julia Lee-Taylor, and Alan Robock, 2014: Multi-decadal global cooling and unprecedented ozone loss following a regional nuclear conflict. *Earth's Future*, **2**, 161-176, doi:10.1002/2013EF000205.

- CESM1/WACCM4-CARMA: coupled to full ocean, land, sea ice and land ice models
- 1.9° lat x 2.5° lon resolution
- BC initialized in 50 columns on Jan 1, 2013, 150-300 hPa, uniform mmr
- Wet and dry deposition passed to surface models
- 10-year ensembles: 3 experiment, 3 control runs based on CMIP5 RCP4.5



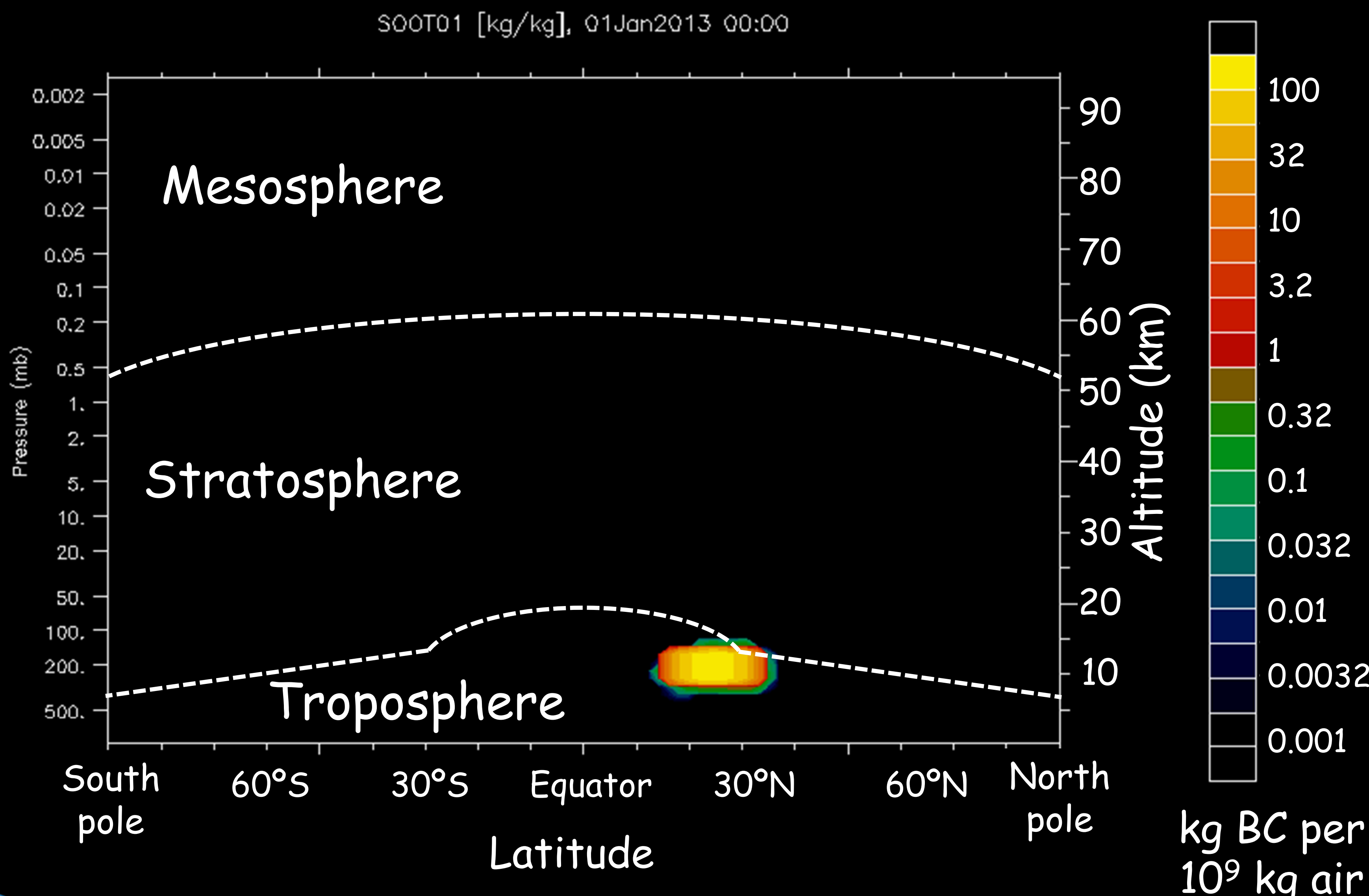
NCAR WACCM Whole Atmosphere Community Climate Model

Black carbon mass mixing ratio



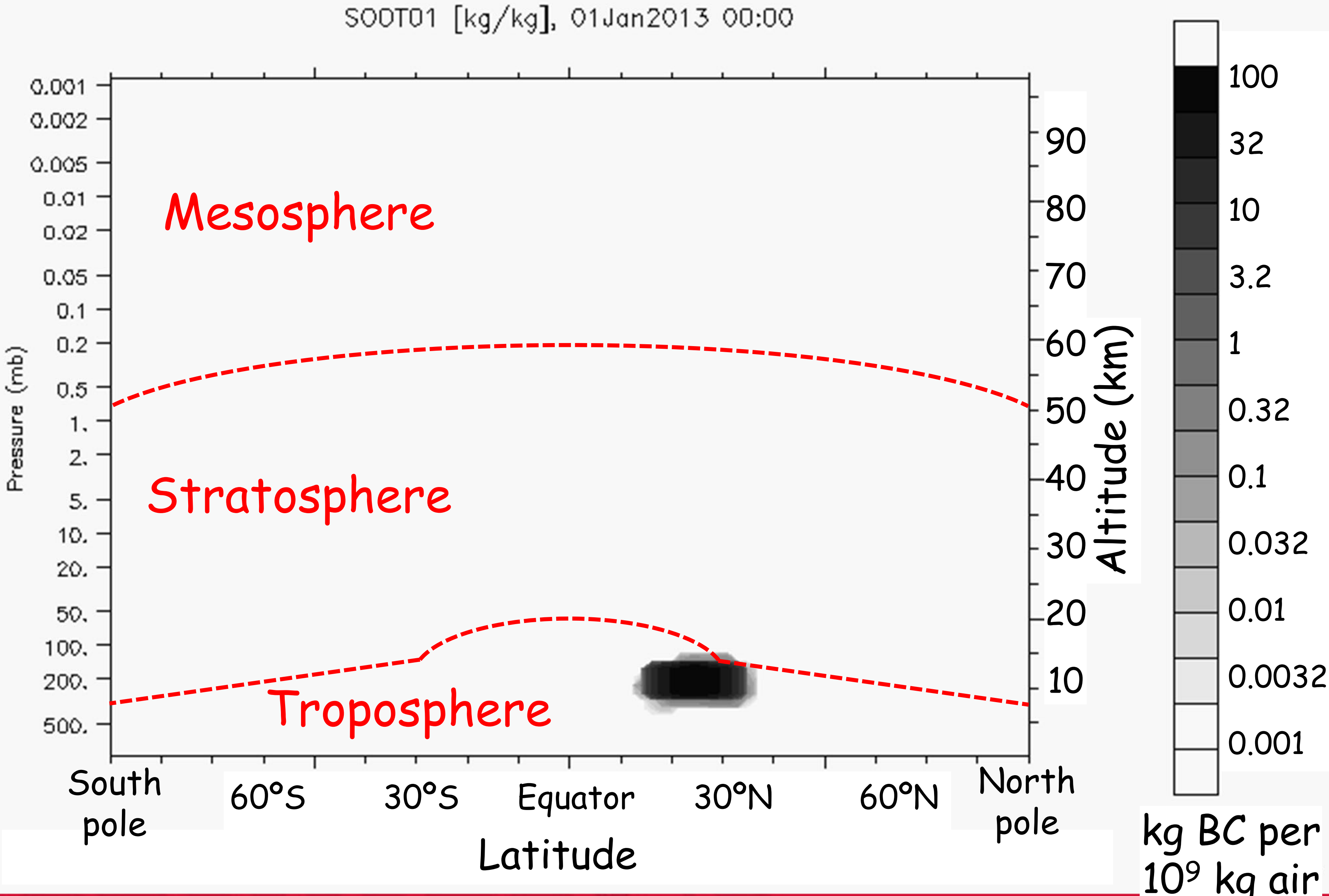
Mills et al. (2014)

Black carbon mass mixing ratio



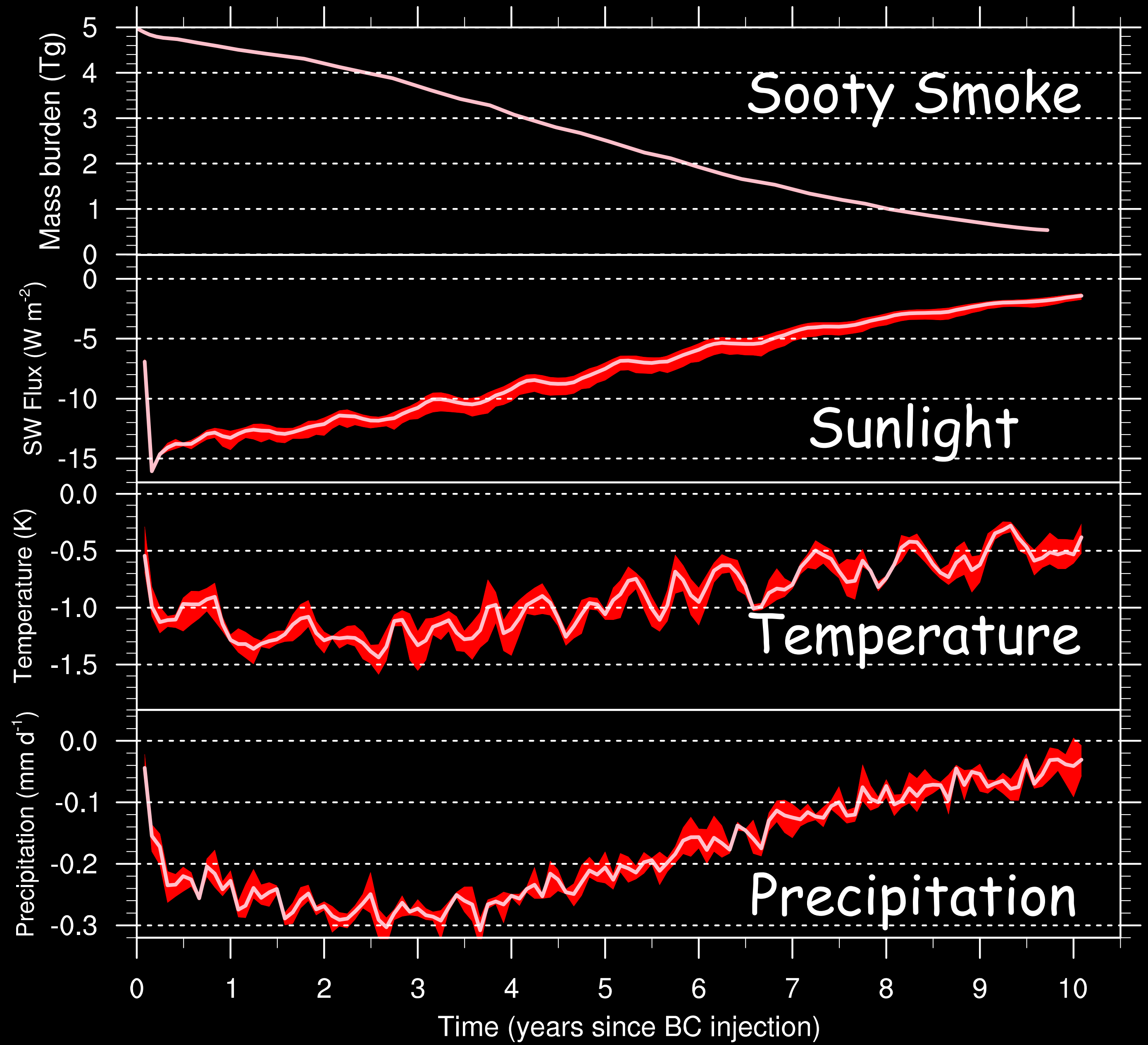
Mills et al. (2014)

Black carbon mass mixing ratio



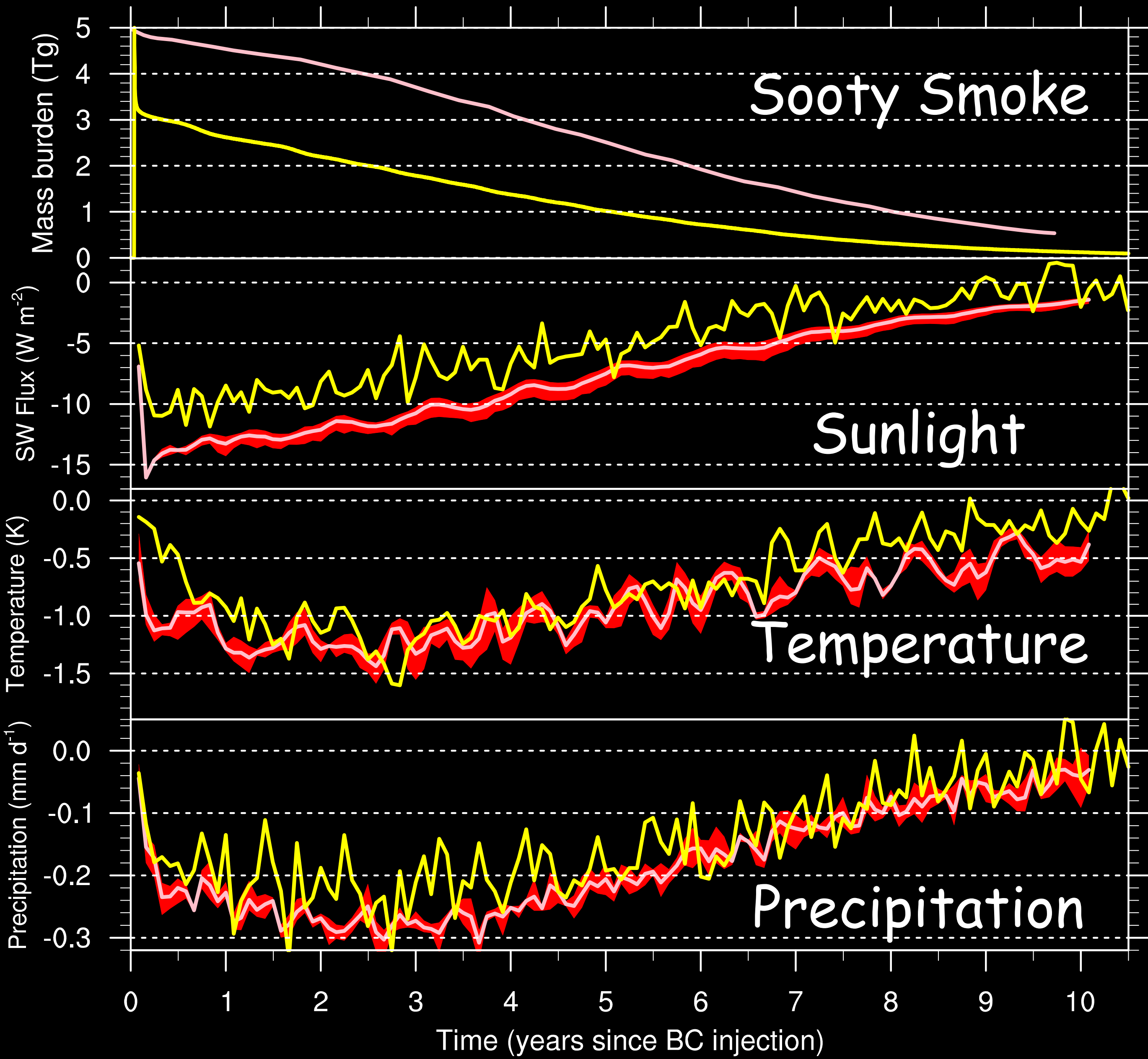
Mills et al. (2014)

Global climate response to regional war



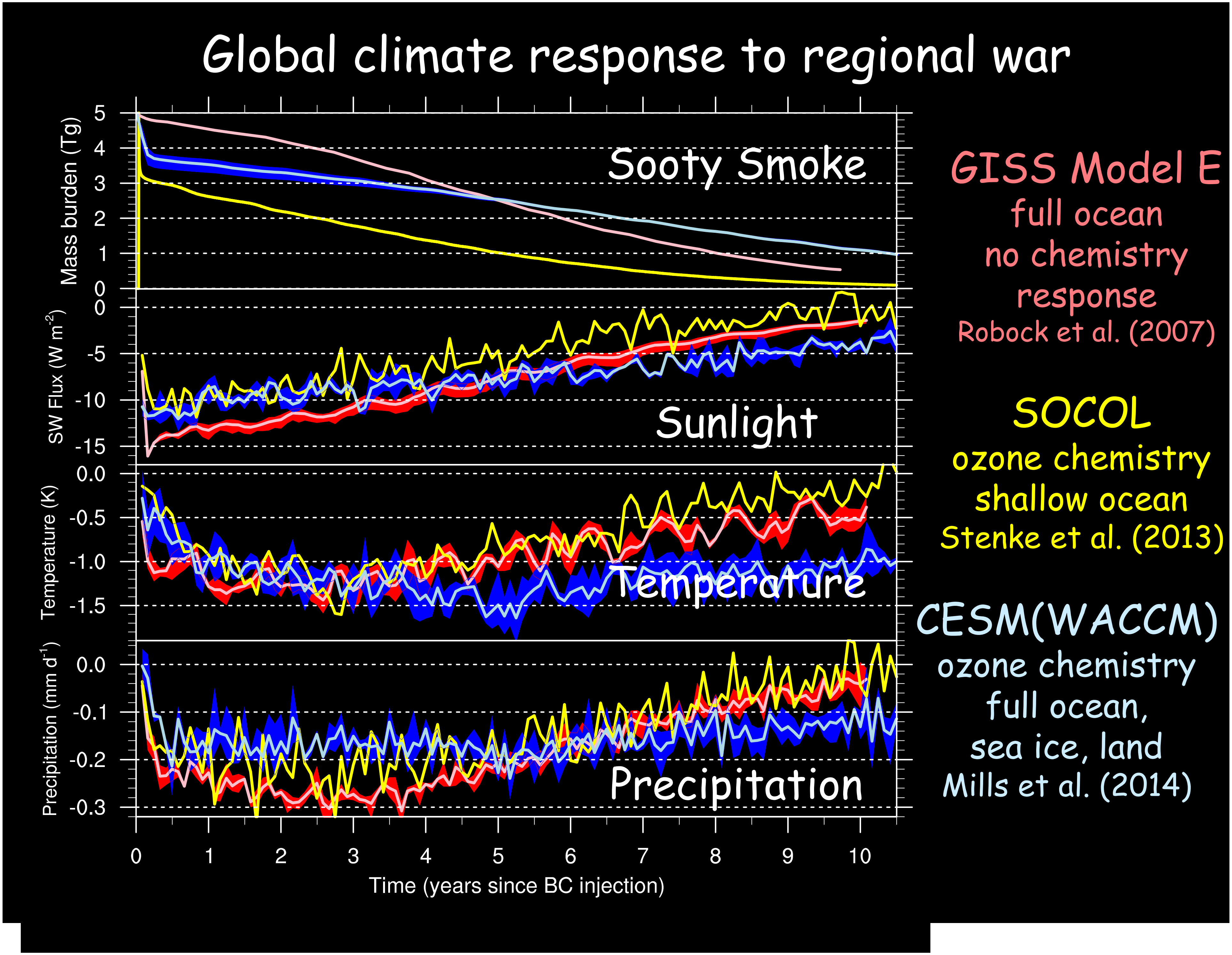
GISS Model E
full ocean
no chemistry
response
Robock et al. (2007)

Global climate response to regional war



GISS Model E
full ocean
no chemistry
response
Robock et al. (2007)

SOCOL
ozone chemistry
shallow ocean
Stenke et al. (2013)



Global climate response to regional war
Mass burden (Tg)
5
4
3
2
1
0
Sooty Smoke
SW Flux (W m-2)
0
-5
-10
-15
Sunlight
Temperature (K)
0.0
-0.5
-1.0
-1.5
Temperature
Precipitation (mm d-1)
0.0
-0.1
-0.2
-0.3
Precipitation
0 1 2 3 4 5 6 7 8 9 10
Time (years since BC injection)
GISS Model E
full ocean
no chemistry
response
Robock et al. (2007)
SOCOL
ozone chemistry
shallow ocean
Stenke et al. (2013)
CESM(WACCM)
ozone chemistry
full ocean,
sea ice, land
Mills et al. (2014)

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Research Article

Climate impact of a regional nuclear weapons exchange: An improved assessment based on detailed source calculations

Jon Reisner, Gennaro D'Angelo, Eunmo Koo, Wesley Even, Matthew Hecht, Elizabeth Hunke, Darin Comeau, Randall Bos, James Cooley

Accepted manuscript online: 13 February 2018 Full publication history

Abstract

We present a multi-scale study examining the impact of a regional exchange of nuclear weapons on global climate. Our models investigate multiple phases of the effects of nuclear weapons usage, including growth and rise of the nuclear fireball, ignition and spread of the induced firestorm, and comprehensive Earth system modeling of the oceans, land, ice, and atmosphere. This study follows from the scenario originally envisioned by Robock et al. (2007a), based on the analysis of Toon et al. (2007), which assumes a regional exchange between India and Pakistan of fifty 15-kiloton weapons detonated by each side. We expand this scenario by modeling the processes that lead to production of black carbon, in order to refine the black carbon forcing estimates of these previous studies. When the Earth system model is initiated with 5×10^9 kg of black carbon in the upper troposphere (approximately 9 to 13 km), the impact on climate variables such as global temperature and precipitation in our simulations is similar to that predicted by previously published work. However, while our thorough simulations of the firestorm produce about 3.7×10^9 kg of black carbon, we find that the vast majority of the black carbon never reaches an altitude above weather systems (approximately 12 km). Therefore, our Earth system model simulations conducted with model-informed atmospheric distributions of black carbon produce significantly lower global climatic impacts than assessed in prior studies, as the carbon at lower altitudes is more quickly removed from the atmosphere. In addition, our model ensembles indicate that statistically significant effects on global surface temperatures are limited to the first 5 years and are much smaller in magnitude than those shown in earlier works. None of the simulations produced a nuclear winter effect. We find that the effects on global surface temperatures are not uniform and are concentrated primarily around the highest arctic latitudes, dramatically reducing the global impact on human health and agriculture compared with that reported by earlier studies. Our analysis demonstrates that the probability of significant global cooling from a limited exchange scenario as envisioned in the previous studies is highly unlikely, a conclusion supported by examination of natural analogs, such as large forest fires and volcanic eruptions.

BUT:

1. “the impact of secondary ignitions, such as gas line breaks, are not considered ... For example, evidence of secondary ignitions in the Hiroshima conflagration ensuing the nuclear bombing ... led to unique conditions that resulted in significantly enhanced fire behavior.” Since we used the fire in Hiroshima as a model for the area burned in our previous work, already they are preventing their simulation from producing as big fires.

2. In contrast to the Hiroshima fire, Reisner et al. simulated a line fire, similar to most forest fires that start at a single point. Hiroshima mass fires started from many ignition points distributed over the zone of the thermal pulse and pressure wave. Such mass fires are much more intense than line fires.

BUT:

3. They used “a section of suburban Atlanta, GA were chosen for use as a ‘generic suburb’ for the study.” This is clearly not representative of dense cities in India and Pakistan, and therefore would not have the correct fuel loading. They did this because they do not have data for India and Pakistan cities. They claim, without support, that buildings there are primarily concrete and not wood. However, even for concrete buildings, it is the contents that burn and provide the fuel load. We are actually doing inventories of actual buildings to get this right.

BUT:

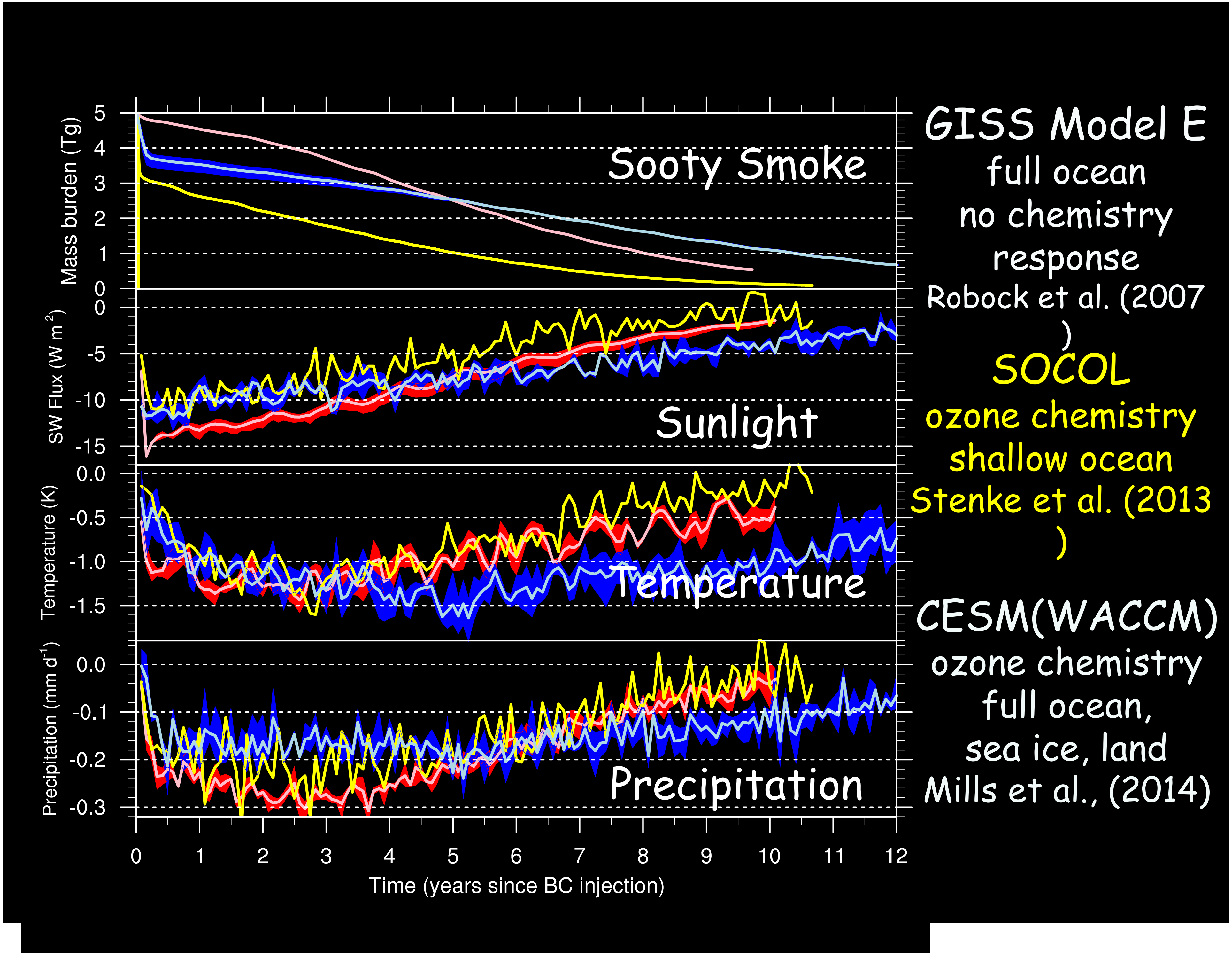
4. “A dry atmosphere was utilized, and pyro-cumulus impacts or precipitation from pyro-cumulonimbus were not considered. While latent heat released by condensation could lead to enhanced vertical motions of the air, increased scavenging of soot particles by precipitation is also possible .... These processes will be examined in future studies using HIGRAD-FIRETEC.” Thus they eliminate a major source of buoyancy that would loft the soot, latent heat of condensation.

In fact, the “mother of all pyroCb” lofted soot into the lower stratosphere in August 2017 over British Columbia, Canada, and over the succeeding weeks the soot was lofted many more kilometers because it was heated by the Sun, as observed by satellites. This August fire is direct evidence of the process we modeled before, from a much smaller heat source than a burning city. We are now modeling this very case with our climate model as a test of the model, which we will subsequently use for smoke from cities. I am presenting the preliminary results at the EGU Meeting in April in Vienna.

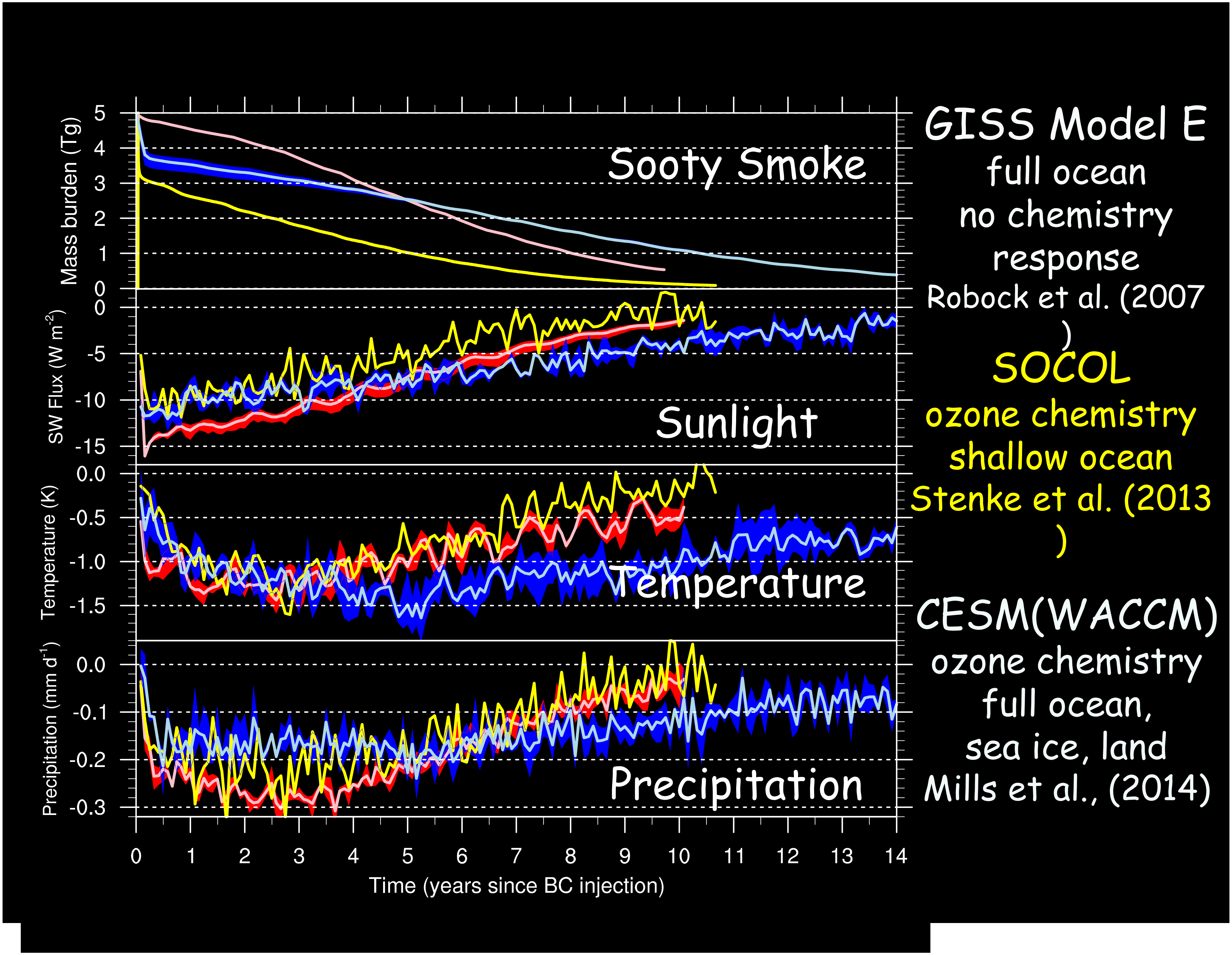
BUT:

5. Their simulations of fire were only run for 40 minutes, and they did not actually model firestorms.

6. **In summary, they modeled the wrong type of fire (they should have modeled a mass fire), in an area with lower fuel loading than we considered (a suburb not a city), they omitted factors known to be important to smoke lofting (latent heat release), and they didn't model the full duration of the event.**



Mass burden (Tg)
SW Flux (W m-2)
Temperature (K)
Precipitation (mm d-1)
Time (years since BC injection)
Sooty Smoke
Sunlight
Temperature
Precipitation
GISS Model E
full ocean
no chemistry
response
Robock et al. (2007
)
SOCOL
ozone chemistry
shallow ocean
Stenke et al. (2013
)
CESM(WACCM)
ozone chemistry
full ocean,
sea ice, land
Mills et al., (2014)



Mass burden (Tg)
SW Flux (W m^{-2})
Temperature (K)
Precipitation (mm d^{-1})
Sooty Smoke
Sunlight
Temperature
Precipitation
Time (years since BC injection)
GISS Model E
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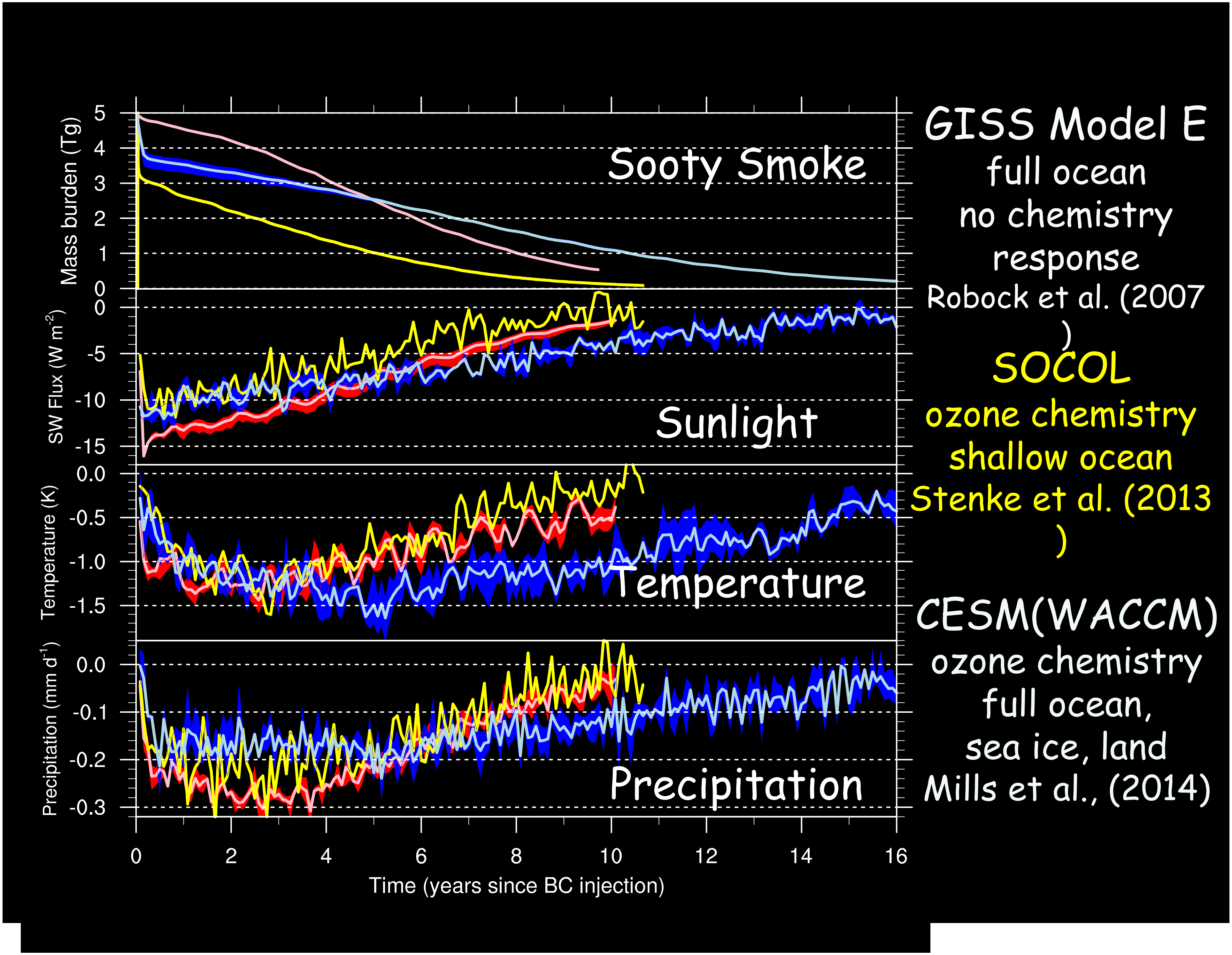

Sooty Smoke
Sunlight
Temperature
Precipitation
Mass burden (Tg)
SW Flux (W m-2)
Temperature (K)
Precipitation (mm d-1)
Time (years since BC injection)
GISS Model E
full ocean
no chemistry
response
Robock et al. (2007
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SOCOL
ozone chemistry
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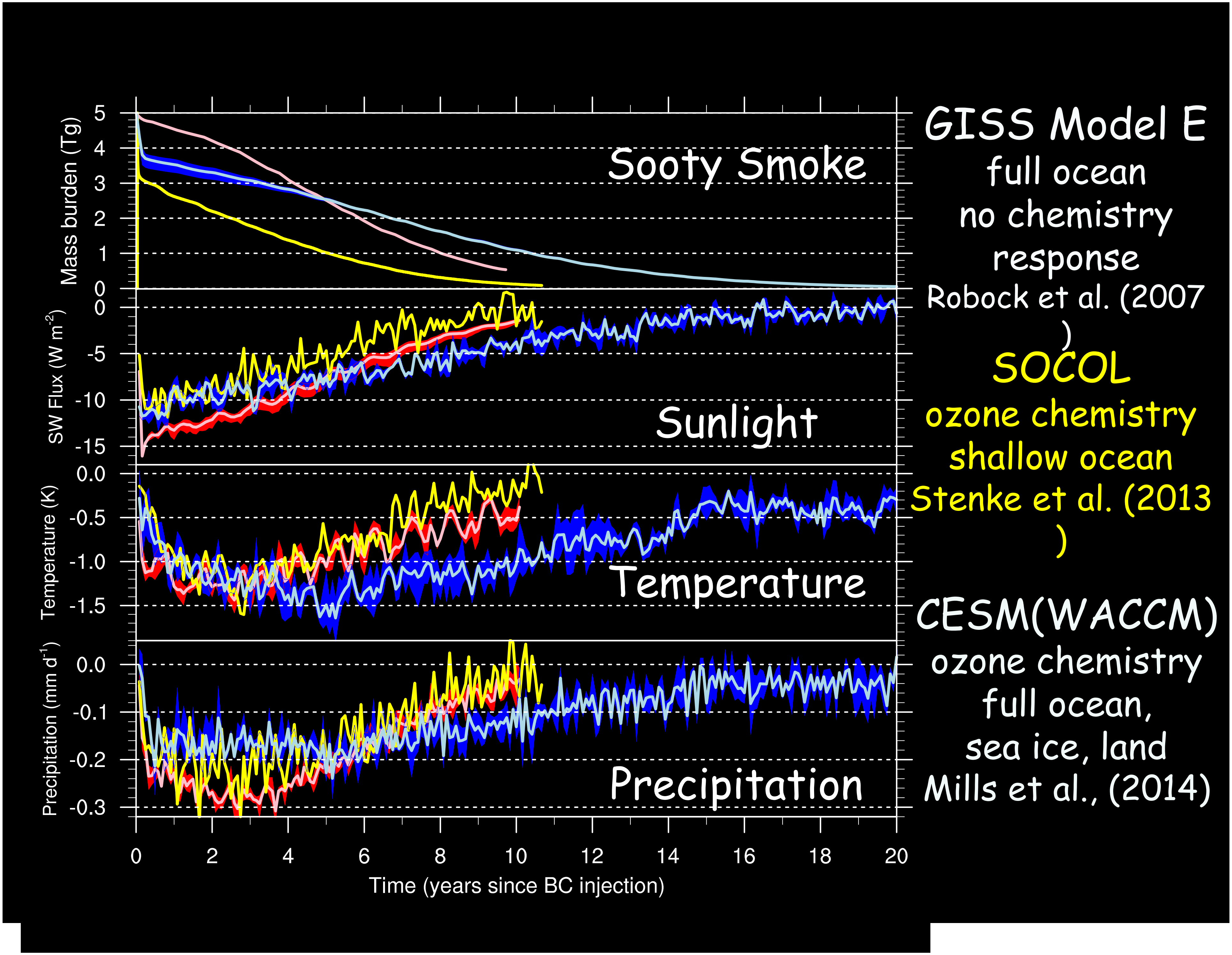
ozone chemistry
full ocean,
sea ice, land
Mills et al., (2014)



Sooty Smoke
Sunlight
Temperature
Precipitation
Mass burden (Tg)
SW Flux (W m-2)
Temperature (K)
Precipitation (mm d-1)
Time (years since BC injection)
GISS Model E
full ocean
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Robock et al. (2007
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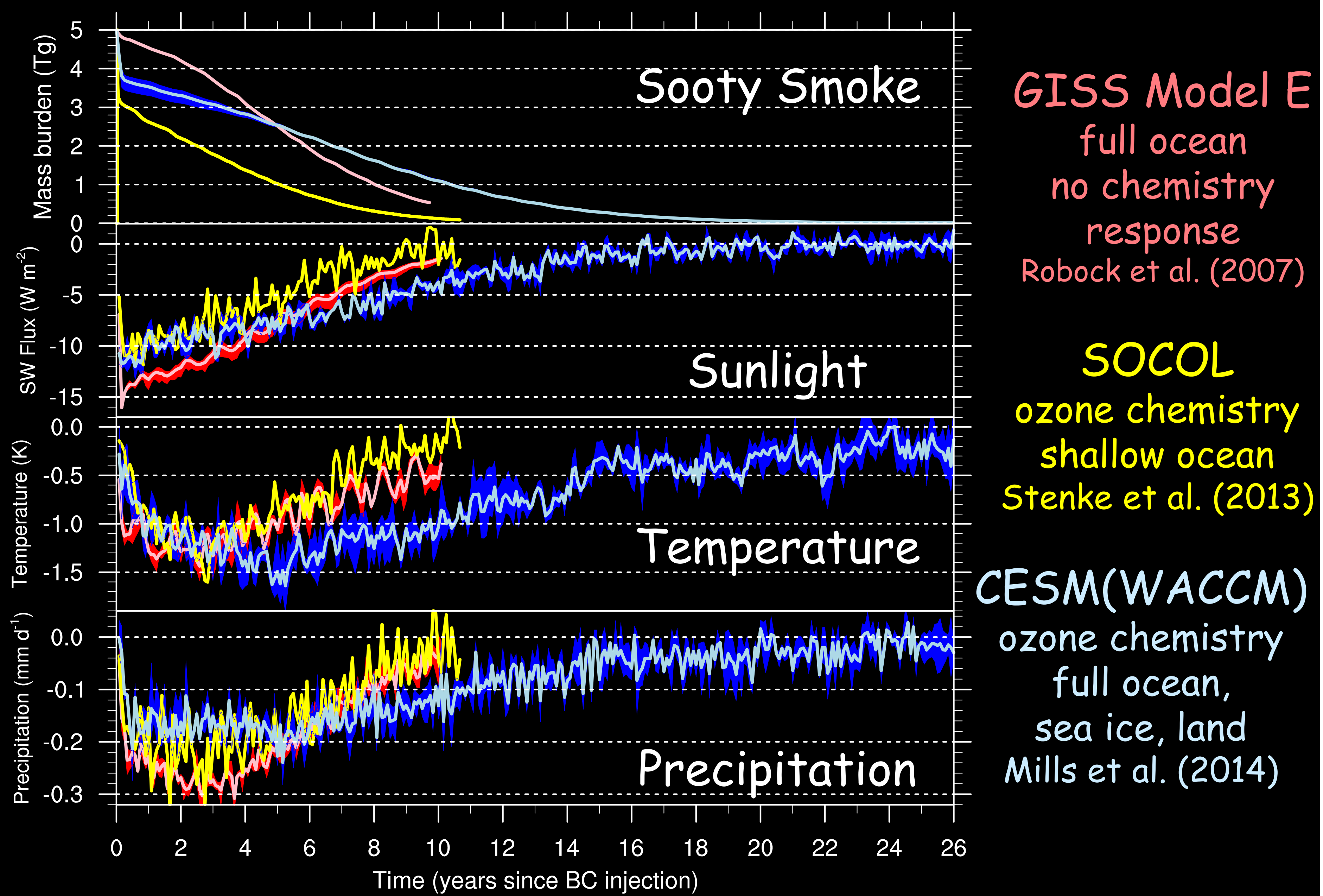
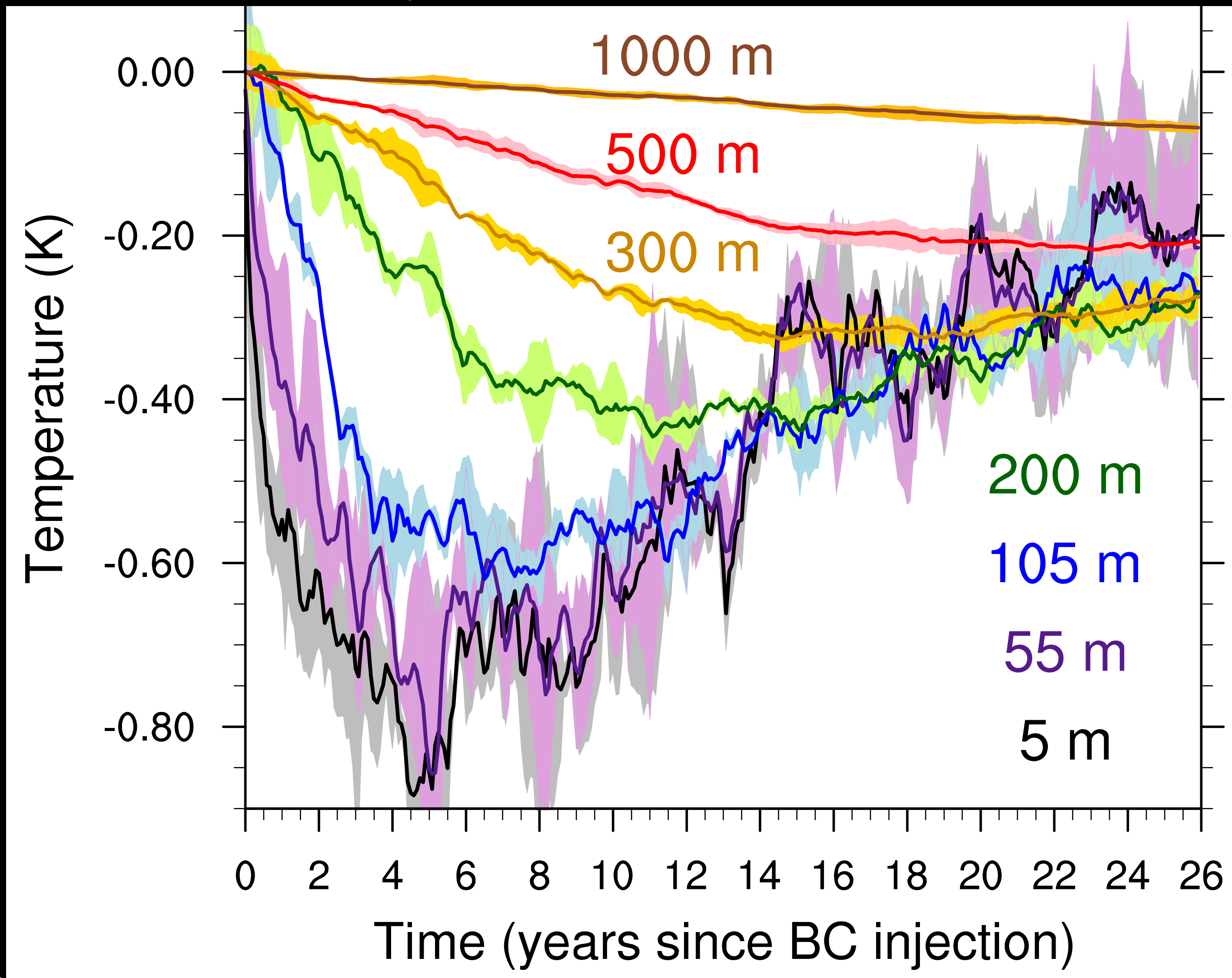
ozone chemistry
full ocean,
sea ice, land
Mills et al., (2014)

Global climate response to regional war



Large ocean cooling for 5 Mt case

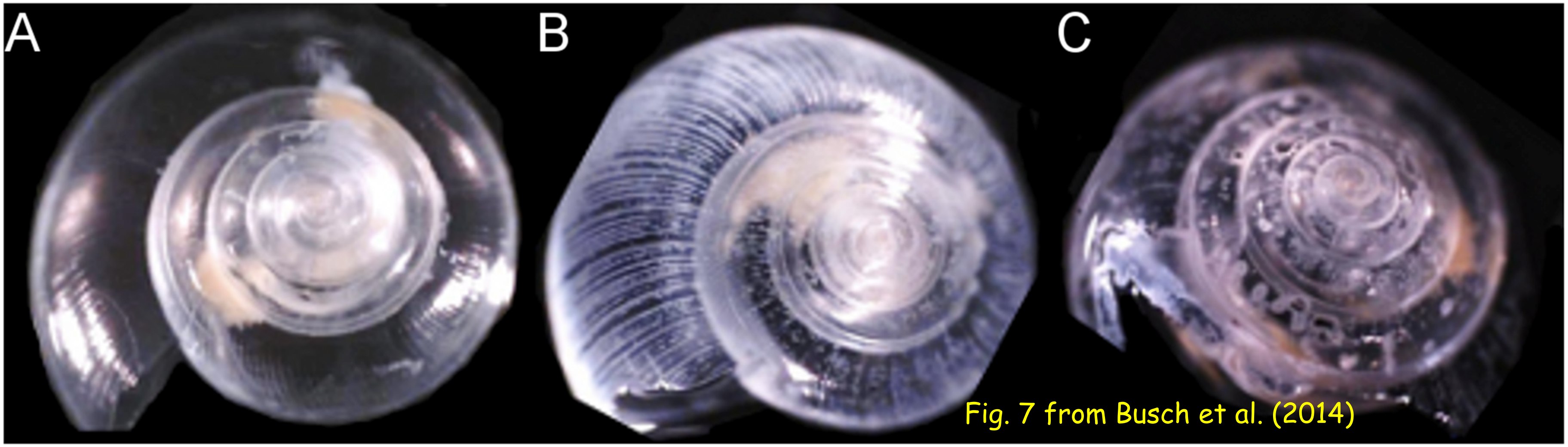
Significant disruptions for ocean biota expected



NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Mills et al. (2014)

"The global cooling dissolves atmospheric carbon into the upper ocean, driving a 0.1 to 0.3 unit decrease in the aragonite saturation state (Ω_{arag}) that persists for ~10 years. … The decrease in Ω_{arag} would exacerbate a primary threat of ocean acidification: the inability of marine calcifying organisms to maintain their shells/skeletons in a corrosive environment."

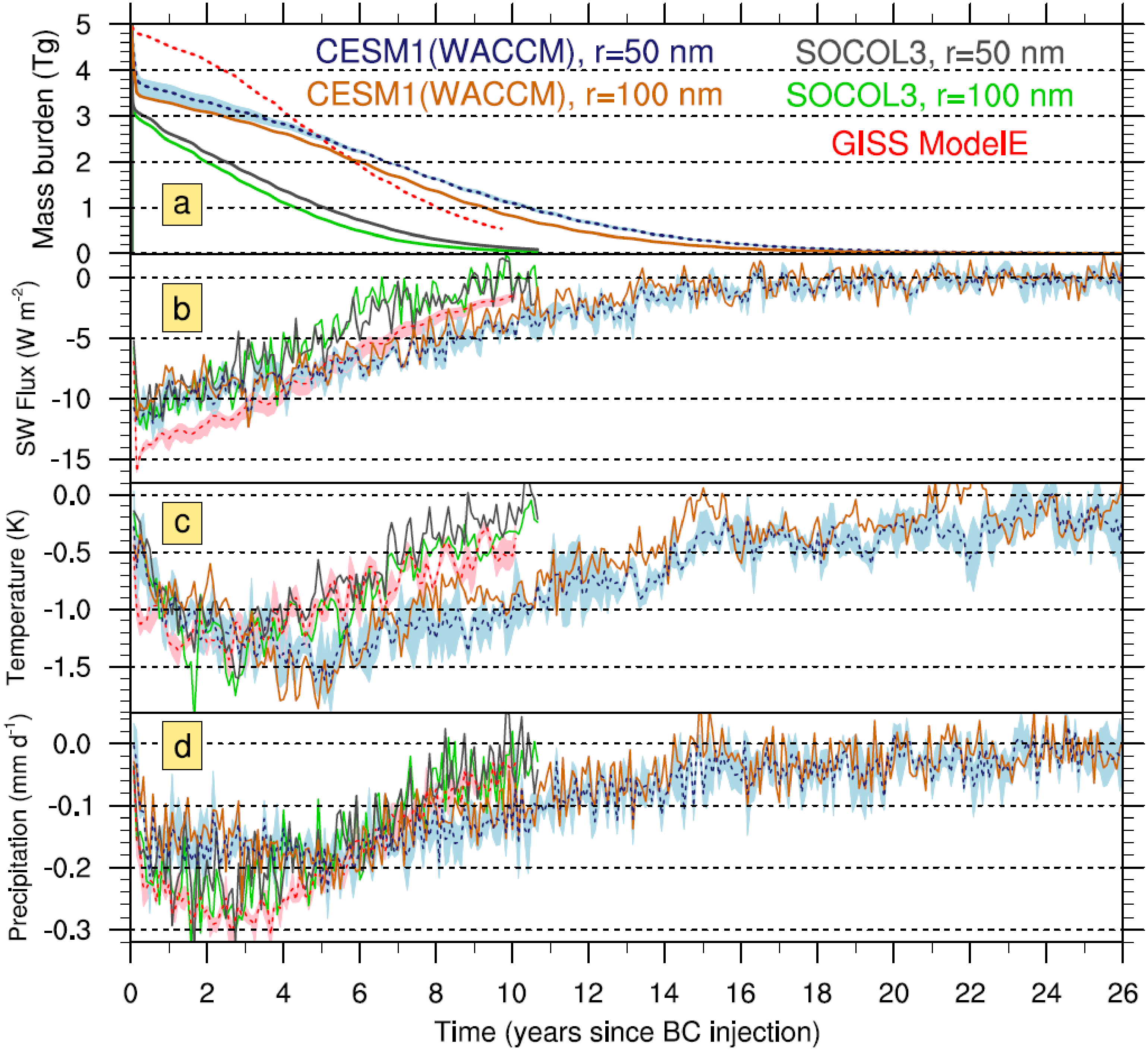


Busch DS, Maher M, Thibodeau P, McElhany P (2014) Shell Condition and Survival of Puget Sound Pteropods Are Impaired by Ocean Acidification Conditions. PLOS ONE 9(8): e105884. https://doi.org/10.1371/journal.pone.0105884

Three models' simulations for the **5 Tg** case.

This is the amount of smoke from the use of less than 1% of the current nuclear arsenal.

Mills et al., 2014



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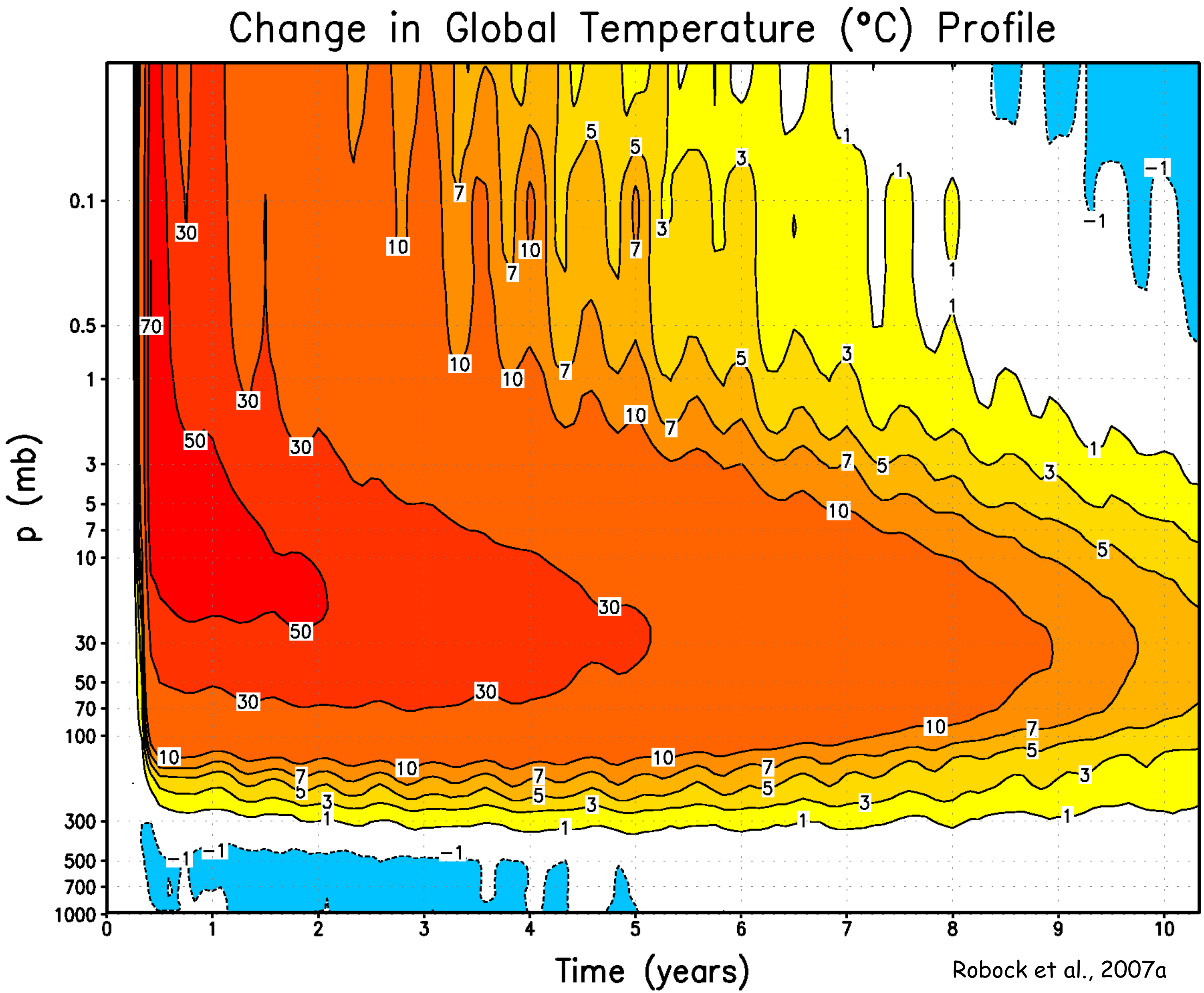
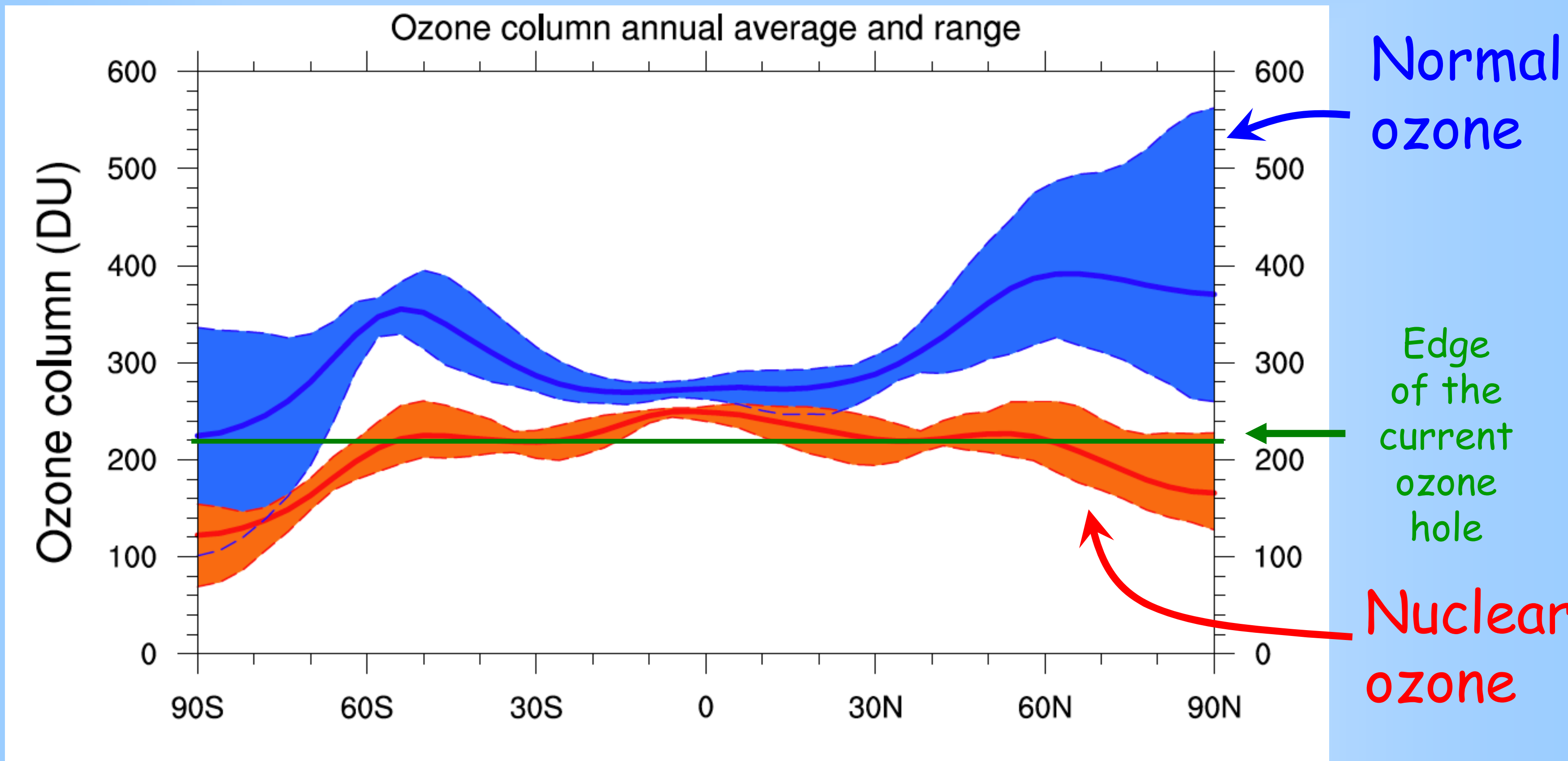


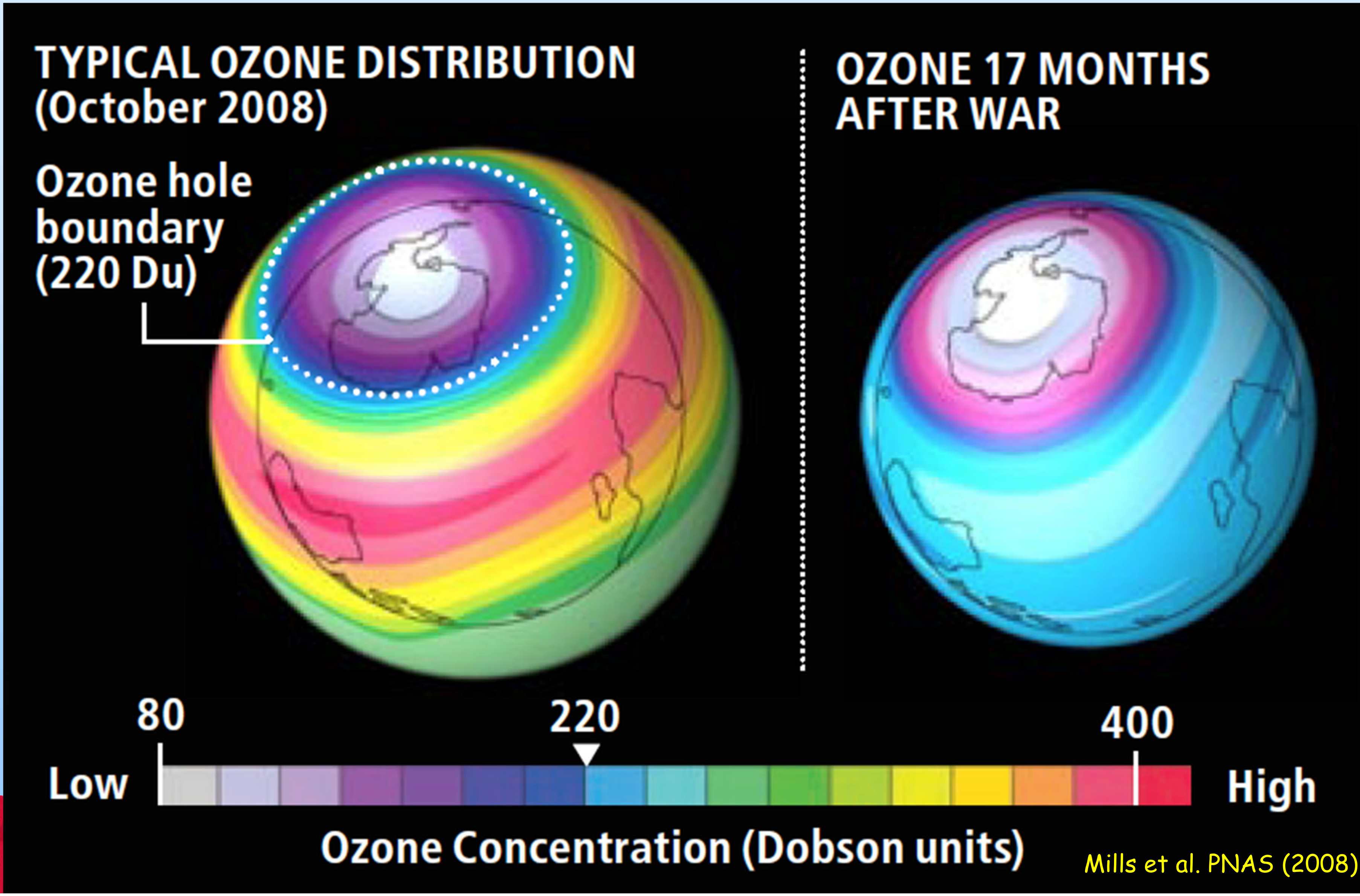
Robock et al., 2007a

Ozone depletion 3 years after soot injection



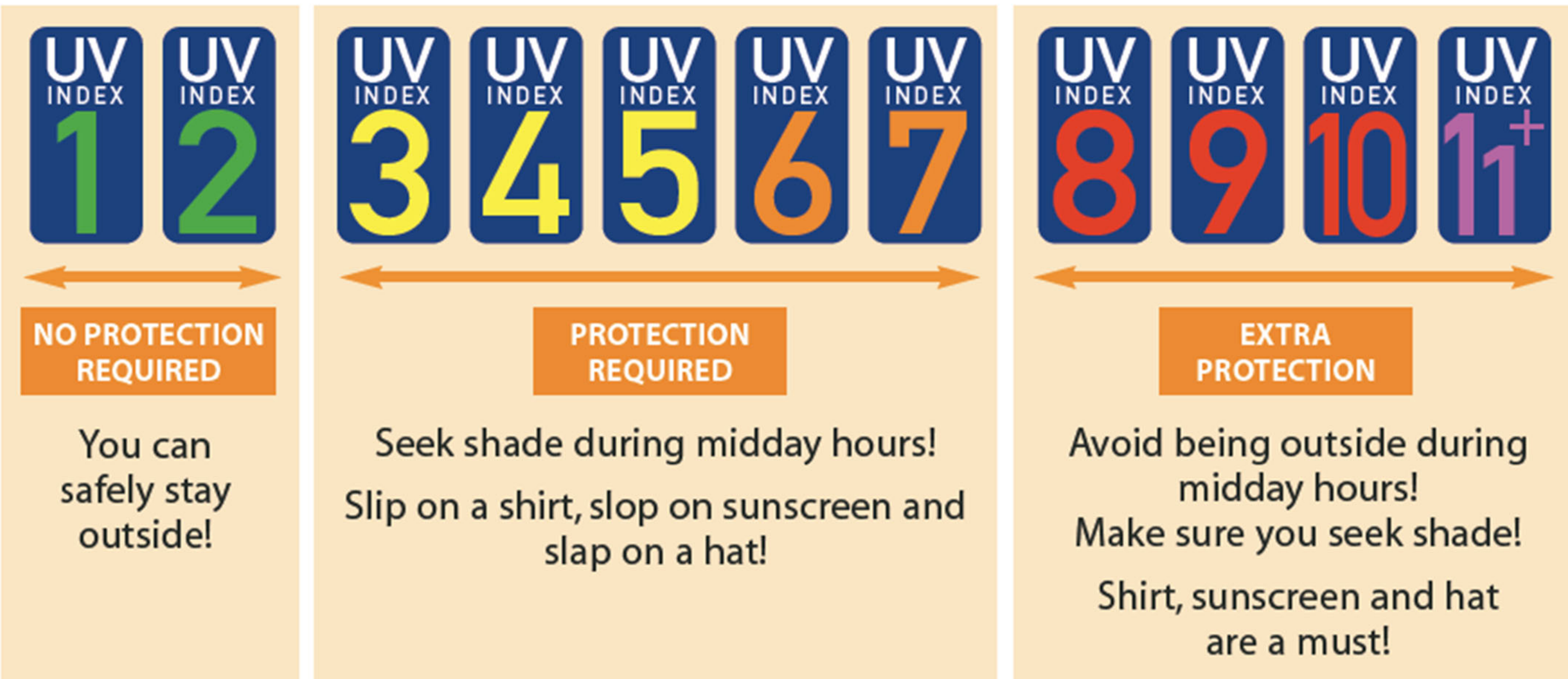
Mills, Michael J., Owen B. Toon, Richard P. Turco, Douglas E. Kinnison, and Rolando R. Garcia, 2008: Massive global ozone loss predicted following regional nuclear conflict, *Proc. Nat. Acad. Sci.*, **105**, 5307–5312.

Global ozone loss following a 5 million ton soot injection creates a near global ozone hole.

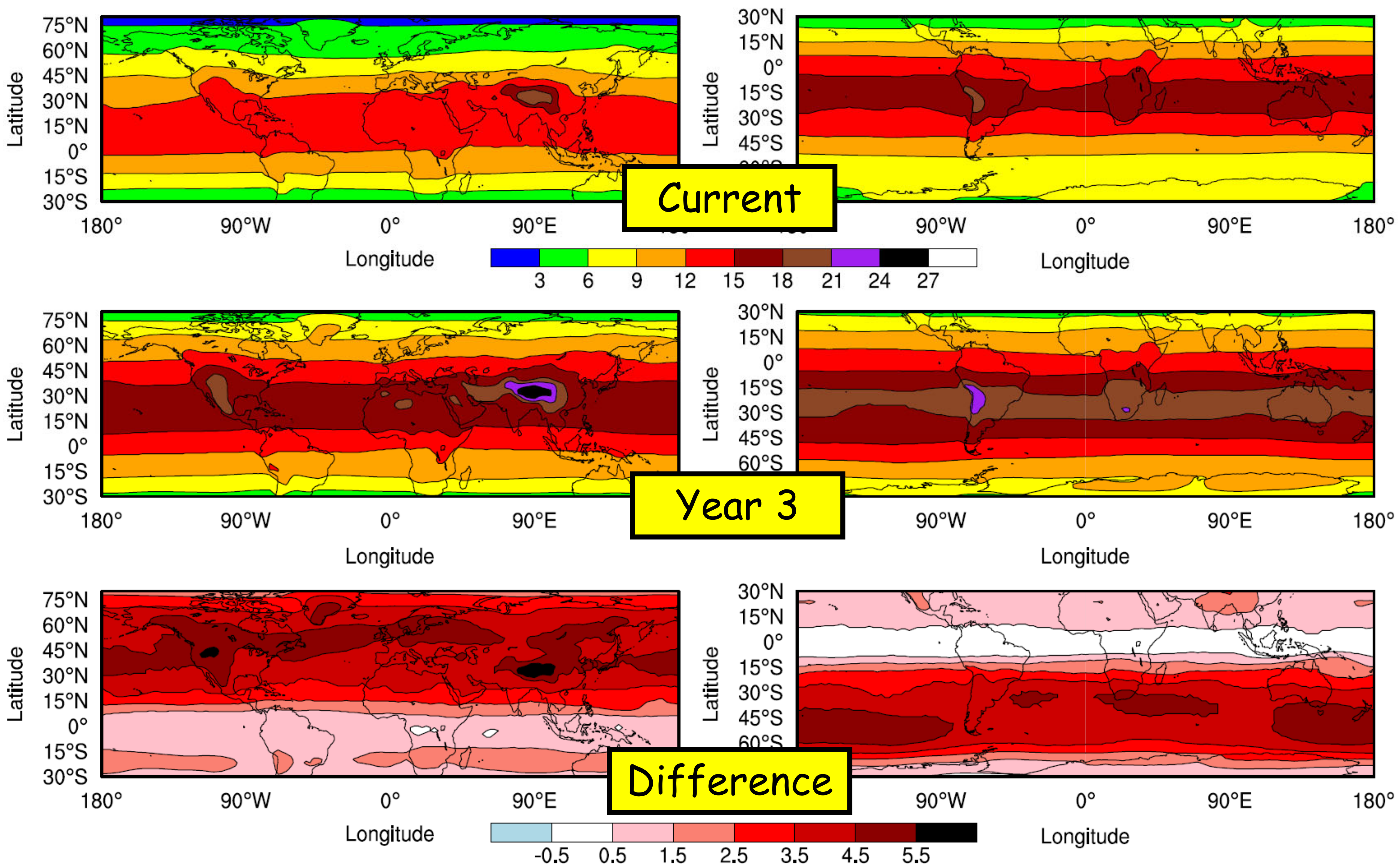


Mills et al. PNAS (2008)

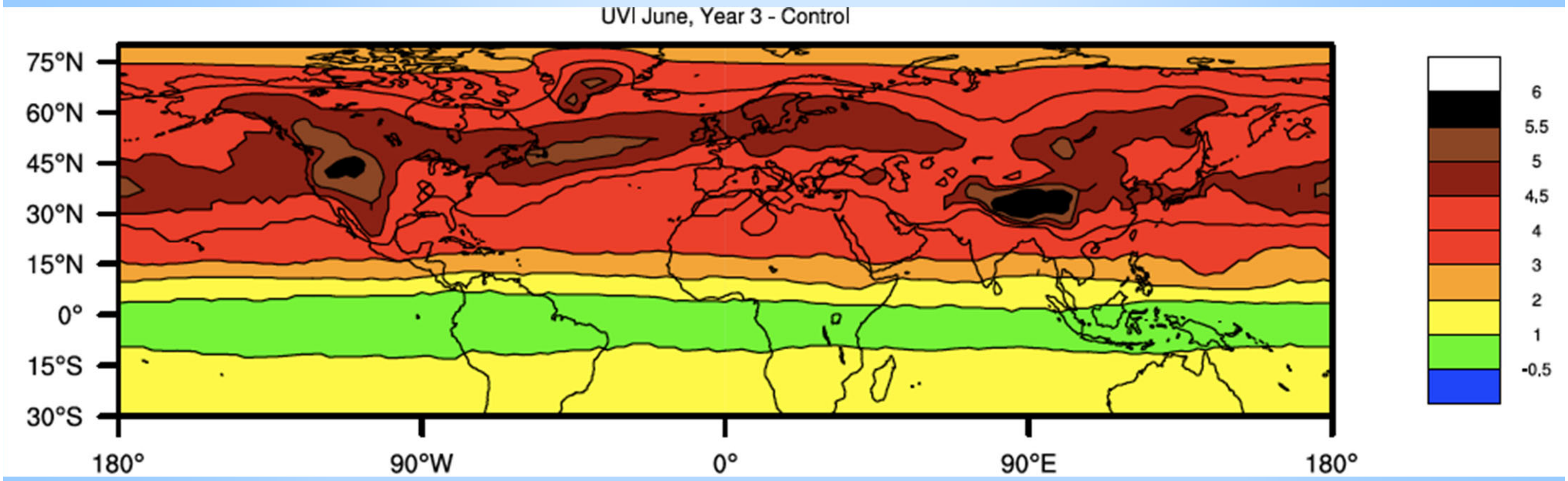
From *Global Solar UV Index: A Practical Guide*
World Health Organization, 2002



June UV Index December



5 million tons of smoke in the upper atmosphere
could destroy so much ozone
that huge increases in UV
would produce dangers for
humans, animals, agriculture and the natural ecosystem.



Change in UVI in June, 3 years after war.

Consequences of severe ozone loss and enhanced UV

Human health

A fair-skinned North American would receive a painful, noticeable sunburn after 6 minutes in the sun at noon in June.

Increased skin cancer rates

Land crops and ecosystems

Plant height, shoot mass, and foliage area would be reduced.

Beneficial soil bacteria would be disrupted.

Genetic damage would accumulate over generations.

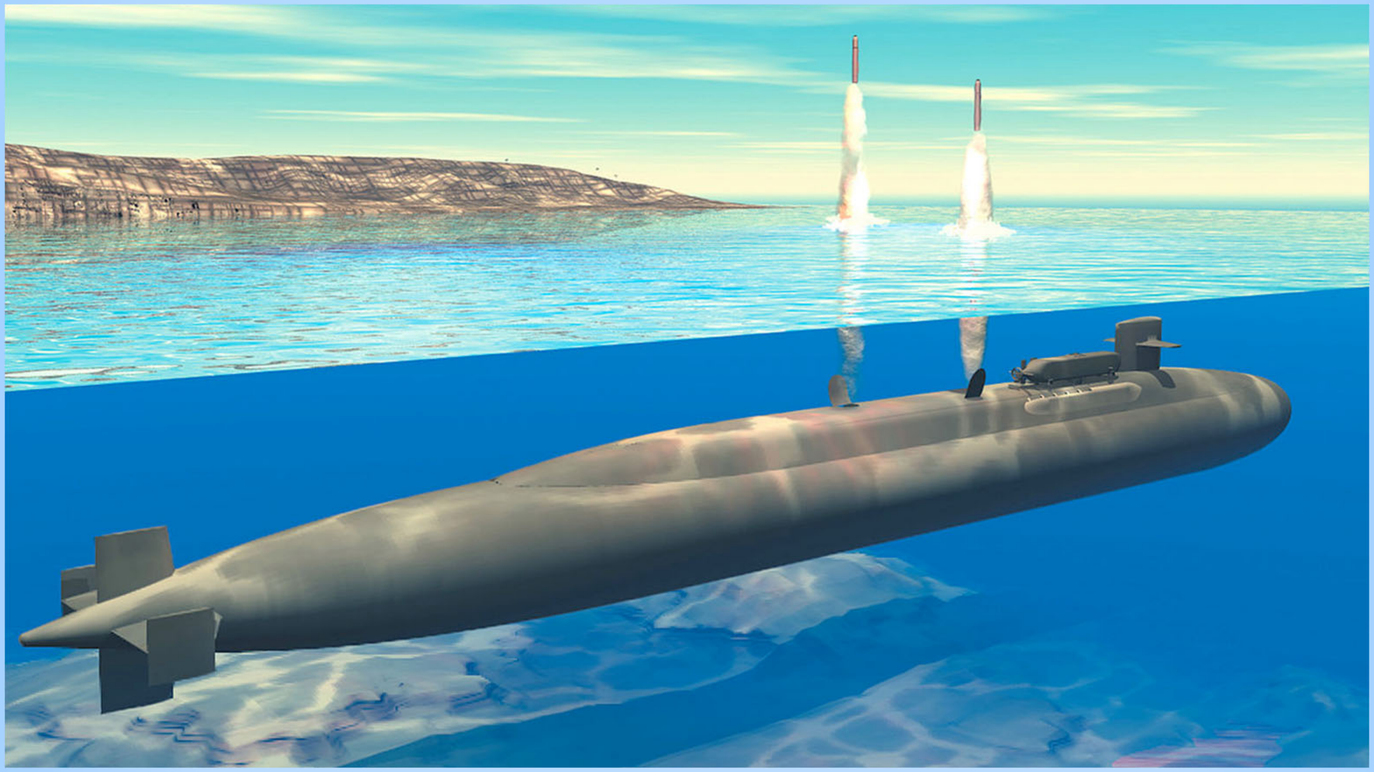
Plants would be more susceptible to attack by insects and pathogens.

Fisheries and ocean ecosystems

Phytoplankton activity in the upper layer of the ocean would be inhibited.

Decreased reproductive capacity and impaired larval development of marine animals

One U.S. Trident submarine has 96 nuclear weapons, each 100 or 475 kt, making each Trident more powerful than 1000 Hiroshimas.



The U.S. has 14 Tridents, and that is less than half the U.S. nuclear arsenal.

What would be the consequences of a full-scale nuclear war between the US and Russia?

We use the NASA GISS ModelE atmosphere-ocean general circulation model.

- 50 Tg or 150 Tg of smoke into the 300-150 mb layer (upper troposphere) over the US and Russia on May 15

- 30-yr control run, two 10-yr runs (50 Tg or 150 Tg)

What could produce 150 Tg of smoke?

- standard nuclear winter scenario of 30 years ago

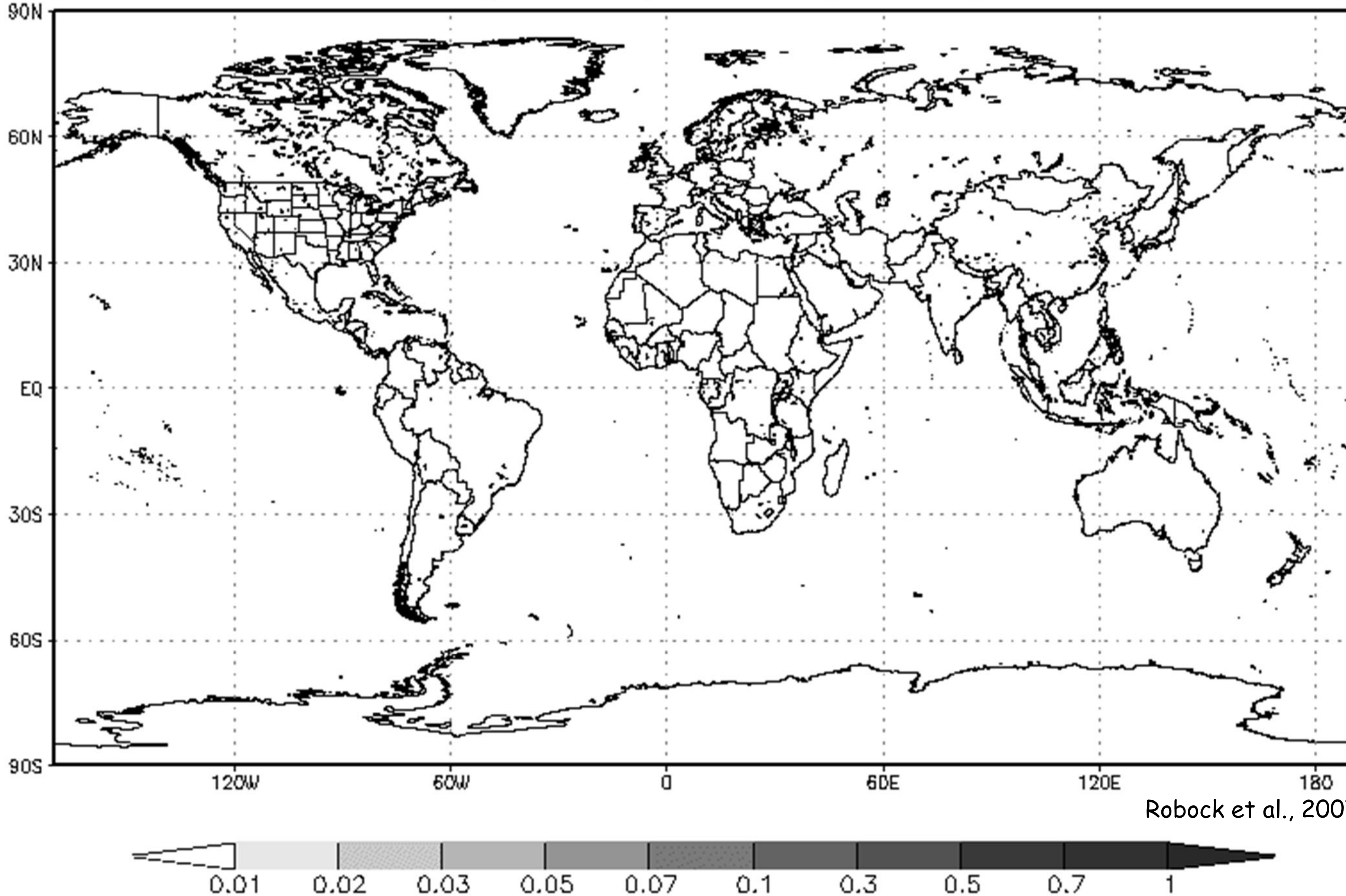
- entire current arsenal if targeted the same way

- only 4000 weapons (2017 global arsenals of New START treaty)

Robock, Alan, Luke Oman, and Georgiy L. Stenchikov, 2007b: Nuclear winter revisited with a modern climate model and current nuclear arsenals: Still catastrophic consequences. *J. Geophys. Res.*, **112**, D13107, doi:10.1029/2006JD008235.

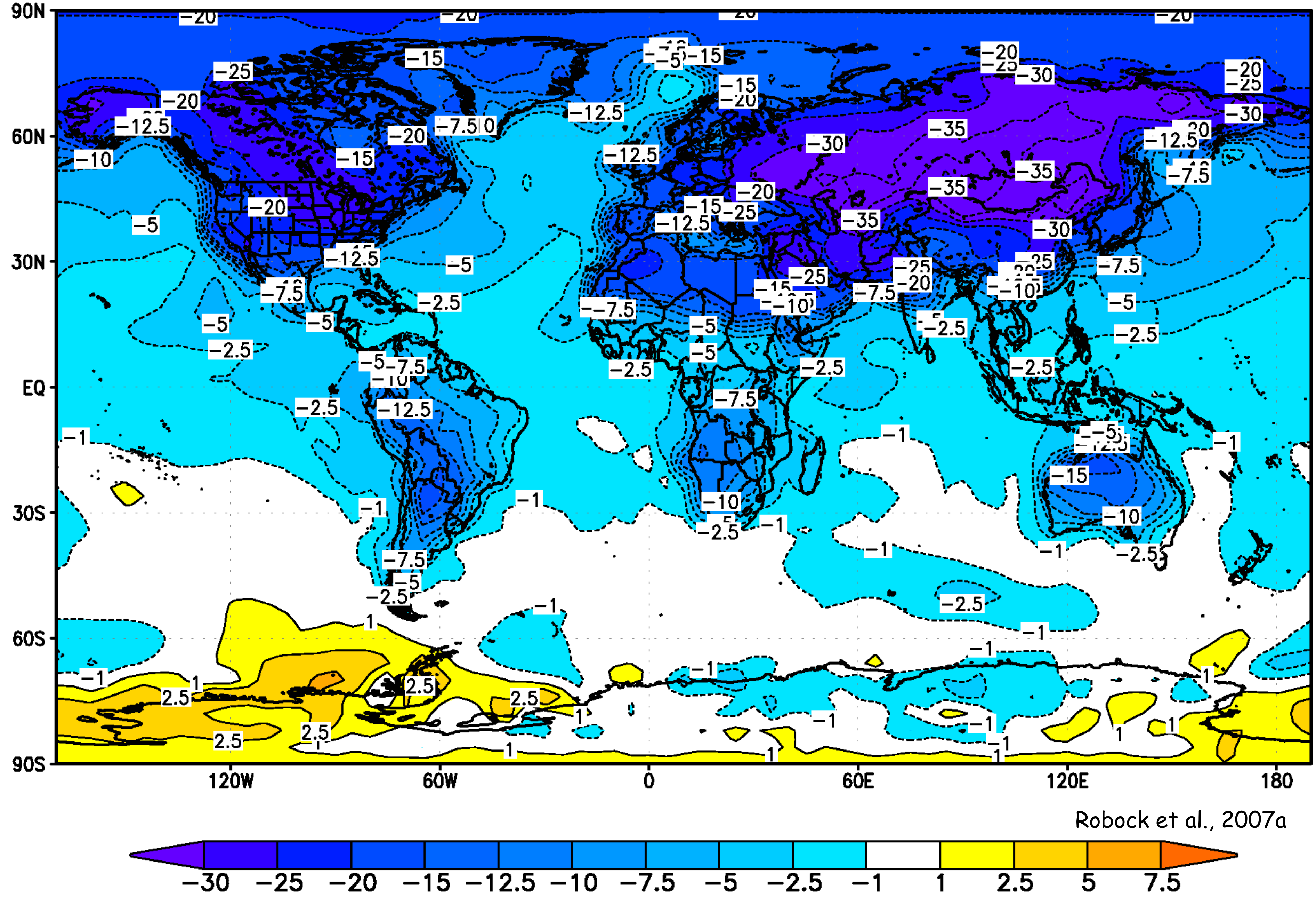
Alan Robock
Department of Environmental Sciences

BC Absorption Optical Depth May 14th

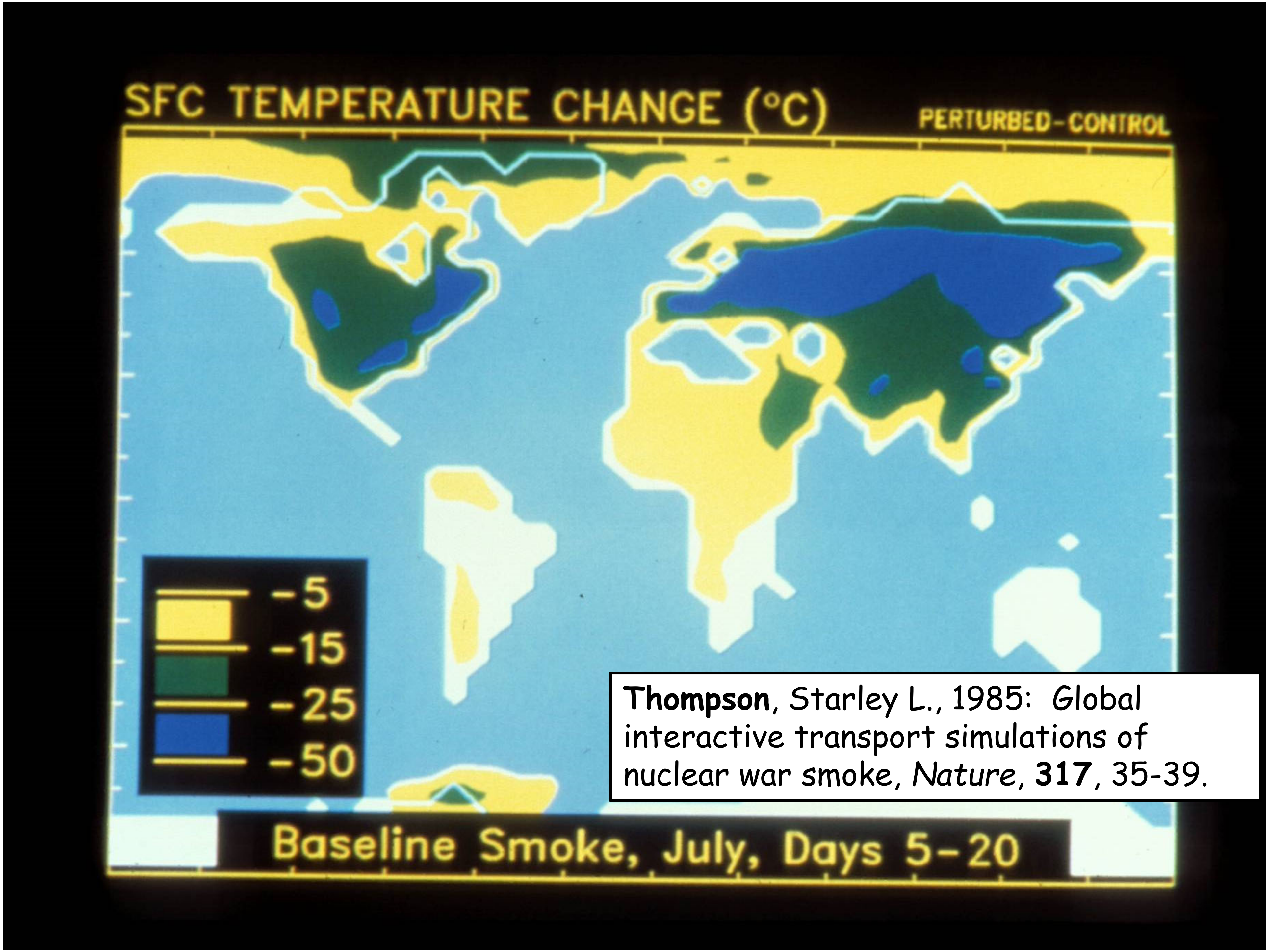


Robock et al., 2007a

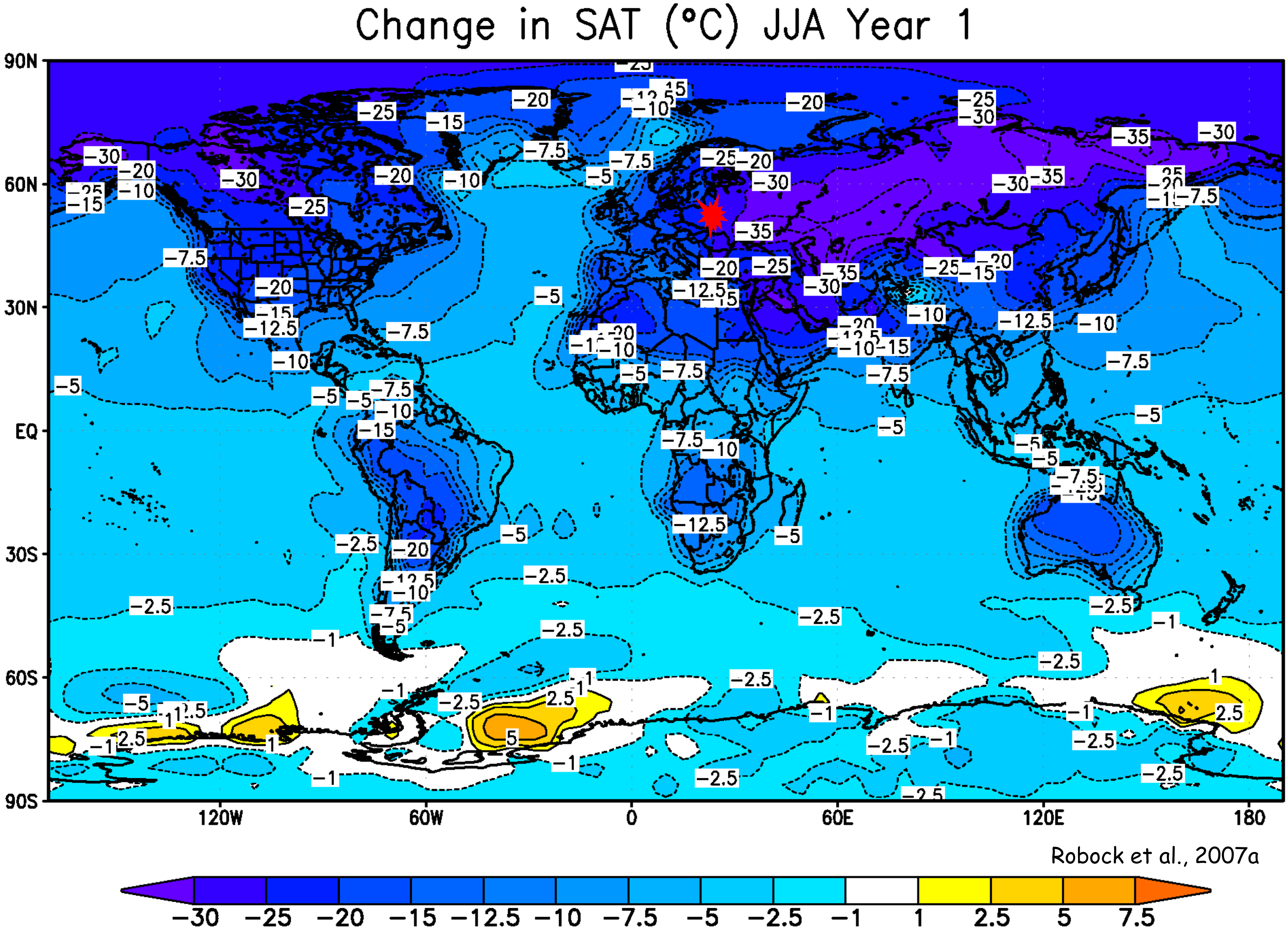
Change in SAT (°C) JJA Year 0 (days 17-109)



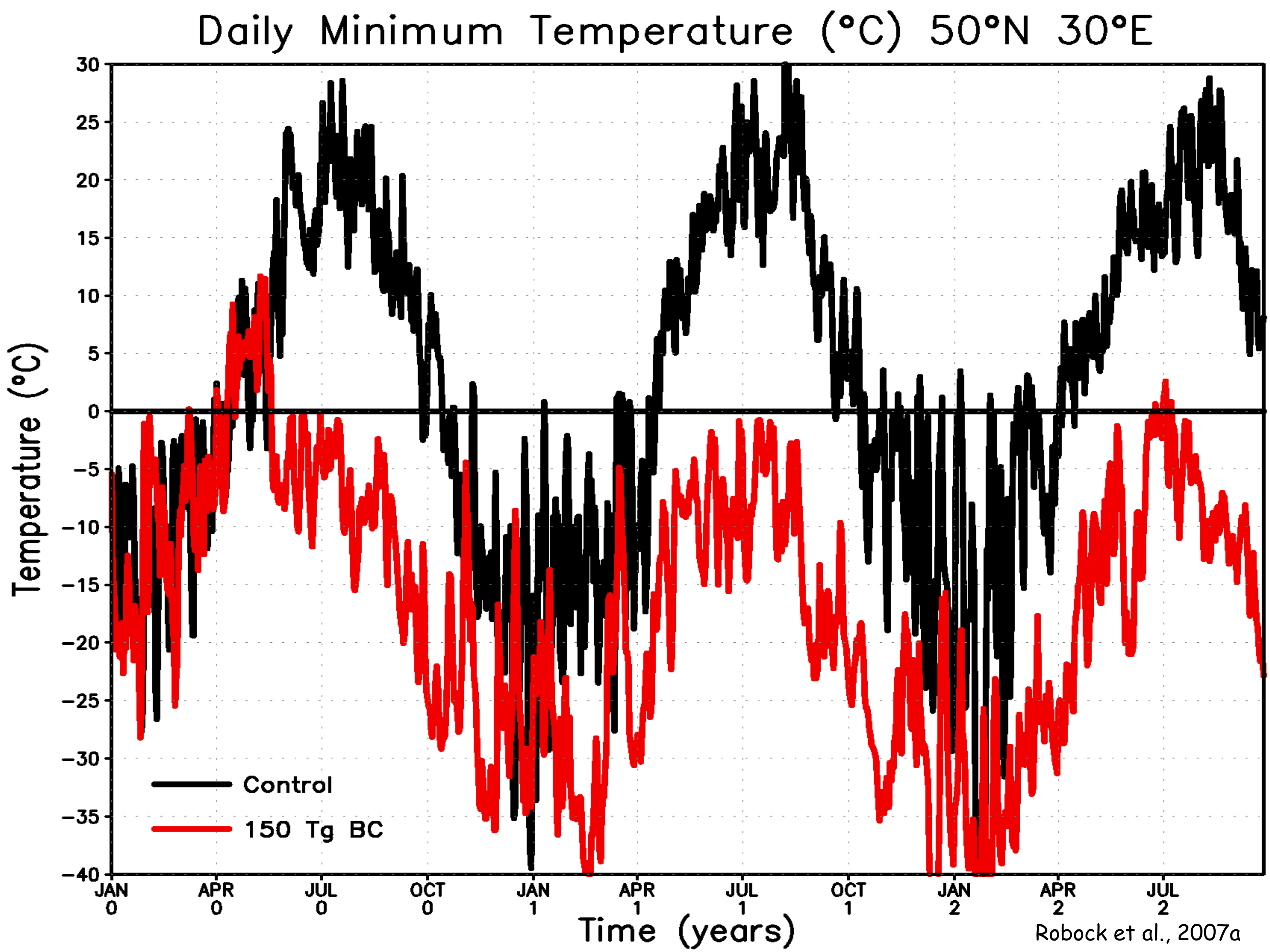
Robock et al., 2007a



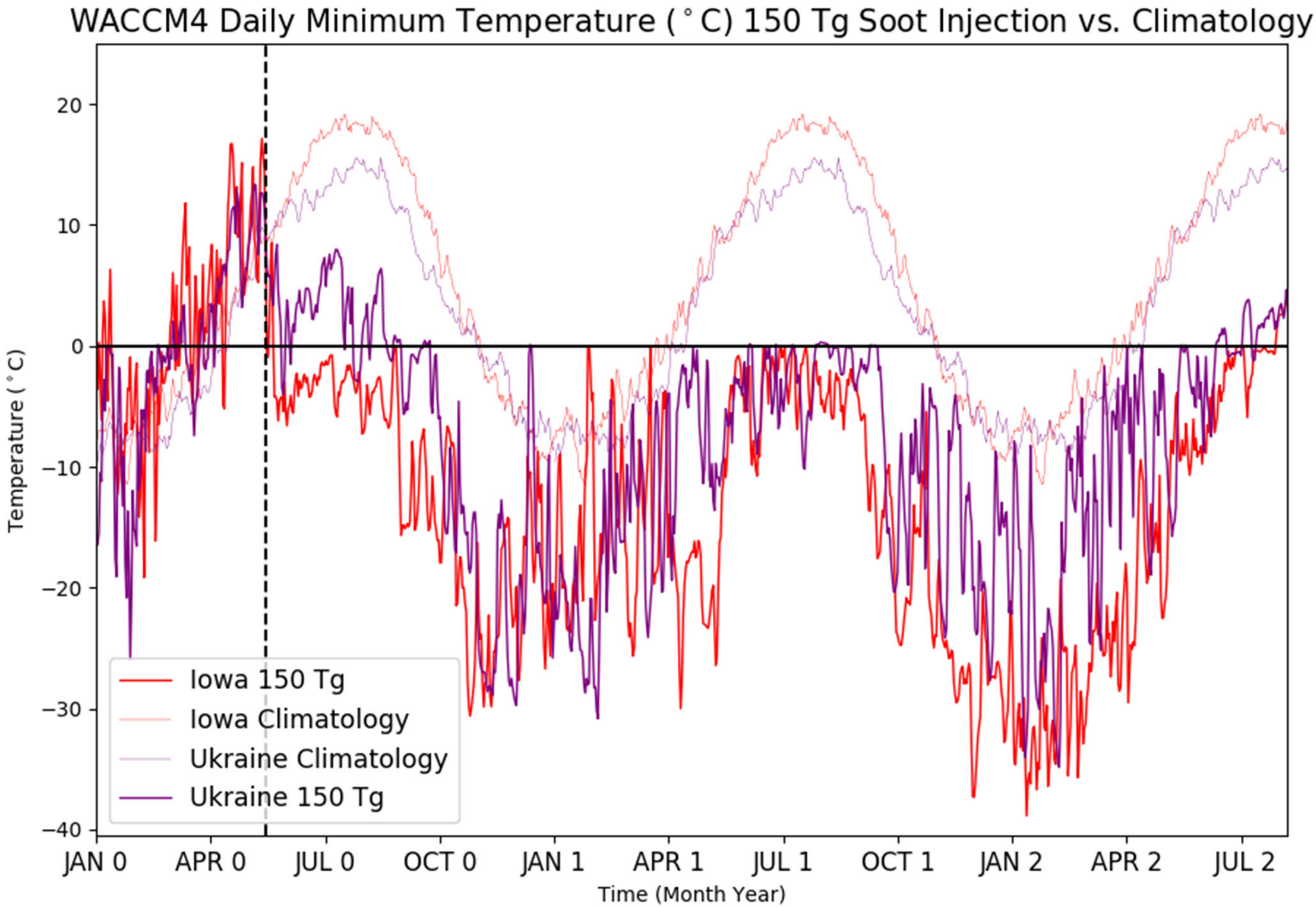
Thompson, Starley L., 1985: Global interactive transport simulations of nuclear war smoke, *Nature*, **317**, 35-39.



Robock et al., 2007a

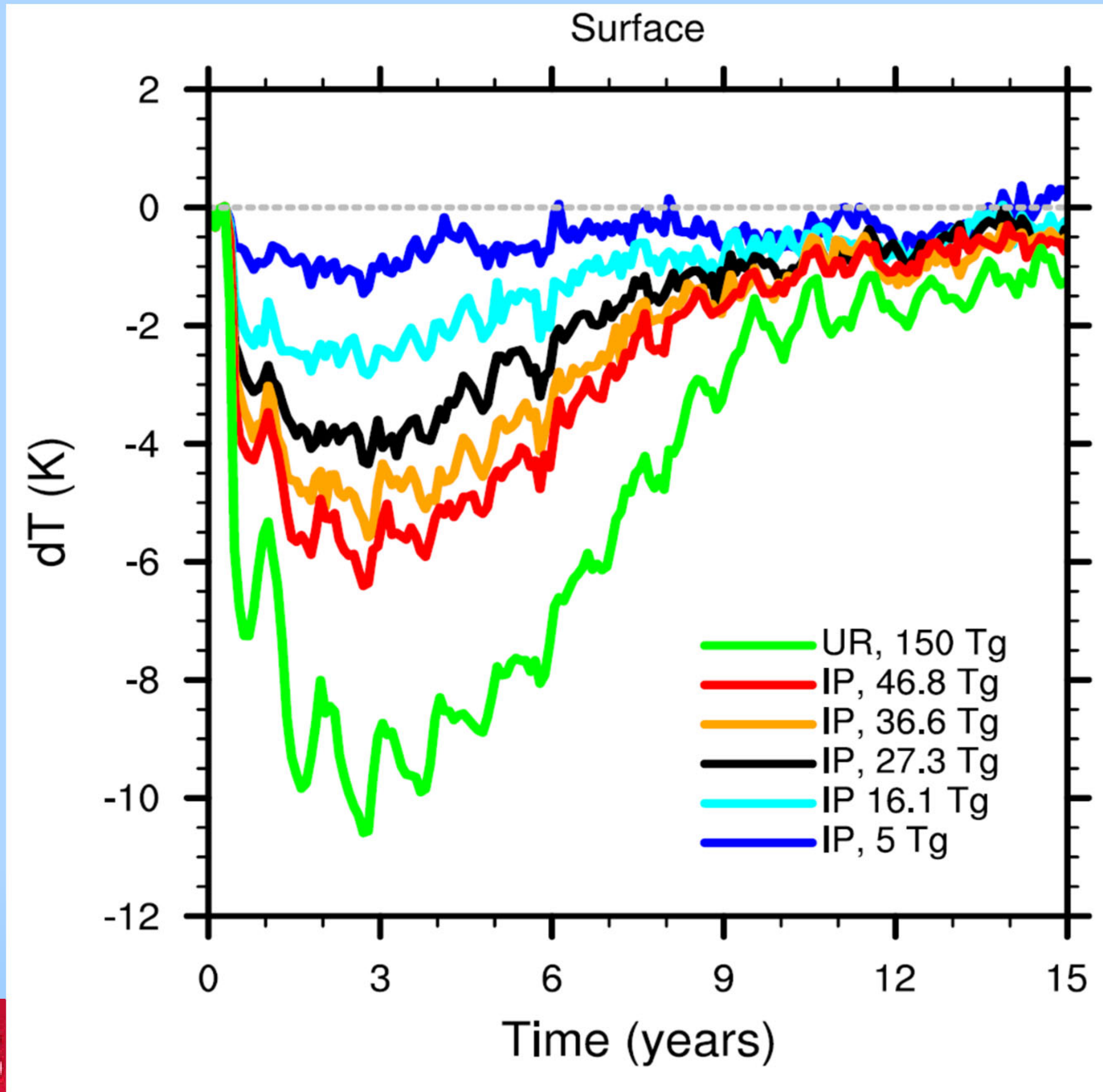


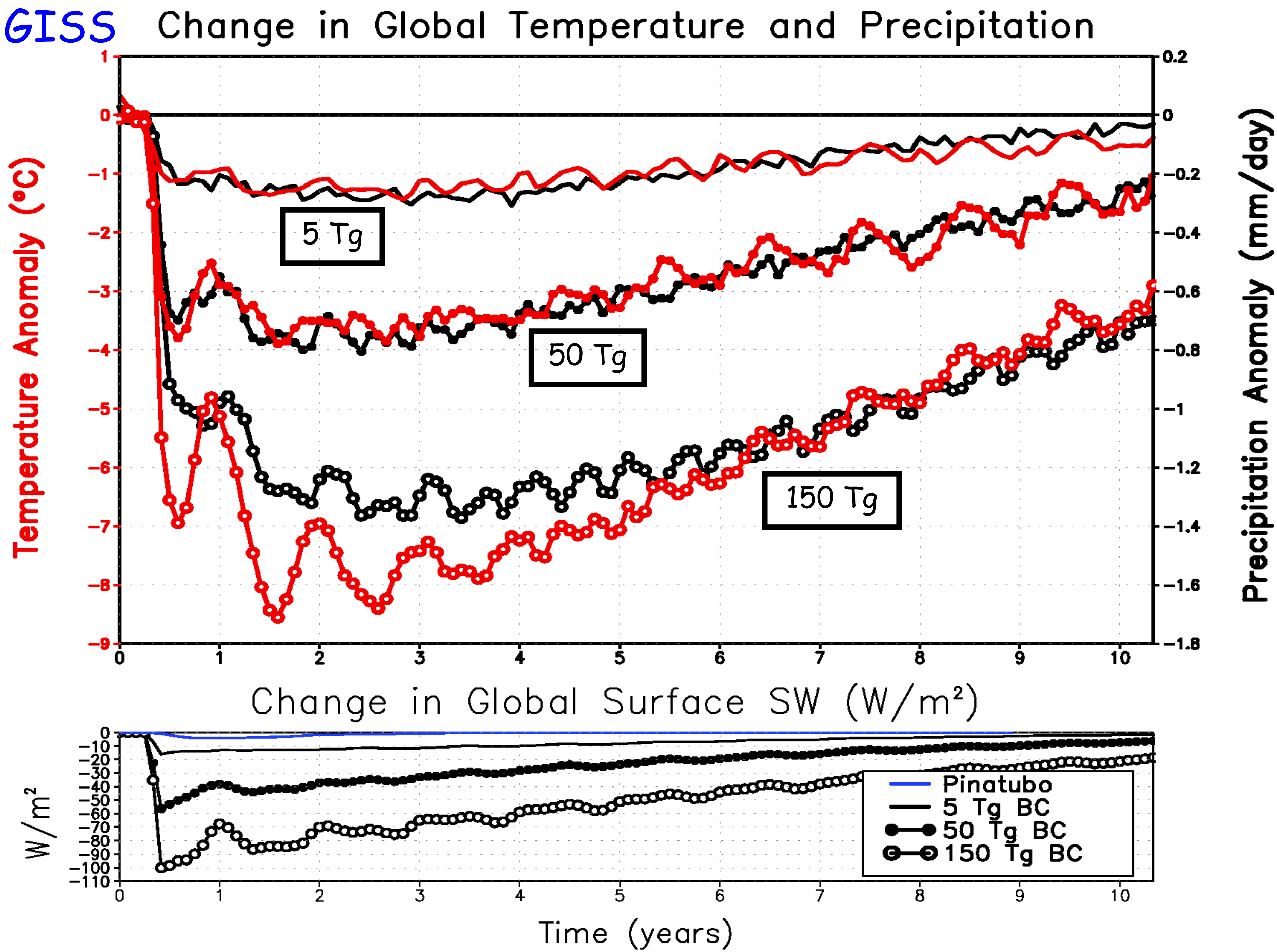
Daily Minimum Temperature (°C) 50°N 30°E
Temperature (°C)
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
−30
−35
−40
Control
150 Tg BC
JAN 0
APR 0
JUL 0
OCT 0
JAN 1
APR 1
JUL 1
OCT 1
JAN 2
APR 2
JUL 2
Time (years)
Robock et al., 2007a



Coupe, Joshua, Charles G. Bardeen, Alan Robock, and Owen B. Toon, 2019: Nuclear winter responses to global nuclear war in the Whole Atmosphere Community Climate Model Version 4 and the Goddard Institute for Space Studies ModelE. *J. Geophys. Res. Atmos.*, **124**, 8522-8543, doi:10.1029/2019JD030509.

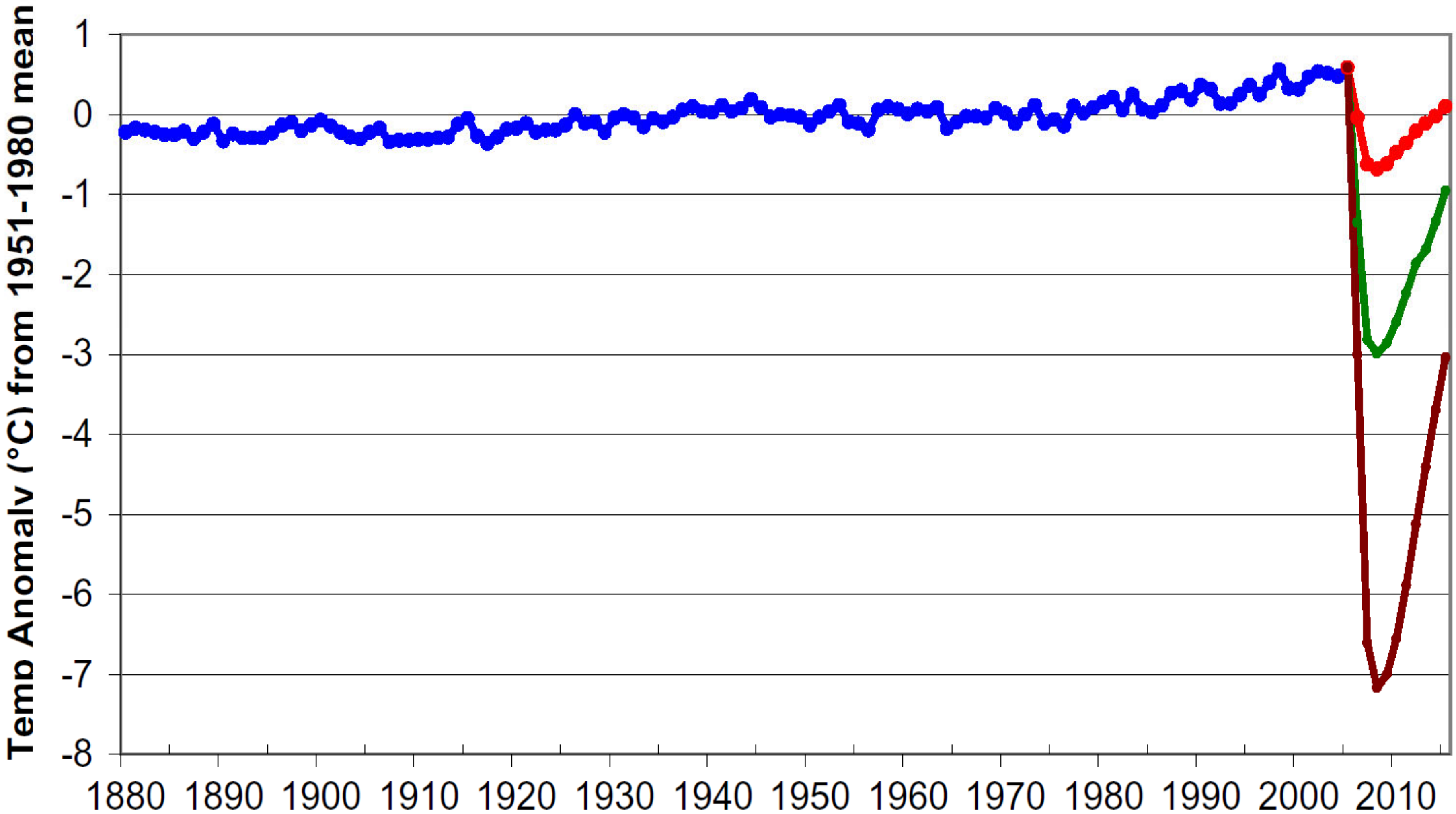
WACCM4 **global average** surface temperature changes for different soot amounts

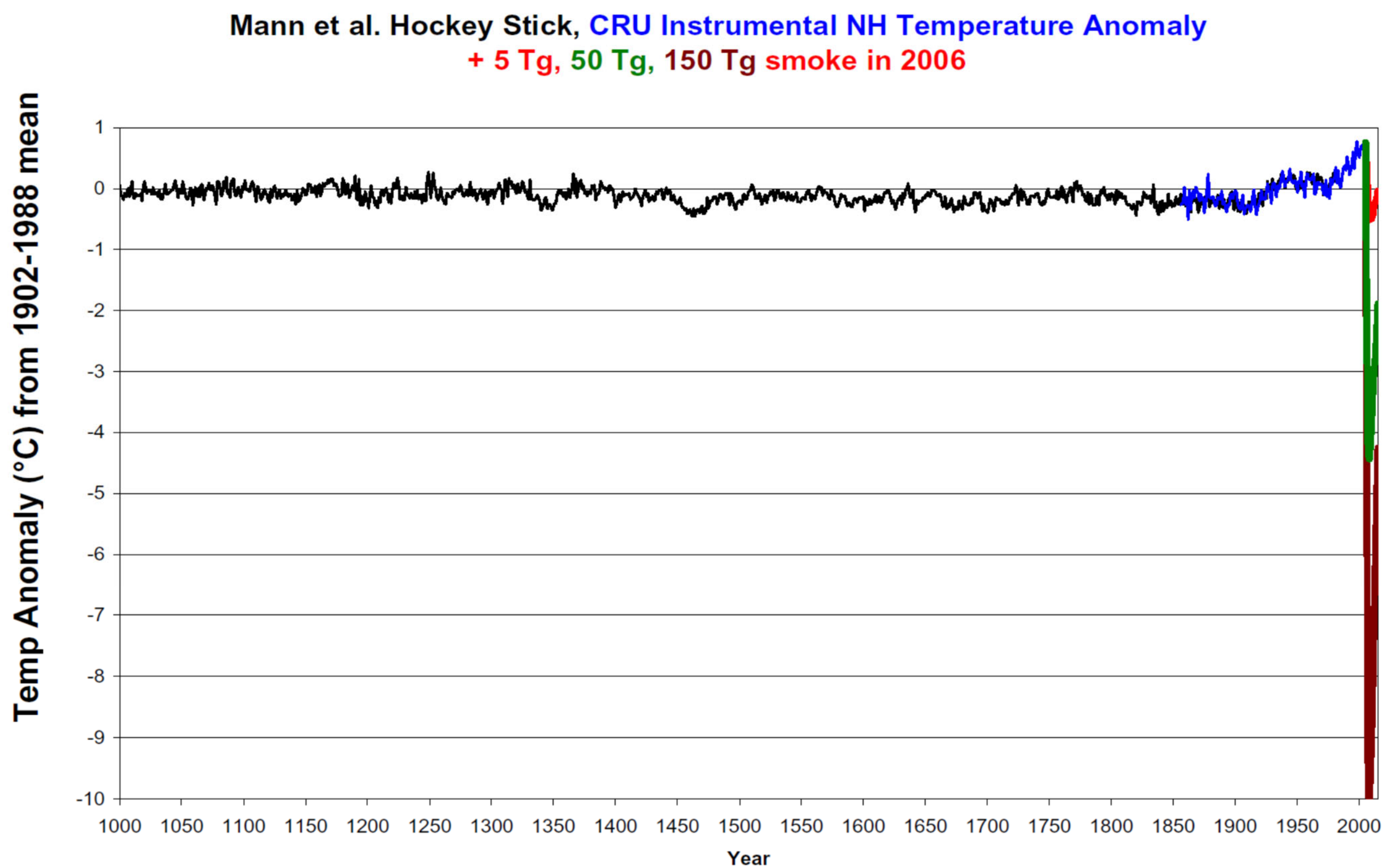




GISS Change in Global Temperature and Precipitation
Temperature Anomaly (°C)
Precipitation Anomaly (mm/day)
5 Tg
50 Tg
150 Tg
Change in Global Surface SW (W/m²)
W/m²
Pinatubo
5 Tg BC
50 Tg BC
150 Tg BC
Time (years)

GISS Global Average Temperature Anomaly
+ 5 Tg, 50 Tg, 150 Tg smoke in 2006





Mann et al. Hockey Stick, CRU Instrumental NH Temperature Anomaly
+ 5 Tg, 50 Tg, 150 Tg smoke in 2006
Temp Anomaly (°C) from 1902-1988 mean
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

150 Tg soot into the upper troposphere

Anthropogenic emissions stop

MAGICC energy-balance model simulation with climate sensitivity of 3 K for doubling CO_2

Would solve global warming problem!

A Modest Proposal, *Huffington Post*, September 1, 2015.

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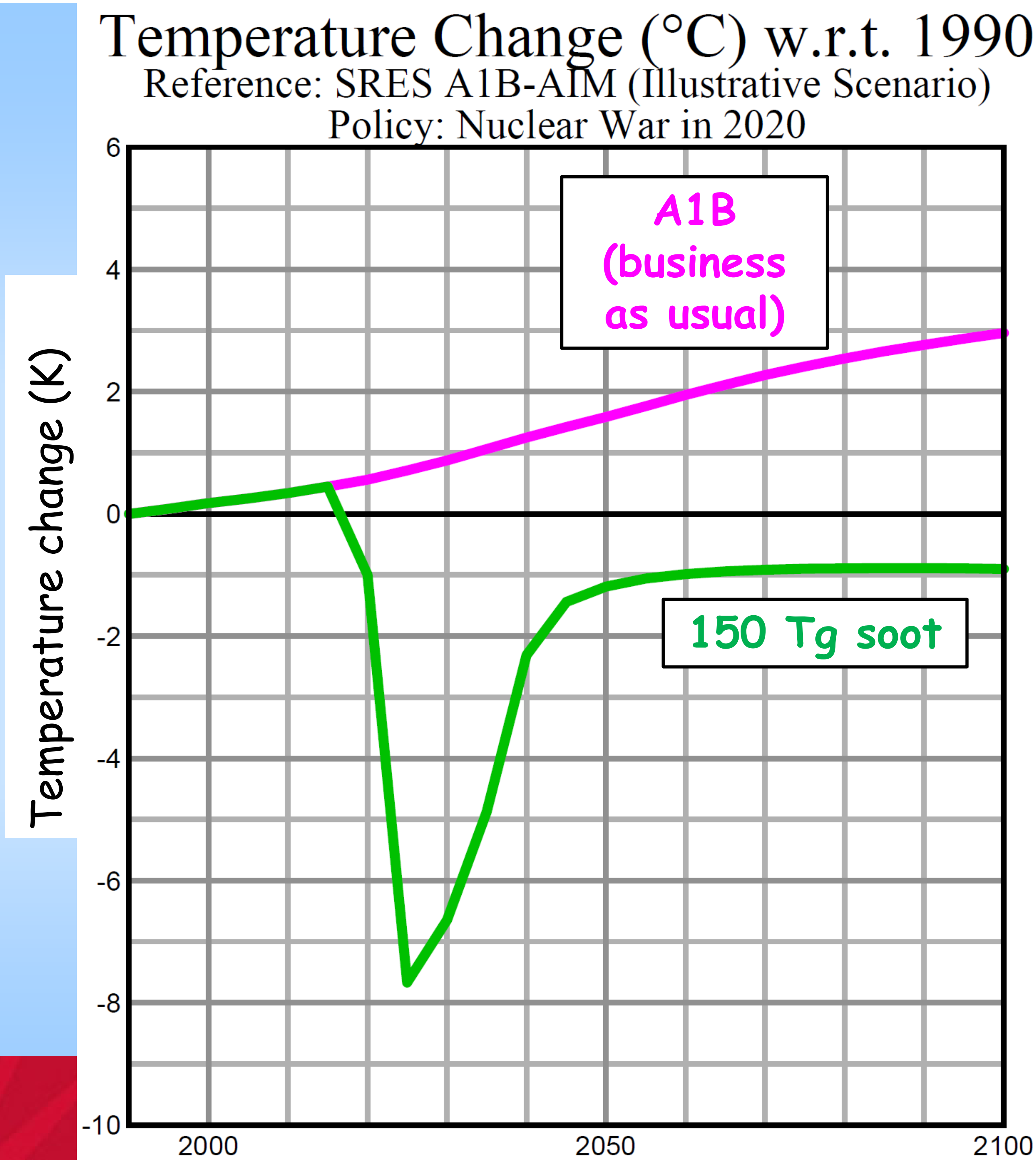

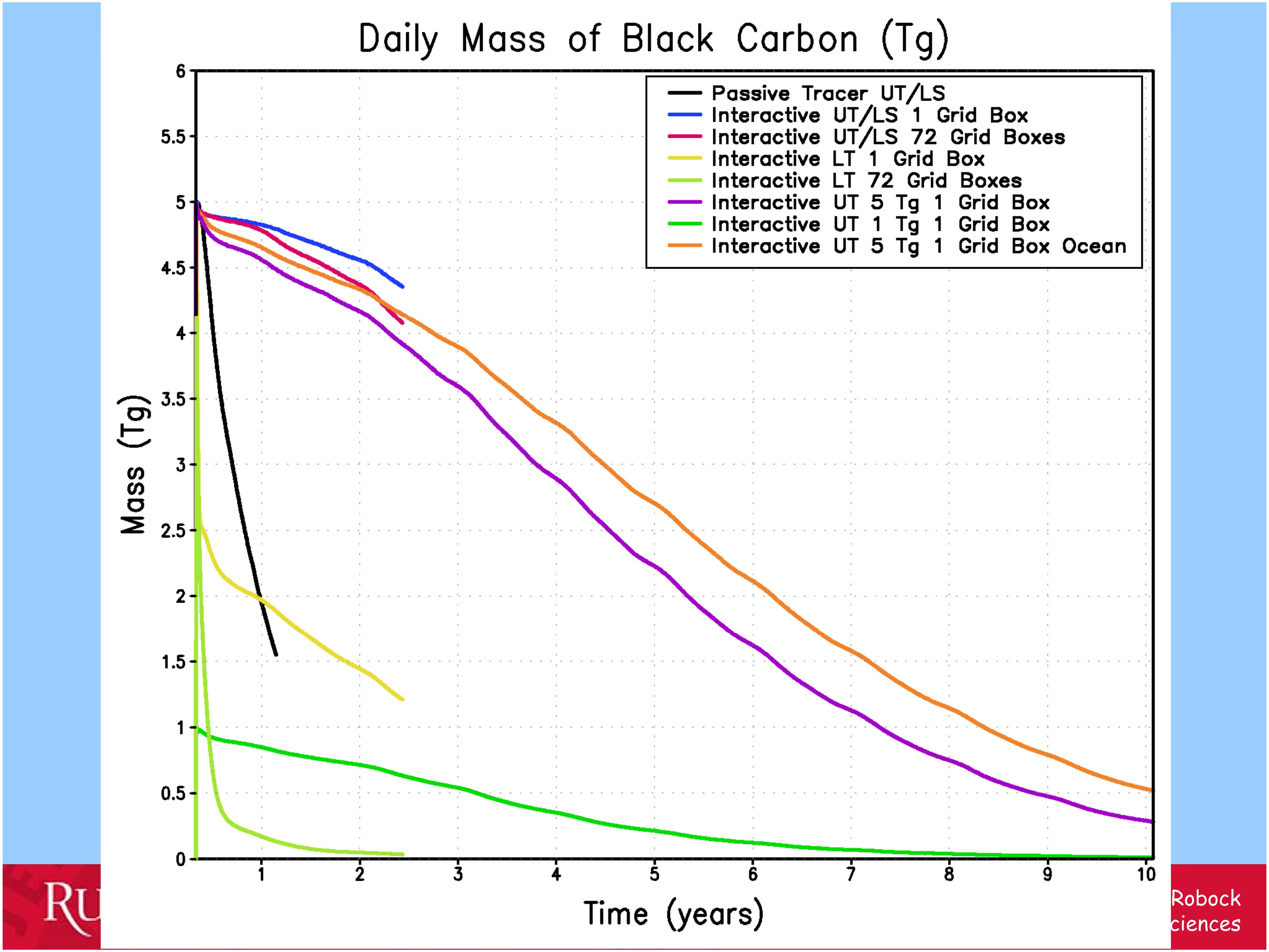
Daily Mass of Black Carbon (Tg)
Passive Tracer UT/LS
Interactive UT/LS 1 Grid Box
Interactive UT/LS 72 Grid Boxes
Interactive LT 1 Grid Box
Interactive LT 72 Grid Boxes
Interactive UT 5 Tg 1 Grid Box
Interactive UT 1 Tg 1 Grid Box
Interactive UT 5 Tg 1 Grid Box Ocean
Mass (Tg)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
1
2
3
4
5
6
7
8
9
10
Time (years)
Robock
ciences

The World's Largest Crops

China is largely self-sufficient in food production and doesn't export much. But it produces and consumes some of the world's largest crops by far. And if recent droughts in China force the country to begin importing on a large scale, it could push the already rising prices of commodities like wheat even higher.

2009 PRODUCTION OF:

RICE	Millions of tons	World share
China	**197**	**29%**
India	131	19
Indonesia	64	9
Bangladesh	45	7
Vietnam	39	6
Thailand*	31	5
Myanmar*	31	4
Philippines	16	2
Brazil	13	2
Japan	11	2
Pakistan	10	2
United States	10	1

WHEAT		
China	**115**	**17%**
India	81	12
Russia	62	9
United States	60	9
France	38	6
Canada	27	4
Germany	25	4
Pakistan	24	4
Australia	22	3
Ukraine	21	3
Turkey	21	3
Kazakhstan	17	3

CORN		
United States	333	41%
China	**163**	**20**
Brazil	51	6
Mexico	20	2
Indonesia	18	2
India	17	2
France	15	2
Argentina	13	2
South Africa	12	1
Ukraine	10	1
Canada	10	1
Romania	8	1

Source: United Nations Food and Agriculture Organization   *2008 production.

THE NEW YORK TIMES

New York Times, February 9, 2011

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Alan Robock
Department of Environmental Sciences

We calculated how agricultural production would change in the 10 years following a nuclear war between India and Pakistan, using crop models, for:

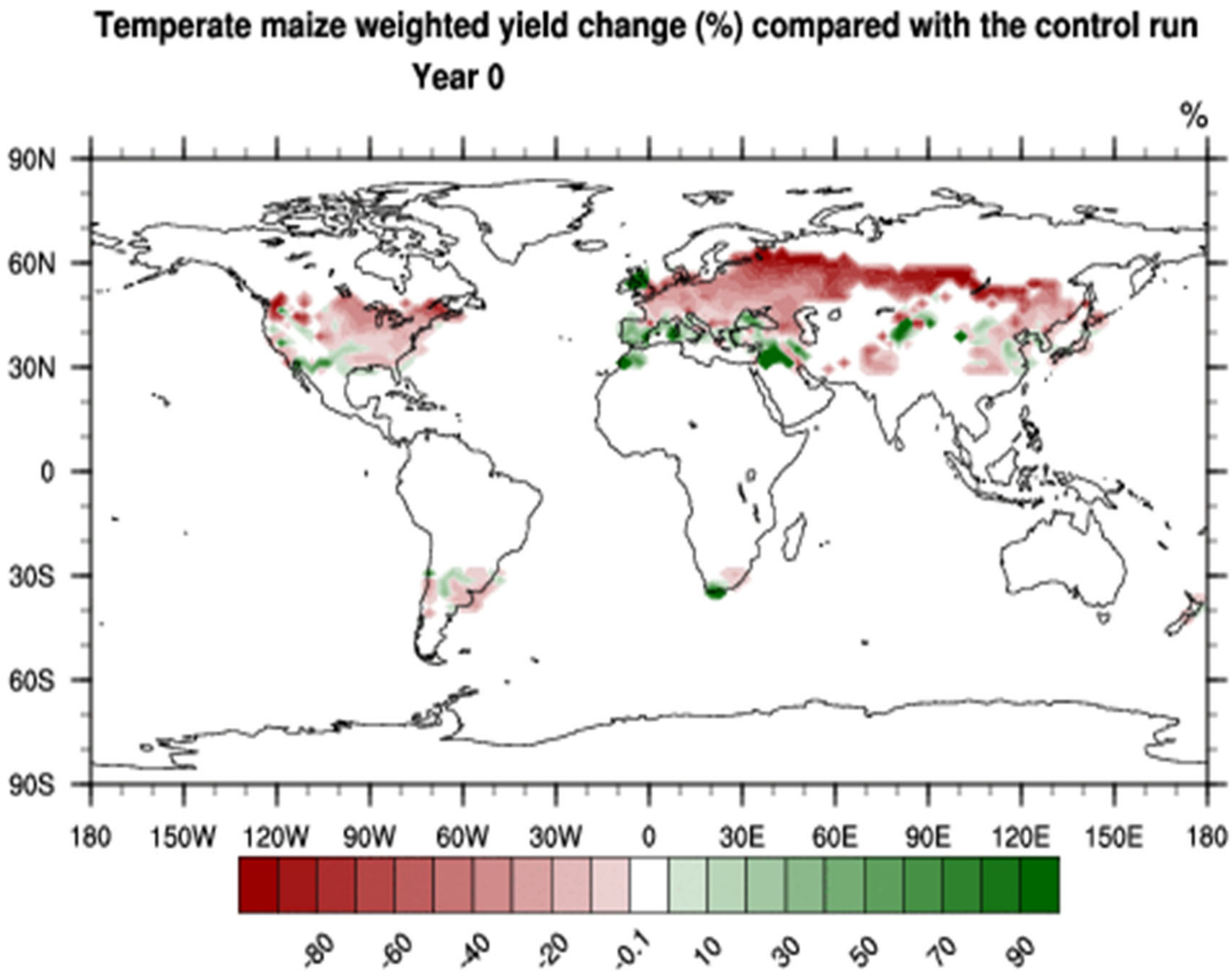
Maize (corn) and **soybeans** in the US Midwest

Rice, **maize**, and **wheat** in China

Özdoğan, Mutlu, Alan Robock, and Christopher Kucharik, 2013: Impacts of a nuclear war in South Asia on soybean and maize production in the Midwest United States. *Climatic Change*, **116**, 373-387, doi:10.1007/s10584-012-0518-1.

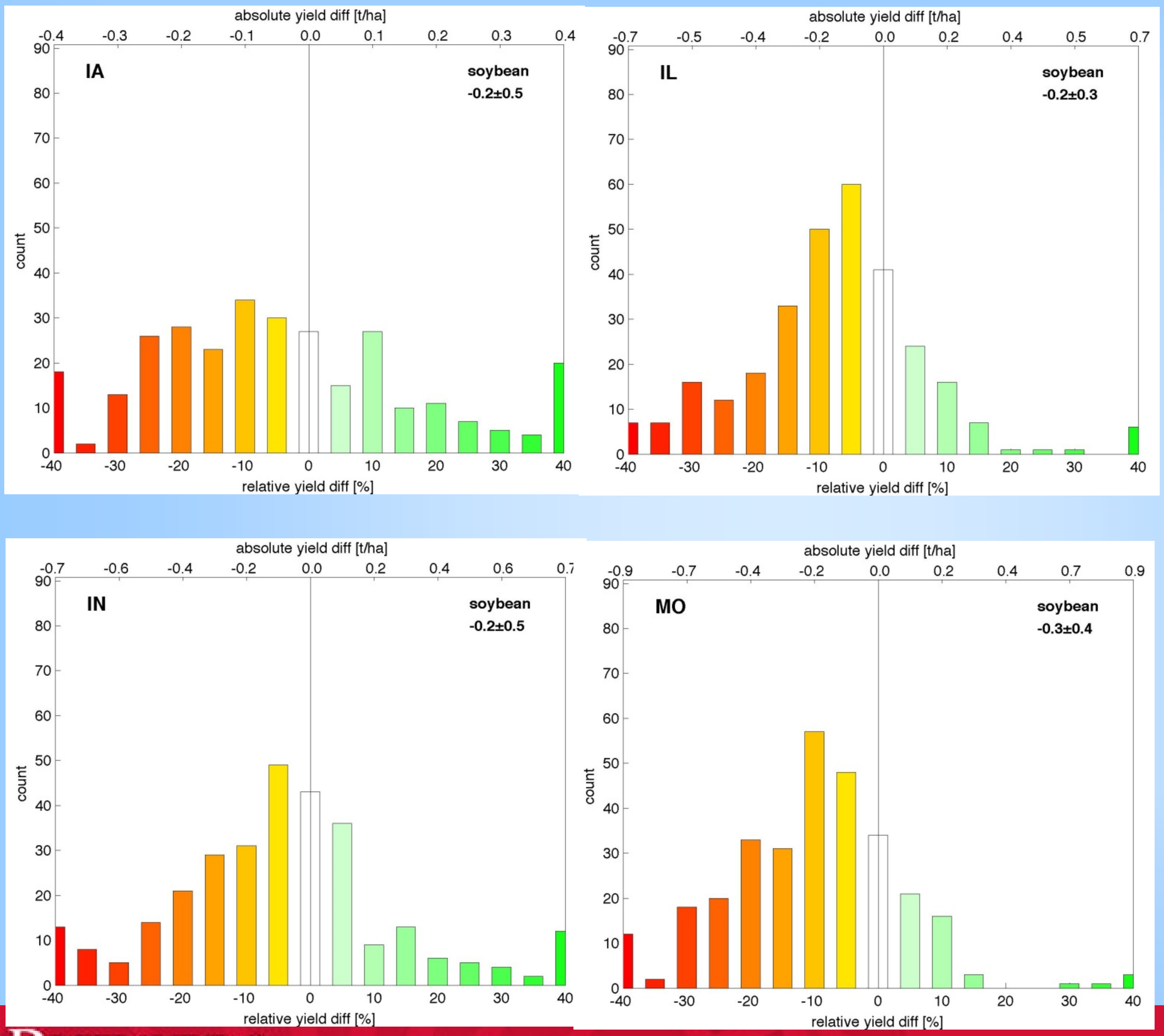
Xia, Lili, and Alan Robock, 2013: Impacts of a nuclear war in South Asia on rice production in mainland China. *Climatic Change*, **116**, 357-372, doi: 10.1007/s10584-012-0475-8.

Xia, Lili, Alan Robock, Michael Mills, Andrea Stenke, and Ira Helfand, 2015: Decadal reduction of Chinese agriculture after a regional nuclear war. *Earth's Future*, **3**, 37-48, doi:10.1002/2014EF000283.



Global temperate maize yield change simulated by CLM-crop (2°) using climate forcing of WACCM [Mills et al., 2014]

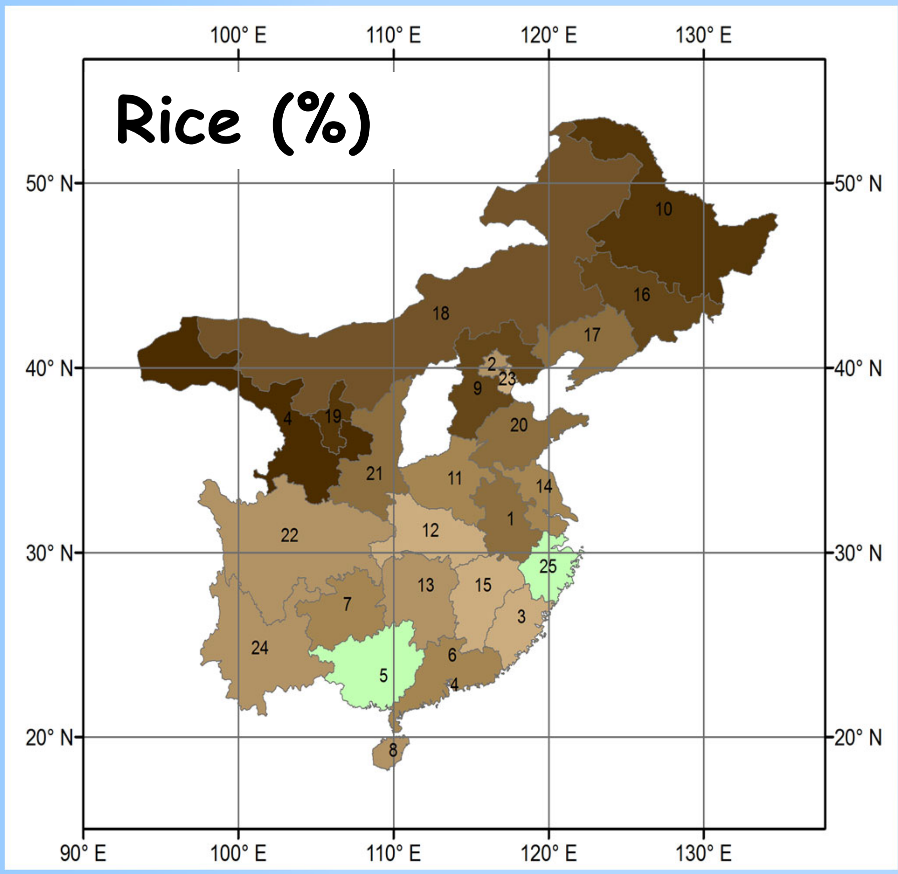
Change in US Midwest **soy** yield for decade after 5 Tg soot injection

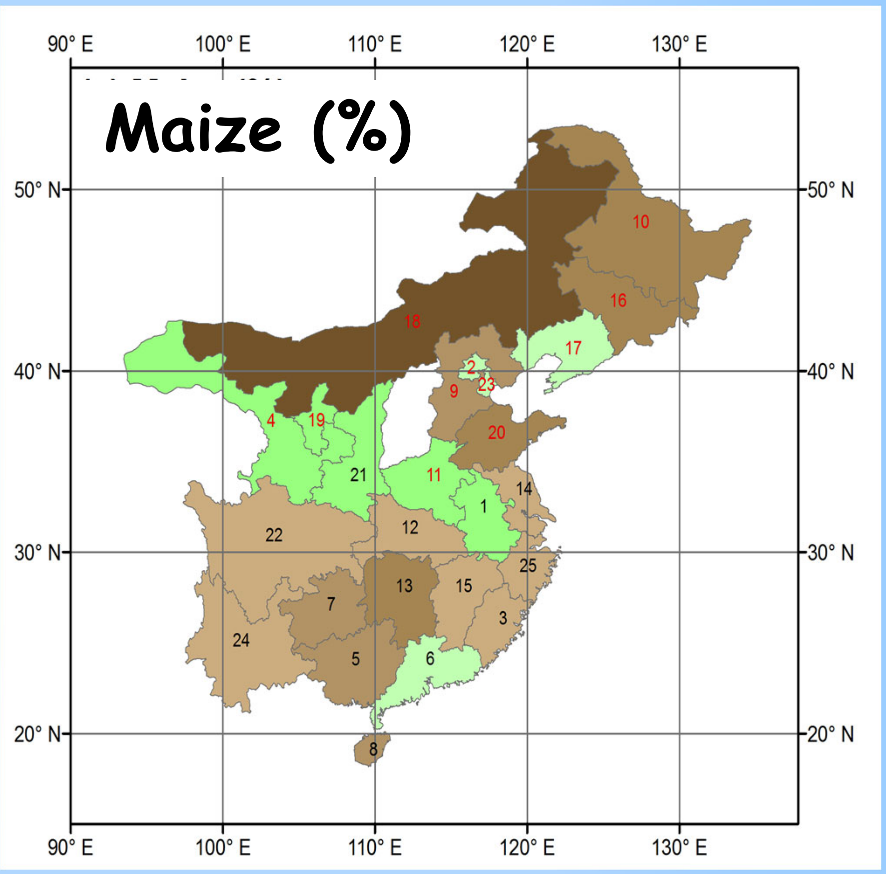


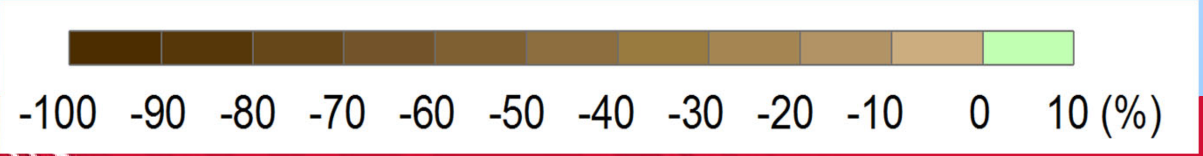
Used Agro-IBIS model

Ozdogan, Robock, and Kucharik (2013), Impacts of a nuclear war in South Asia on soybean and maize production in the Midwest United States, *Climatic Change*.

Rice and maize yield change (%) after a regional nuclear war (second year after a regional nuclear war occurred)







[Xia et al., 2015]

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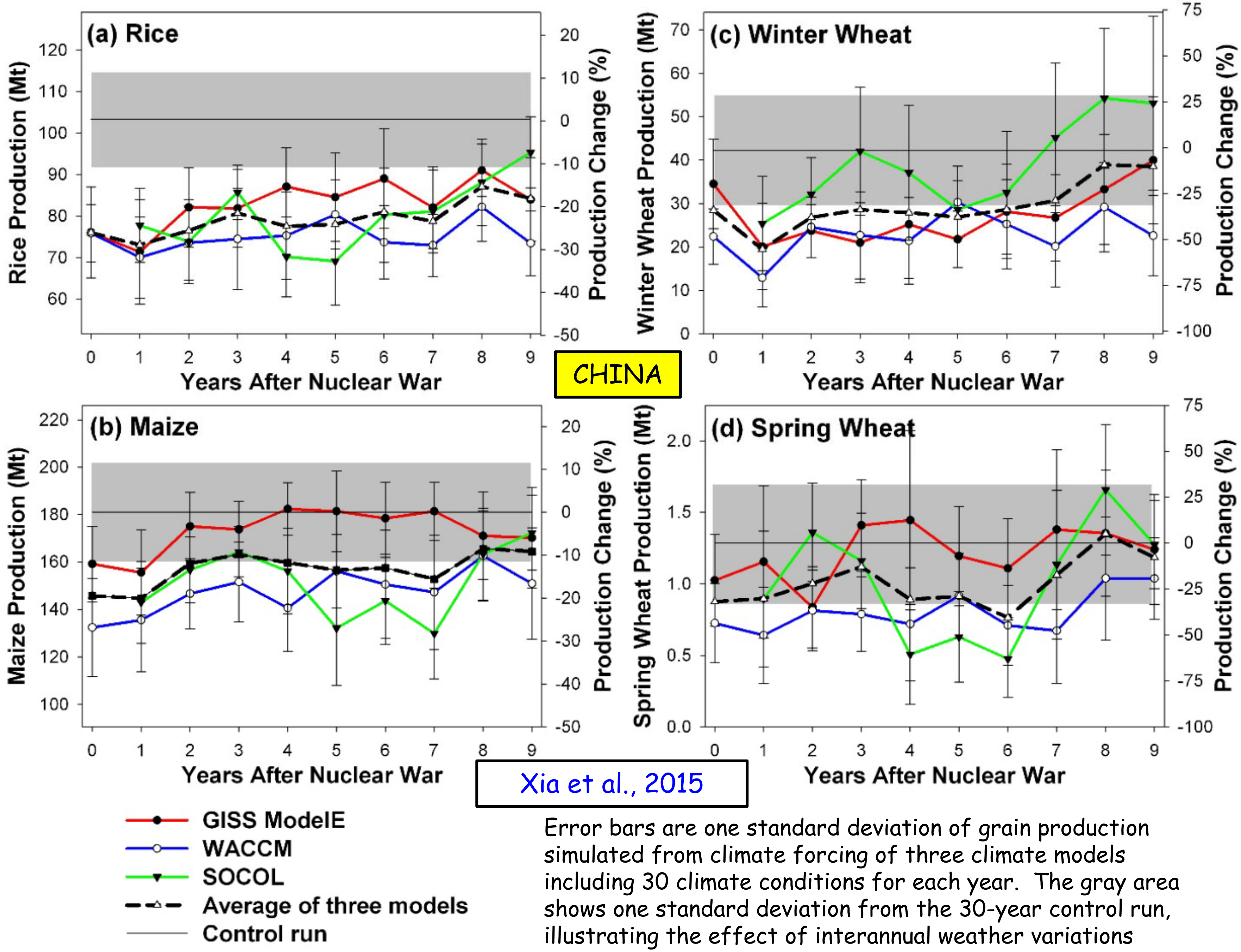
Department of Environmental Sciences

Crop yield changes forced by climate changes of three Climate Models



Error bars are one standard deviation of grain production simulated from climate forcing of three climate models including 30 climate conditions for each year. The gray area shows one standard deviation from the 30-year control run, illustrating the effect of interannual weather variations

How agricultural production would change in the 10 years following a nuclear war between India and Pakistan

(not considering damage from excess UV yet)

Summary:

	First 5 years	Second 5 years
US maize	-20%	-10%
US soybeans	-15%	-10%
China maize	-15%	-10%
China middle season rice	-25%	-20%
China spring wheat	-25%	-20%
China winter wheat	-40%	-25%

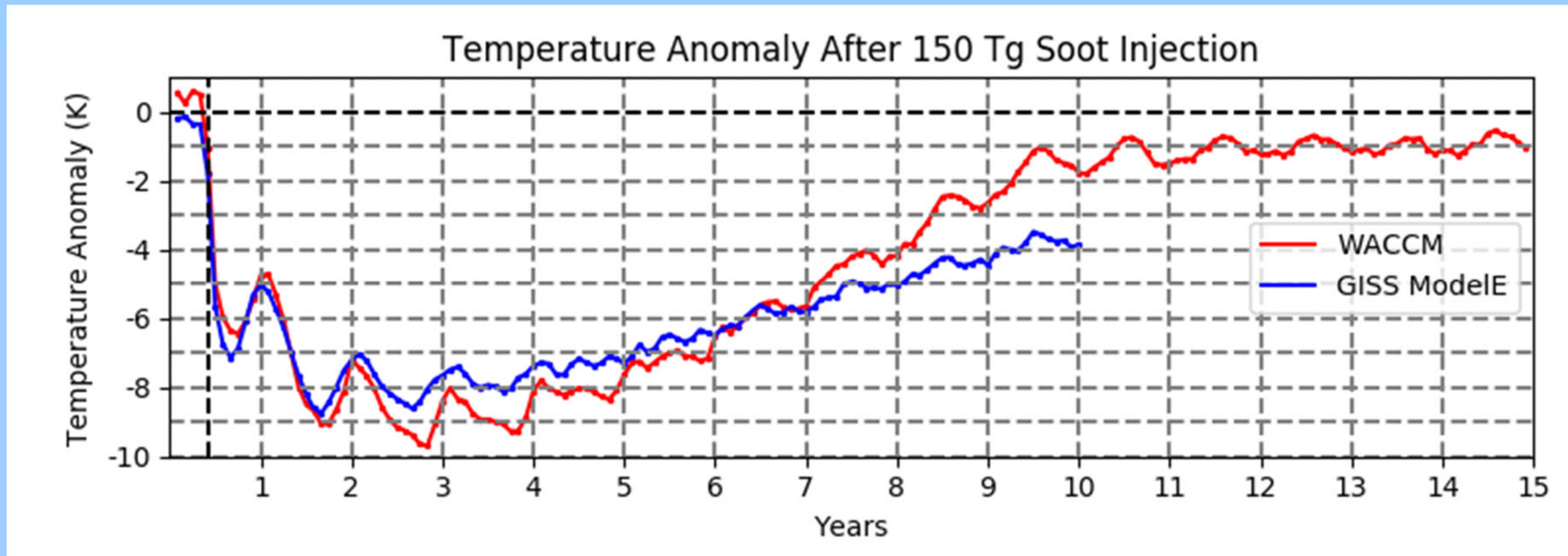
Alan Robock
Department of Environmental Sciences

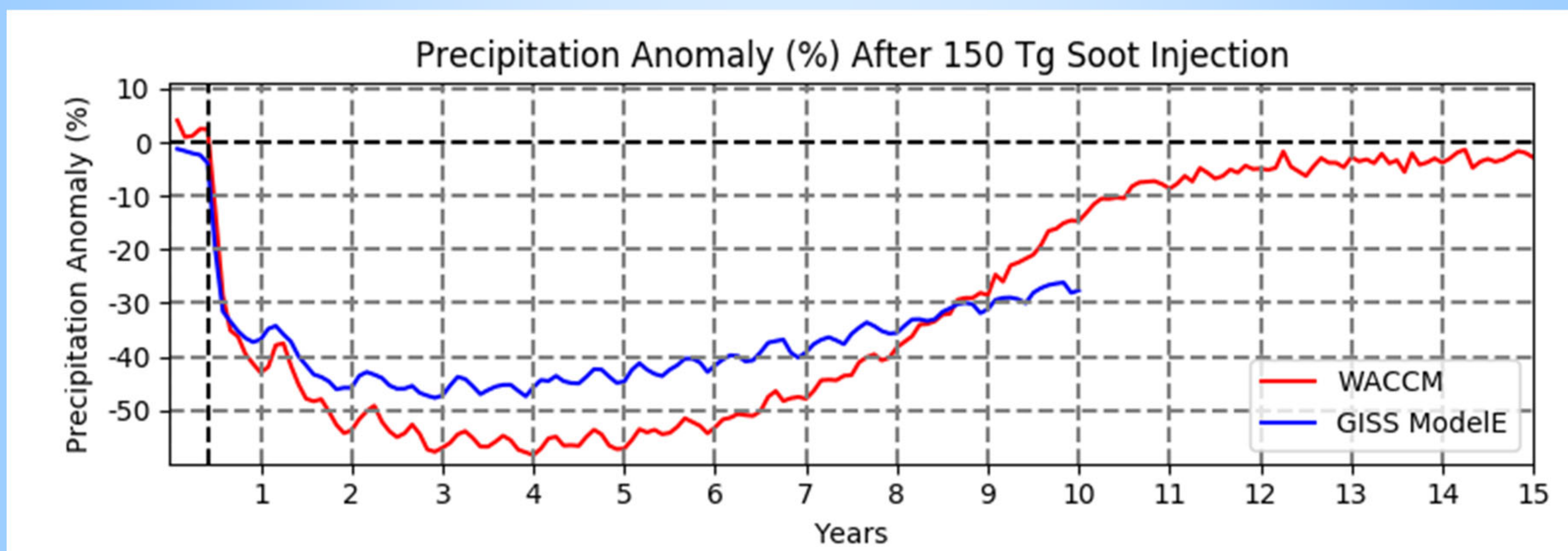
New simulations now being done with the Whole Atmosphere Community Climate Model, version 4 (WACCM4)

- horizontal resolution of 1.9° × 2.5° (lat-lon)
- 66 vertical layers
- model top of 140 km
- transport and removal of soot from fires is handled by the Community Aerosol and Radiation Model for Atmospheres (CARMA), a sectional aerosol model that treats soot as fractal particles and allows them to grow

Toon, Owen B., Charles G. Bardeen, Alan Robock, Lili Xia, Hans Kristensen, Matthew McKinzie, R. J. Peterson, Cheryl Harrison, Nicole S. Lovenduski, and Richard P. Turco, 2019: Rapid expansion of nuclear arsenals by Pakistan and India portends regional and global catastrophe. *Science Advances*, **5**, eaay5478, doi:10.1126/sciadv.aay5478.

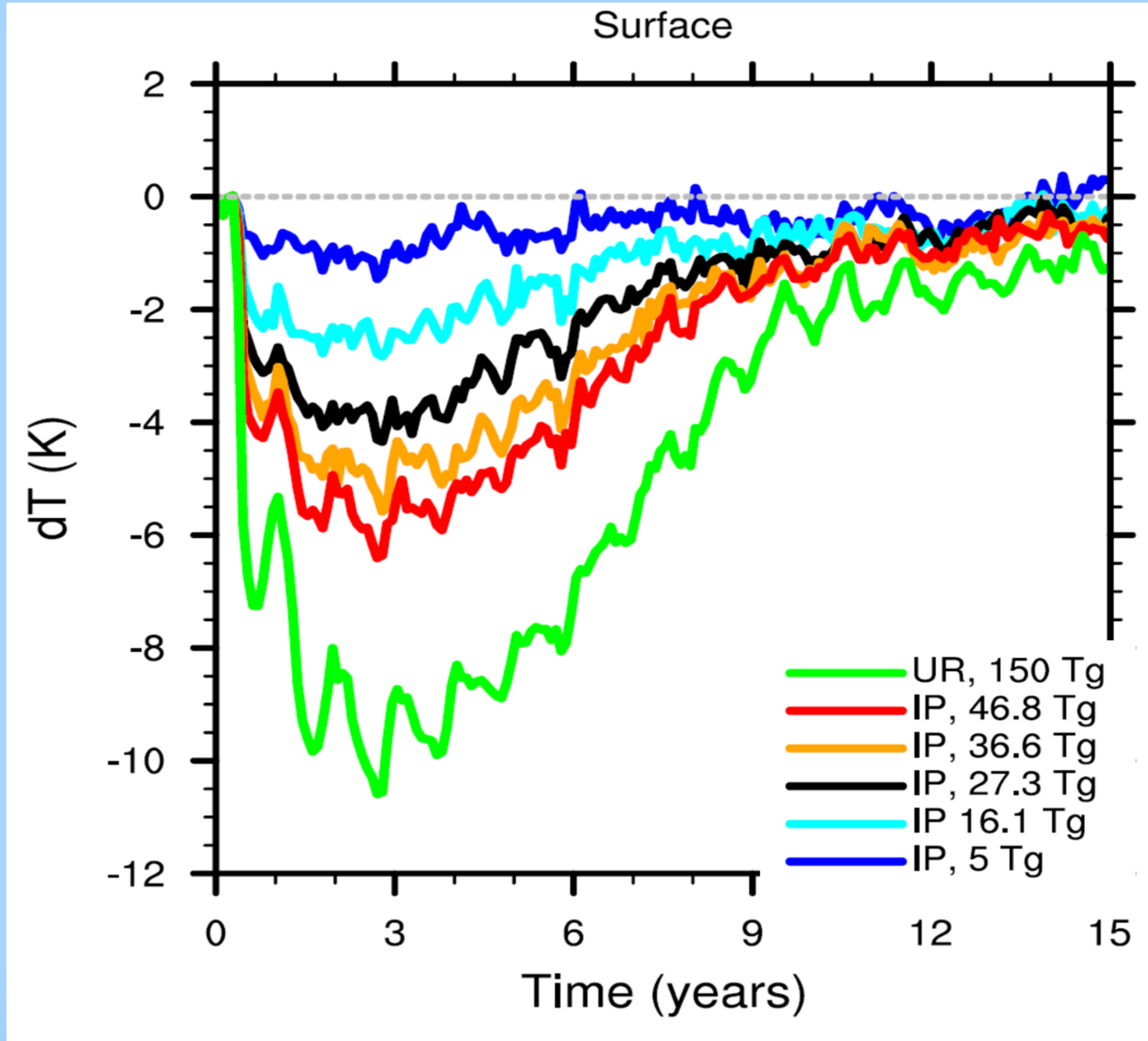
Alan Robock
Department of Environmental Sciences





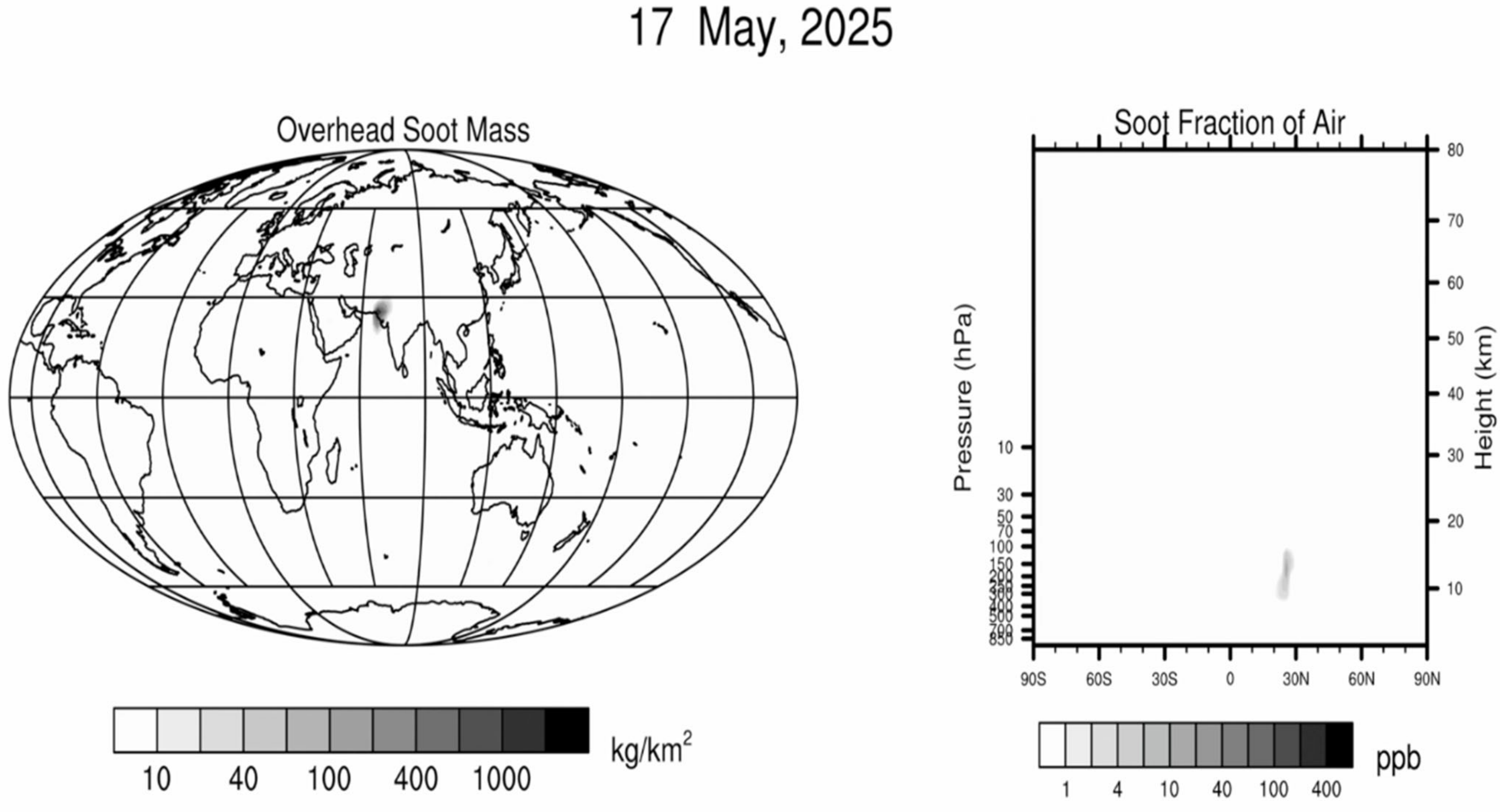
Coupe, Joshua, Charles G. Bardeen, Alan Robock, and Owen B. Toon, 2019: Nuclear winter responses to global nuclear war in the Whole Atmosphere Community Climate Model Version 4 and the Goddard Institute for Space Studies ModelE. *J. Geophys. Res. Atmos.*, **124**, 8522-8543, doi:10.1029/2019JD030509.

WACCM4 Global average surface temperature changes for different soot amounts



Toon, Owen B., Charles G. Bardeen, Alan Robock, Lili Xia, Hans Kristensen, Matthew McKinzie, R. J. Peterson, Cheryl Harrison, Nicole S. Lovenduski, and Richard P. Turco, 2019: Rapid expansion of nuclear arsenals by Pakistan and India portends regional and global catastrophe. *Science Advances*, **5**, eaay5478, doi:10.1126/sciadv.aay5478.

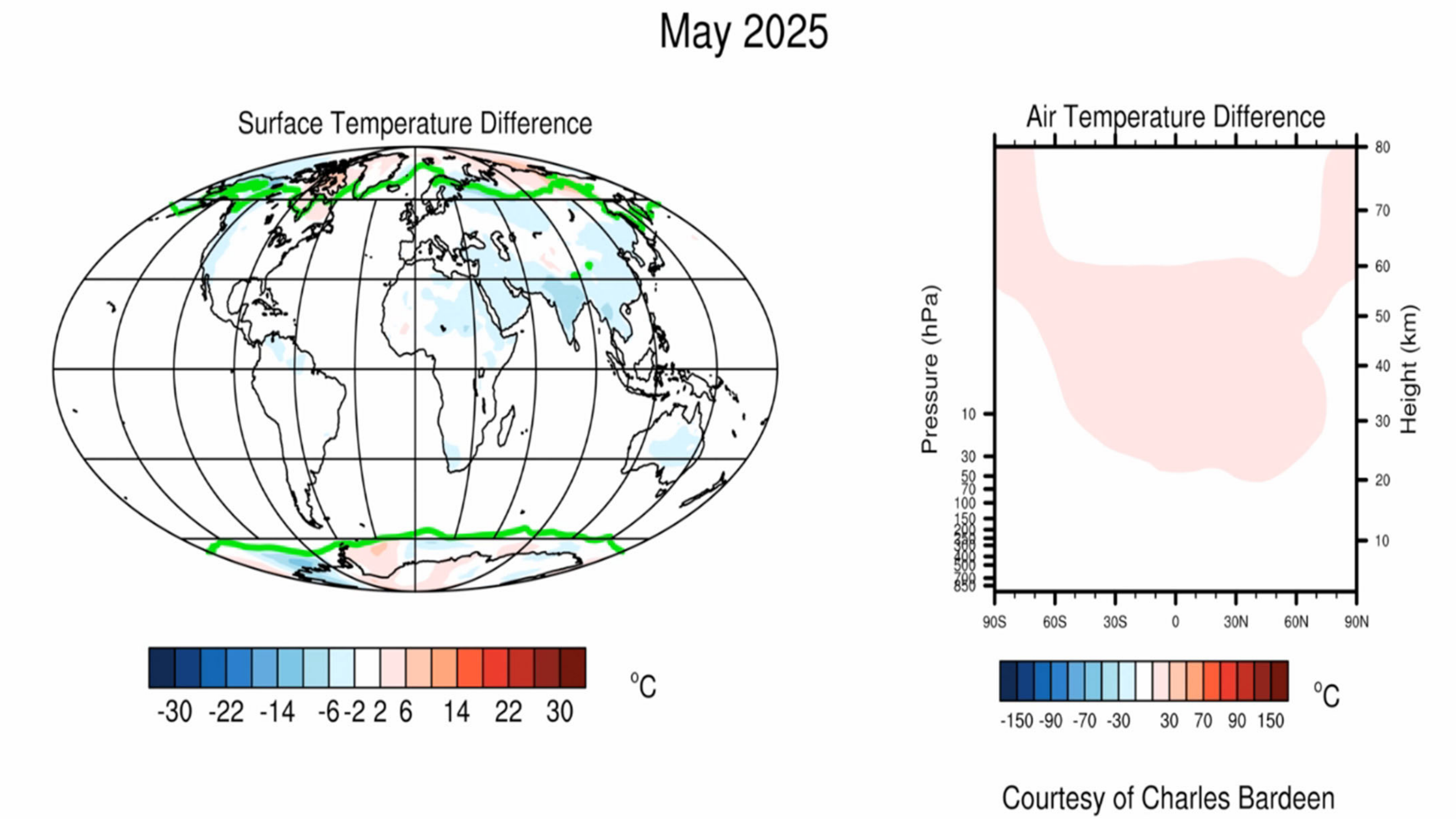
27 Tg soot injection



Courtesy of Charles Bardeen

Toon, Owen B., Charles G. Bardeen, Alan Robock, Lili Xia, Hans Kristensen, Matthew McKinzie, R. J. Peterson, Cheryl Harrison, Nicole S. Lovenduski, and Richard P. Turco, 2019: Rapid expansion of nuclear arsenals by Pakistan and India portends regional and global catastrophe. *Science Advances*, **5**, eaay5478, doi:10.1126/sciadv.aay5478.

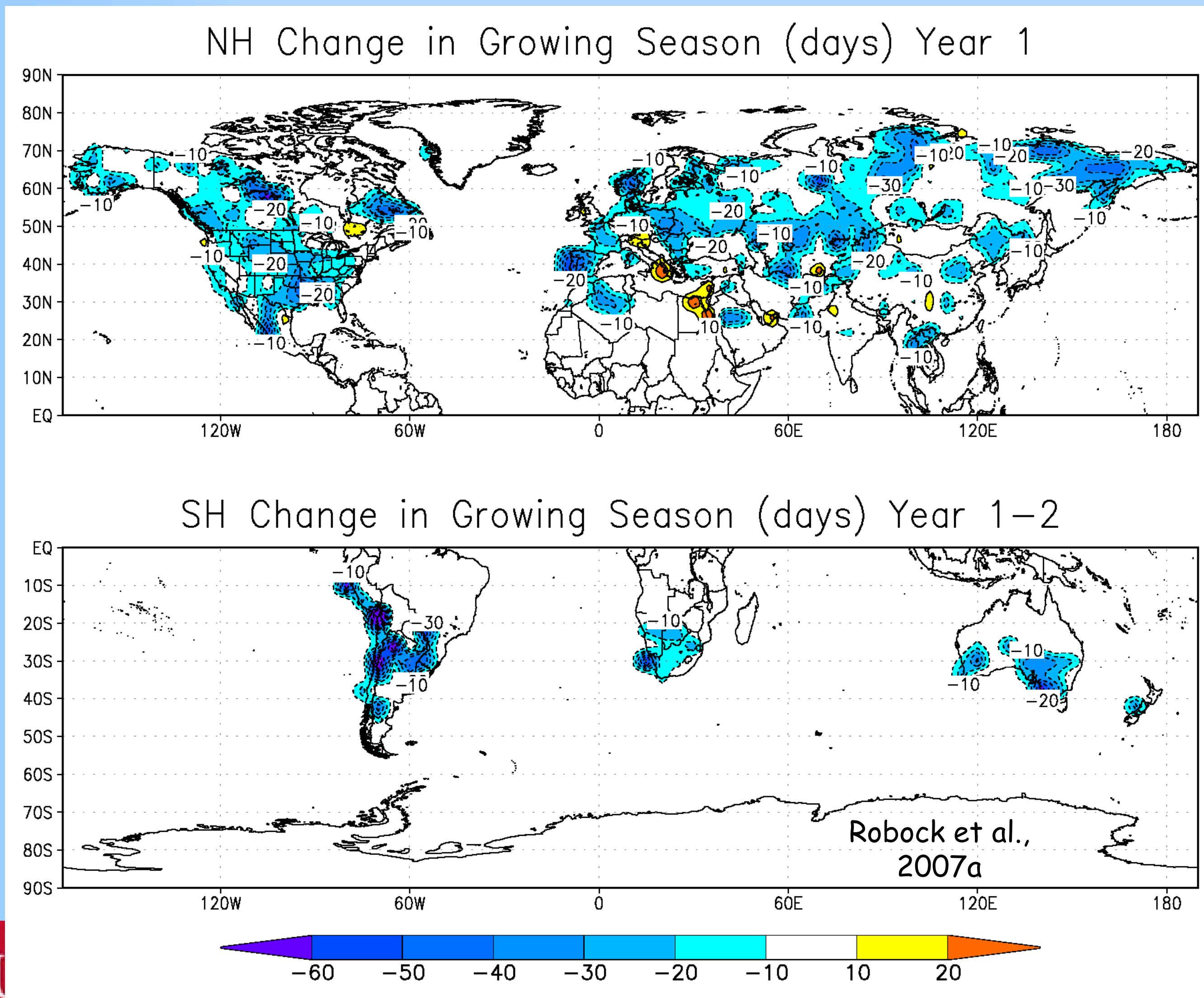
27 Tg soot injection



Toon, Owen B., Charles G. Bardeen, Alan Robock, Lili Xia, Hans Kristensen, Matthew McKinzie, R. J. Peterson, Cheryl Harrison, Nicole S. Lovenduski, and Richard P. Turco, 2019: Rapid expansion of nuclear arsenals by Pakistan and India portends regional and global catastrophe. *Science Advances*, **5**, eaay5478, doi:10.1126/sciadv.aay5478.

Alan Robock
Department of Environmental Sciences

Agricultural effects will include those on temperature, precipitation, reduction of sunlight, and enhancement of ultraviolet radiation.

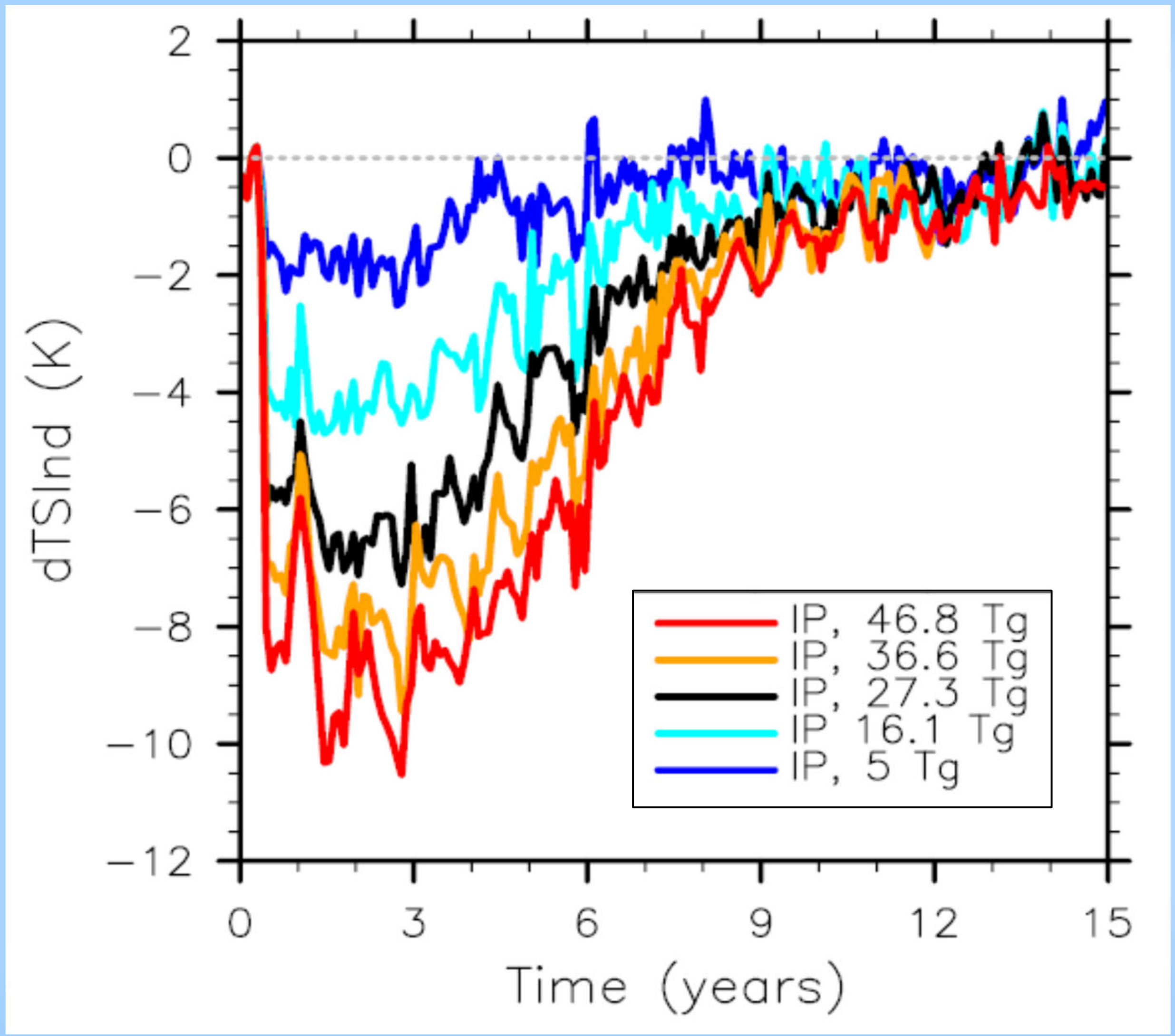


Change in growing season

5 Tg soot

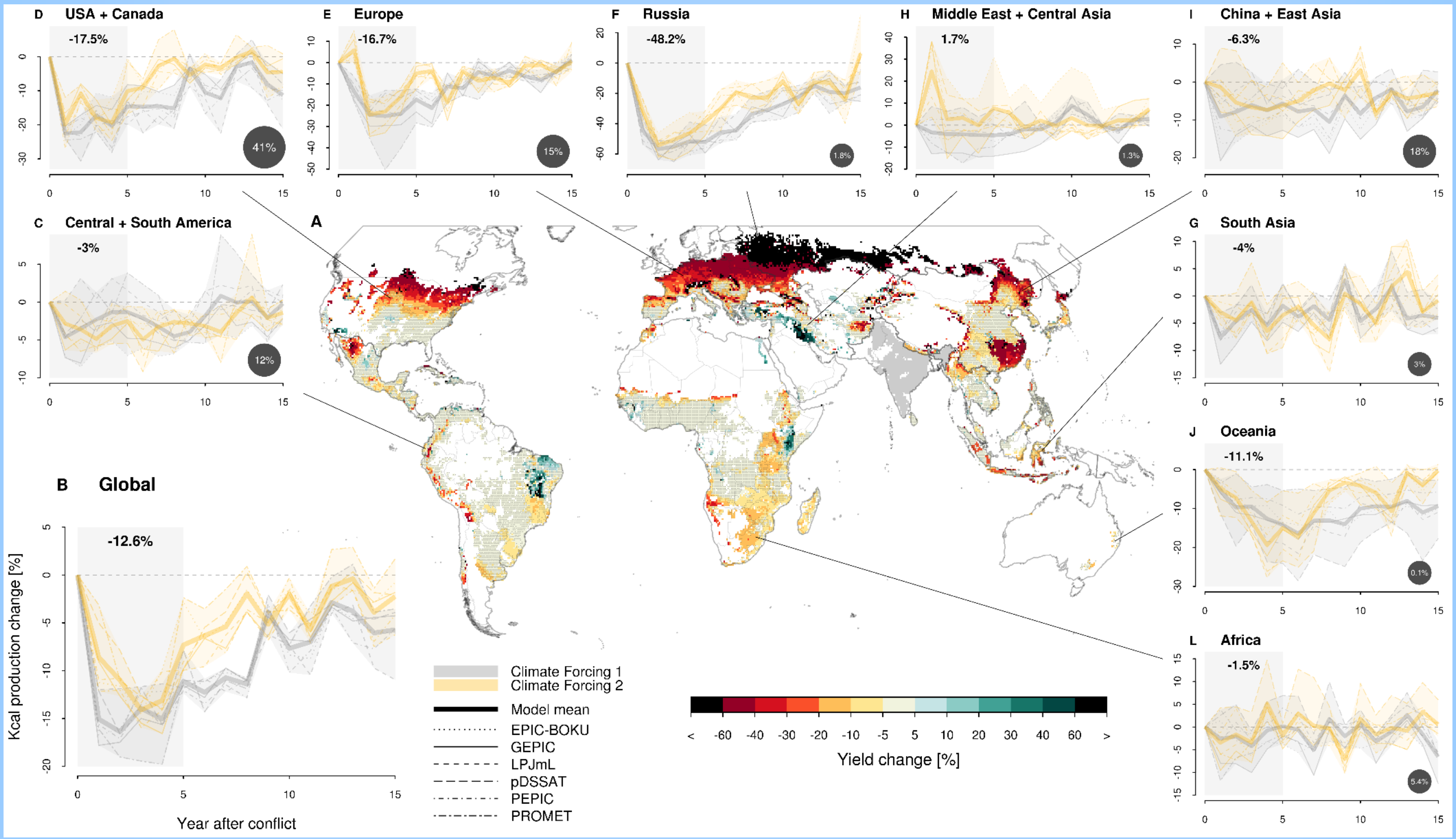
Alan Robock
Department of Environmental Sciences

Global average land surface temperature changes for different soot amounts



Toon, Owen B., Charles G. Bardeen, Alan Robock, Lili Xia, Hans Kristensen, Matthew McKinzie, R. J. Peterson, Cheryl Harrison, Nicole S. Lovenduski, and Richard P. Turco, 2019: Rapid expansion of nuclear arsenals by Pakistan and India portends regional and global catastrophe. *Science Advances*, **5**, eaay5478, doi:10.1126/sciadv.aay5478.

Multi-model maize response 5 Tg



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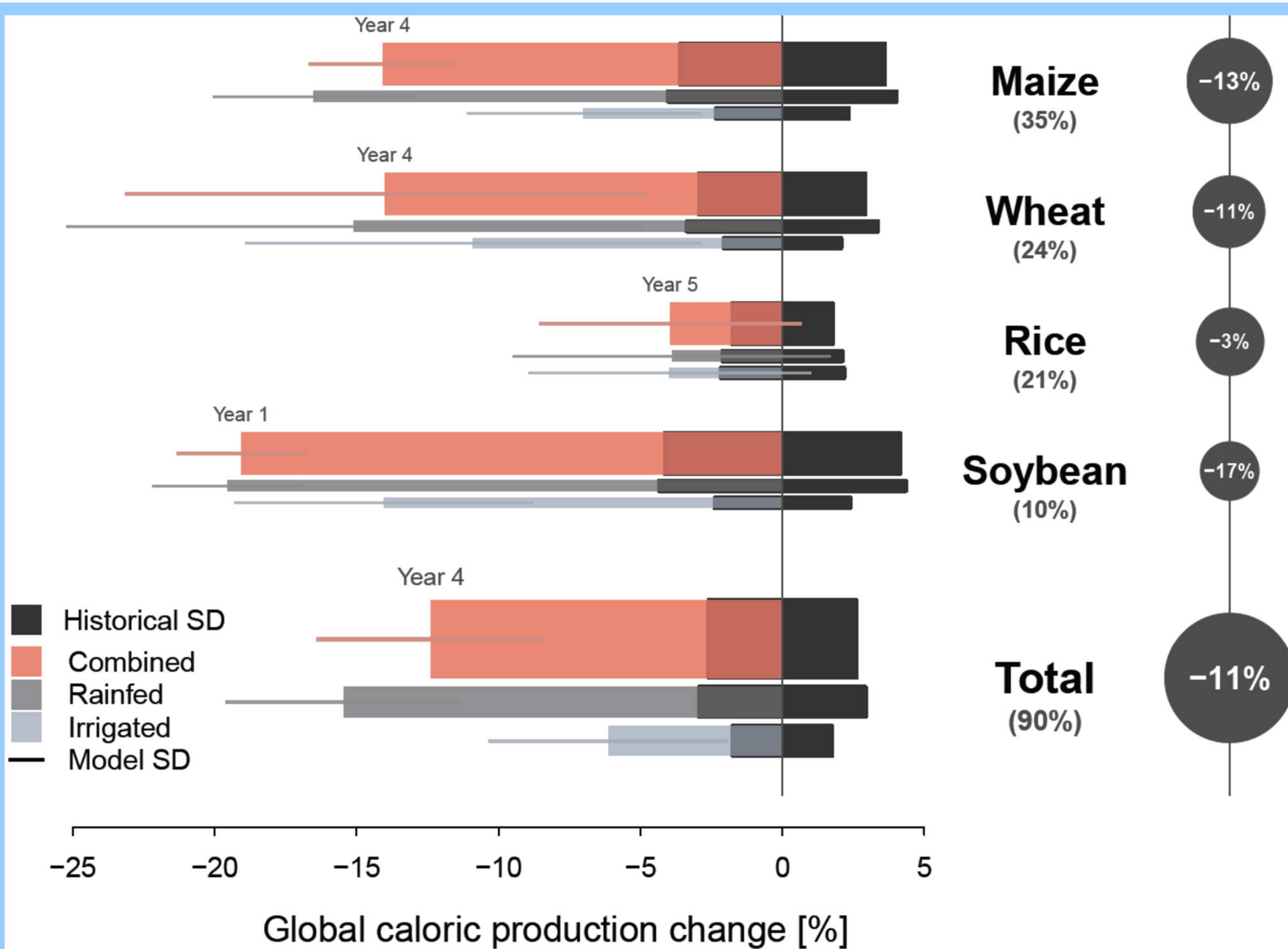
Jägermeyr, Jonas, Alan Robock, et al., 2020: A regional nuclear conflict would compromise global food security. *Proc. Nat. Acad. Sci.*, **117**(13), 7071-7081, doi:10.1073/pnas.1919049117.

Alan Robock
Department of Environmental Sciences



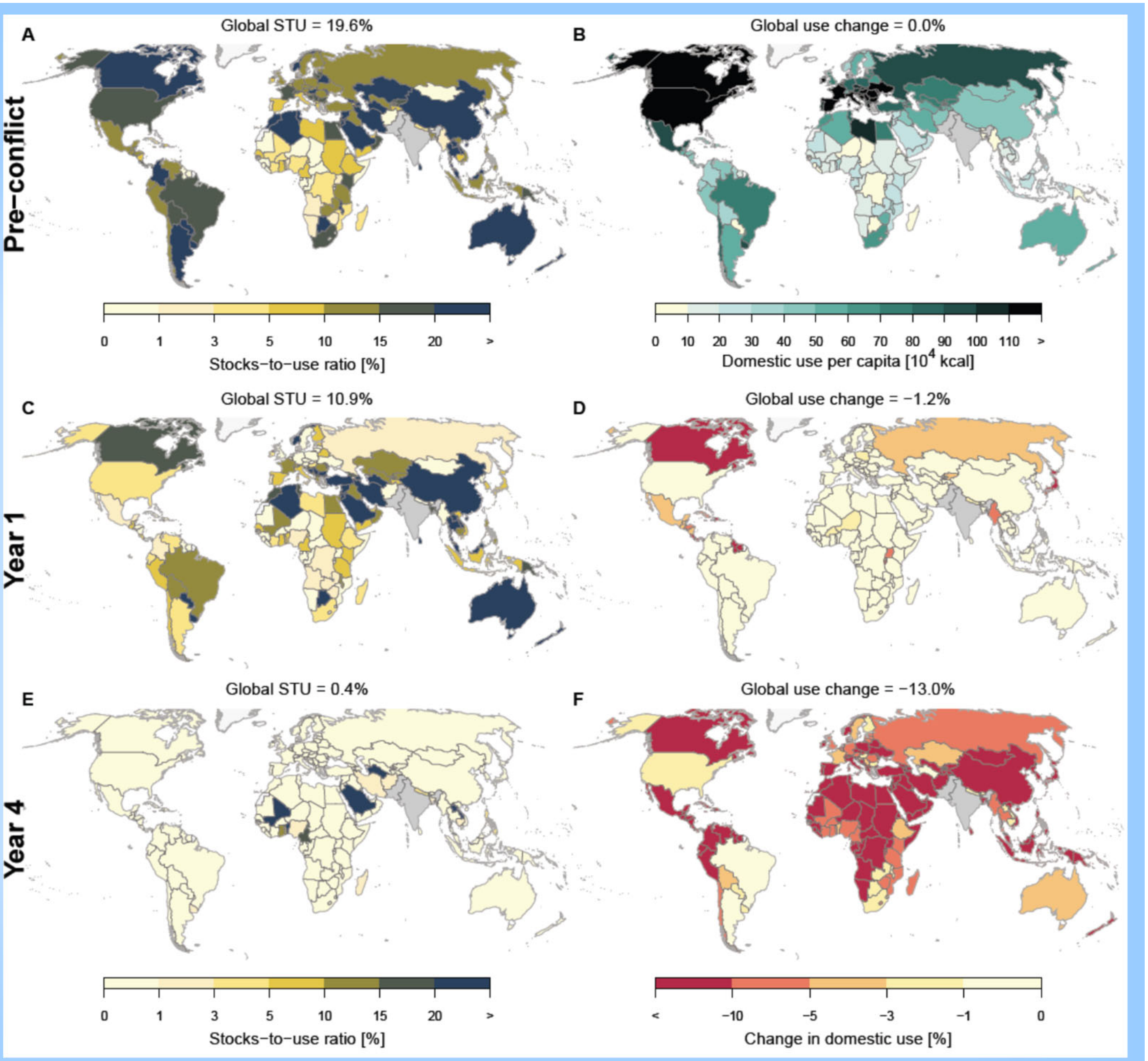
RUTGERS

Jägermeyr, Jonas, Alan Robock, et al., 2020: A regional nuclear conflict would compromise global food security. *Proc. Nat. Acad. Sci.*, **117**(13), 7071-7081, doi:10.1073/pnas.1919049117.

Alan Robock
Department of Environmental Sciences

Stocks to usage ratio (STU) indicates food reserves relative to domestic use

Trade buffers first year shocks but impacts increase in the following years



RUTGERS

Jägermeyr, Jonas, Alan Robock, et al., 2020: A regional nuclear conflict would compromise global food security. *Proc. Nat. Acad. Sci.*, **117**(13), 7071-7081, doi:10.1073/pnas.1919049117.

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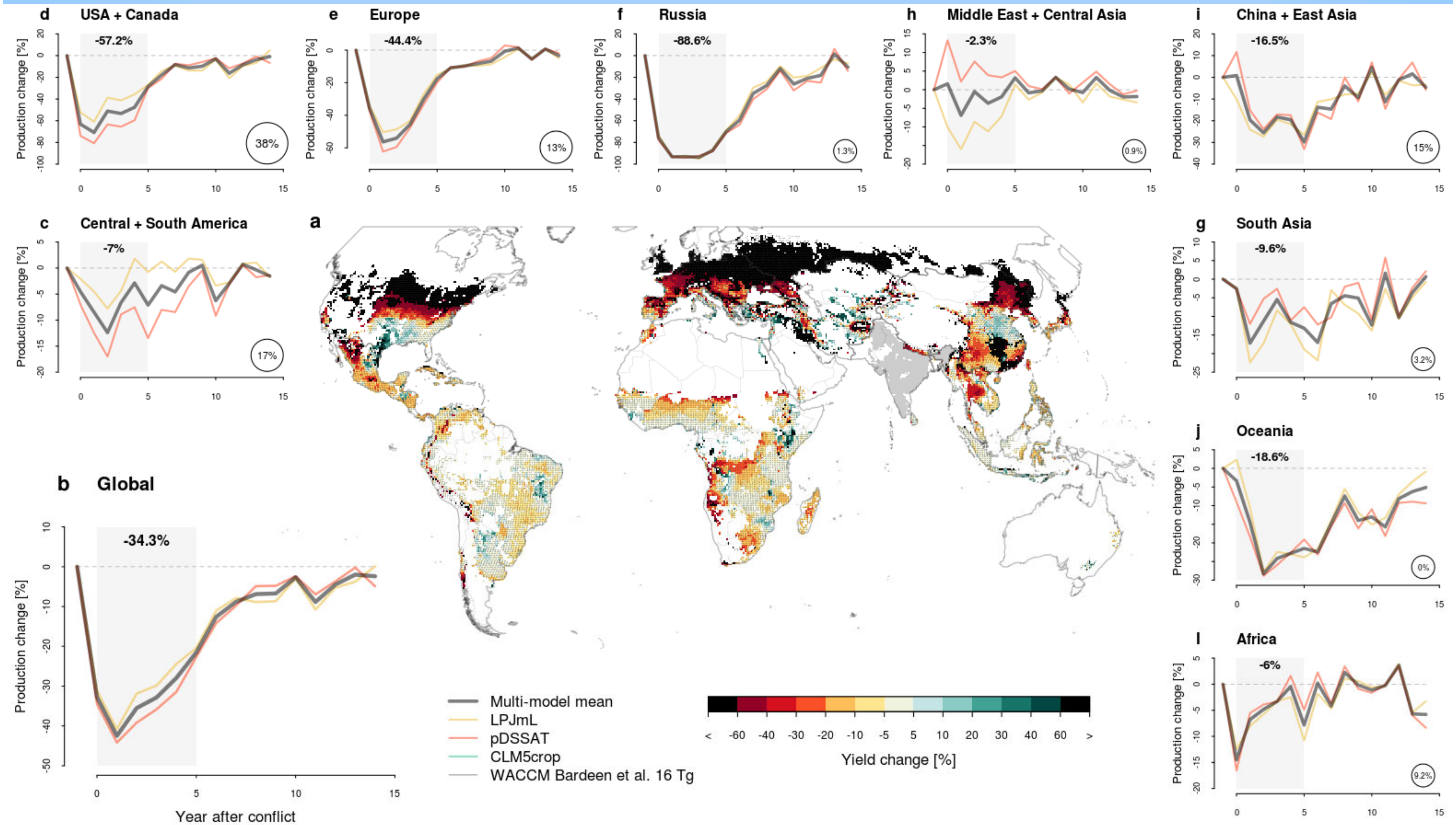
Department of Environmental Sciences

Multi-model maize response 16 Tg



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Jägermeyr et al. (in prep.)

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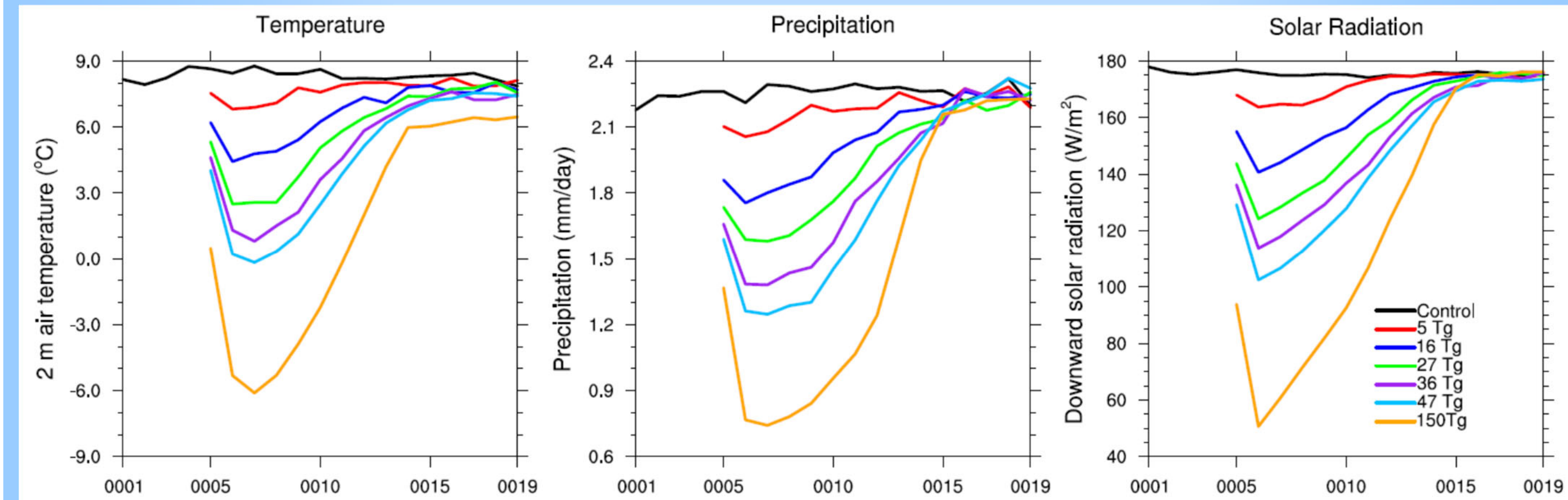
Department of Environmental Sciences

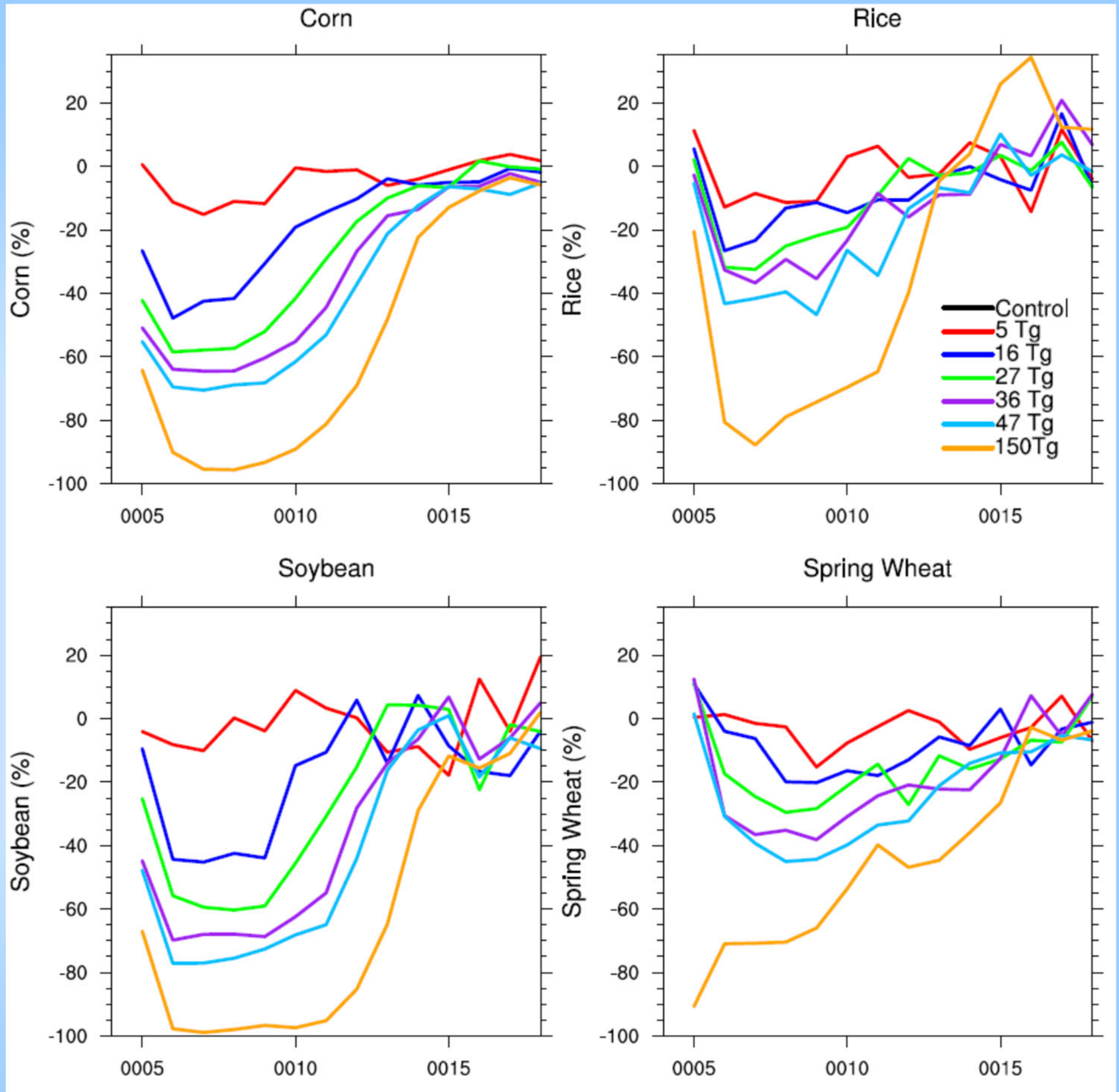
Global average **land** surface air temperature, precipitation, and downward solar radiation changes for different soot amounts



Bottom axis is arbitrary years, with the war starting in year 5.

CLM5-crop simulations in response to temperature, precipitation, and total solar radiation changes.

(work in progress with Lili Xia)



Impacts on Fisheries

BAU = business-as-usual fishing, assuming that there's no change in fishing behavior due to the war

px2 = substantial increase in fishing pressure, e.g., due to lack of food on land raising fish prices (double price of fish)

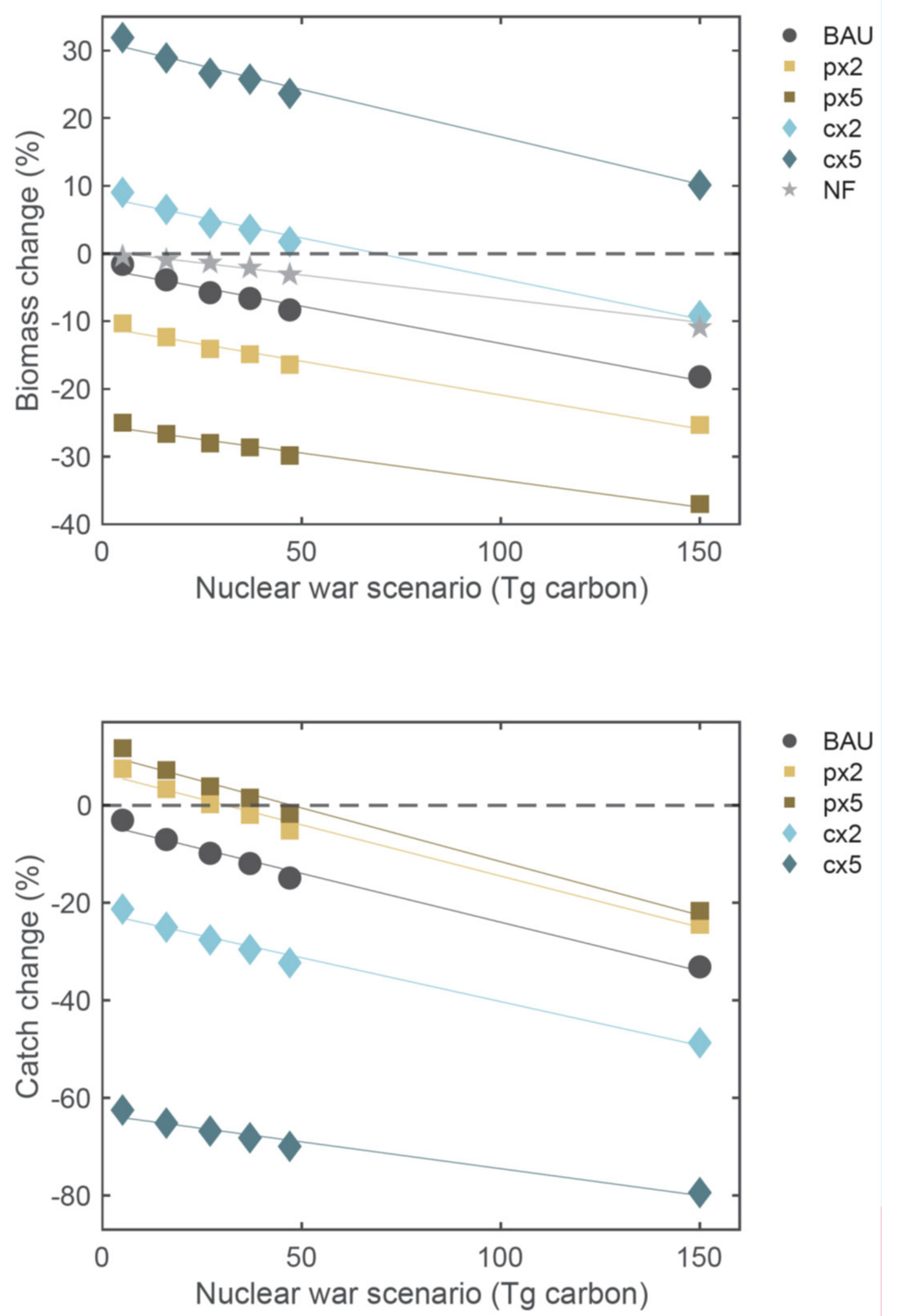
px5 = very large increase in fishing pressure (five-fold increase in price)

cx2 = substantial decrease in fishing pressure, e.g. due to smaller demand, higher fuel prices or damaged infrastructure (double cost of fishing)

cx5 = very large decrease in fishing pressure (five-fold increase in cost of fishing)

NF = no fishing, i.e. showing the effect of nuclear war on the "pristine", unfished ocean

Scherrer, Kim J. N., Cheryl S. Harrison, Ryan Heneghan, Eric Galbraith, Charles G. Bardeen, Jonas Jägermeyr, Nicole S. Lovenduski, August Luna, Alan Robock, Jessica Stevens, Samantha Stevenson, Owen B. Toon, and Lili Xia, 2020: Marine wild-capture fisheries after nuclear war. *Proc. Nat. Acad. Sci.*, **117**, doi:10.1073/pnas.2008256117.



Nuclear Winter Analogs

- **Seasonal cycle**
- **Diurnal cycle (day and night)**
- **Firestorm: 1906 San Francisco earthquake**
- **Fires: World War II firestorms**
  - Dresden, Hamburg, Darmstadt, Tokyo ("conventional" bombs)
  - Hiroshima, Nagasaki (nuclear bombs)
- **Smoke and dust transport, Surface temperature effects**
  - Martian dust storms
  - Asteroid impact → dinosaur extinction
  - Forest fires
  - Saharan dust
  - Volcanic eruptions

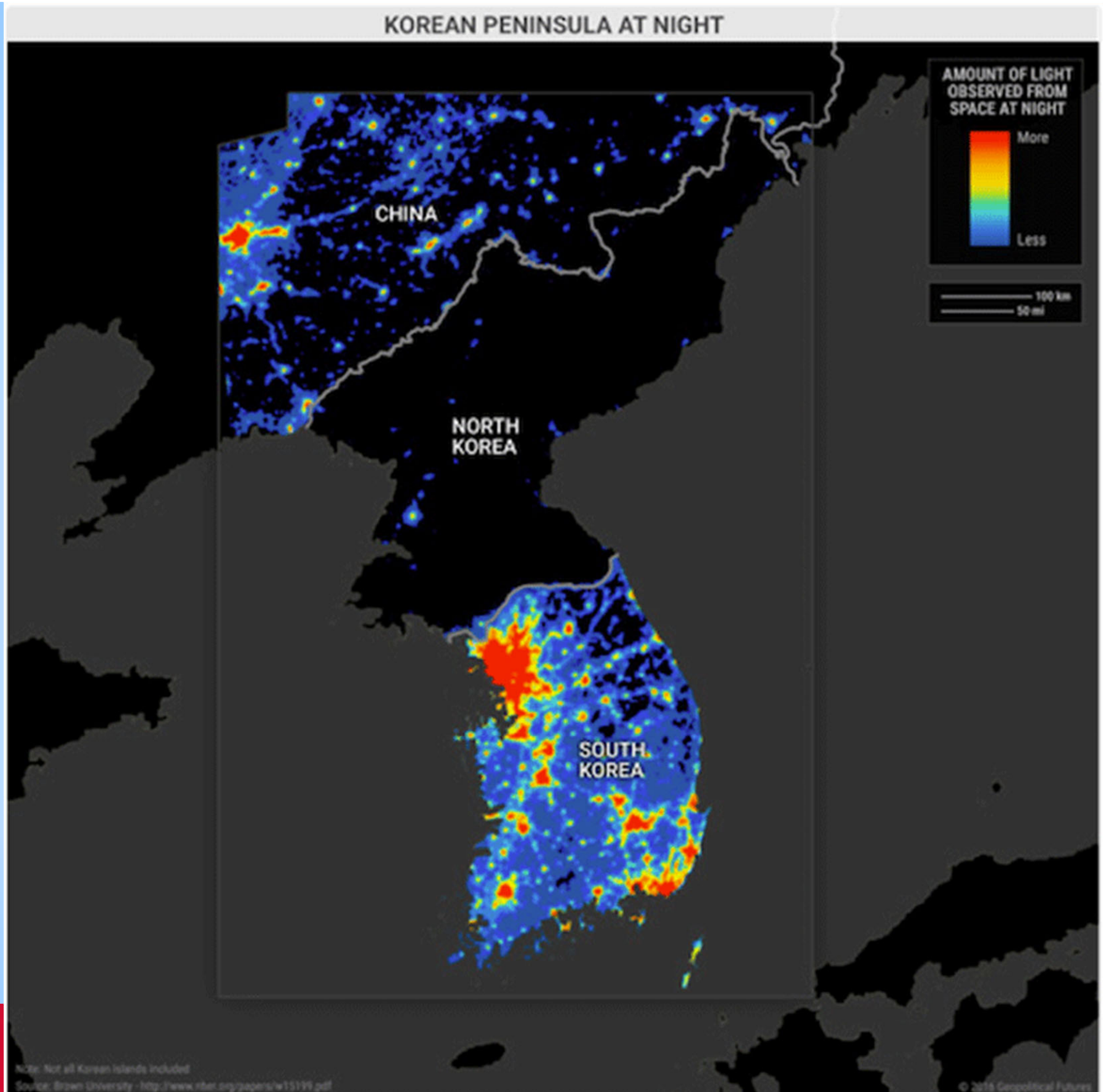
Alan Robock
Department of Environmental Sciences

How much smoke would be produced in a nuclear war between the U.S. and North Korea?

It depends!

It depends on the targets and the size of the weapons.

North Korea can't power its lights at night



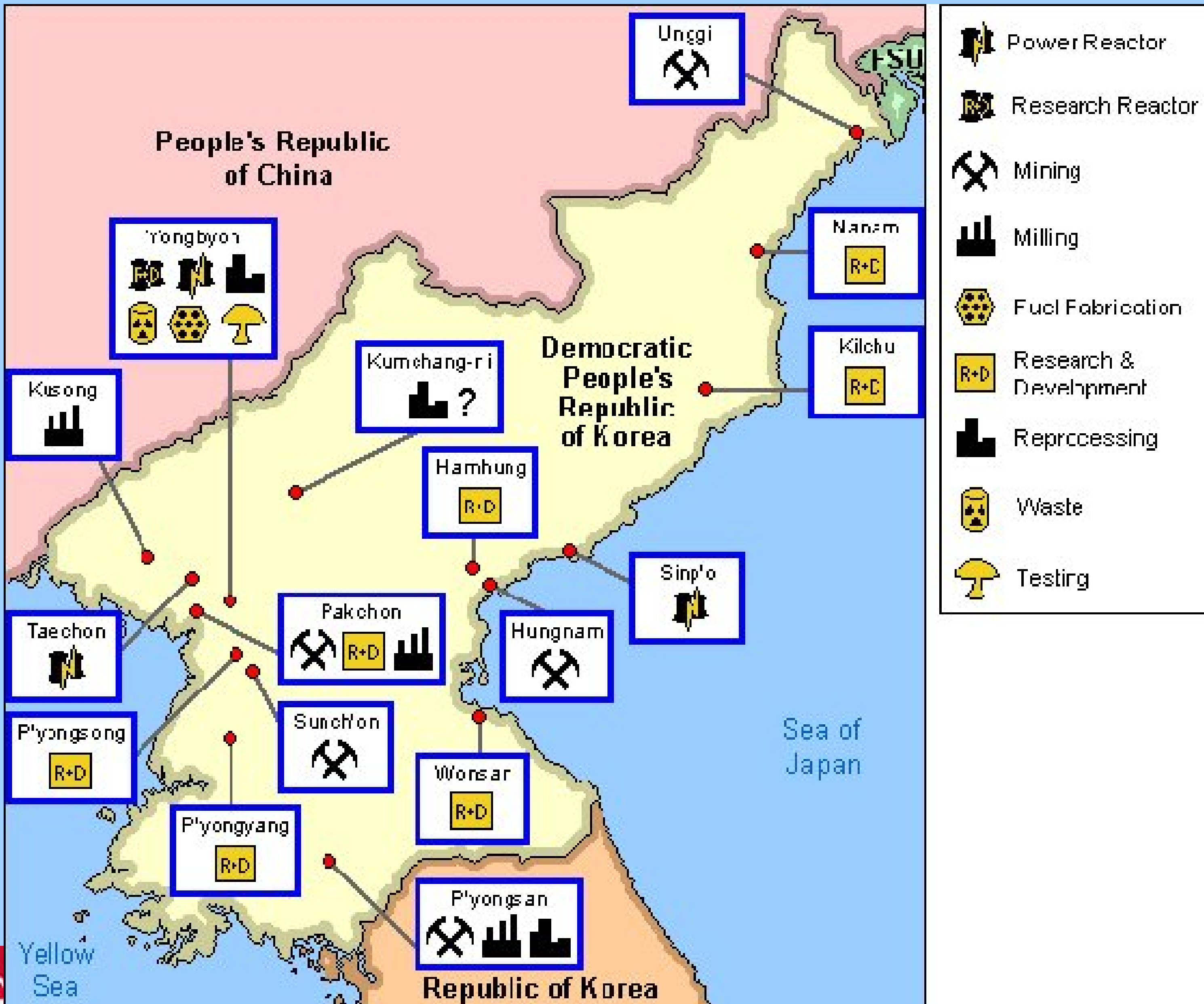
RUTGERS

Military facilities in North Korea.

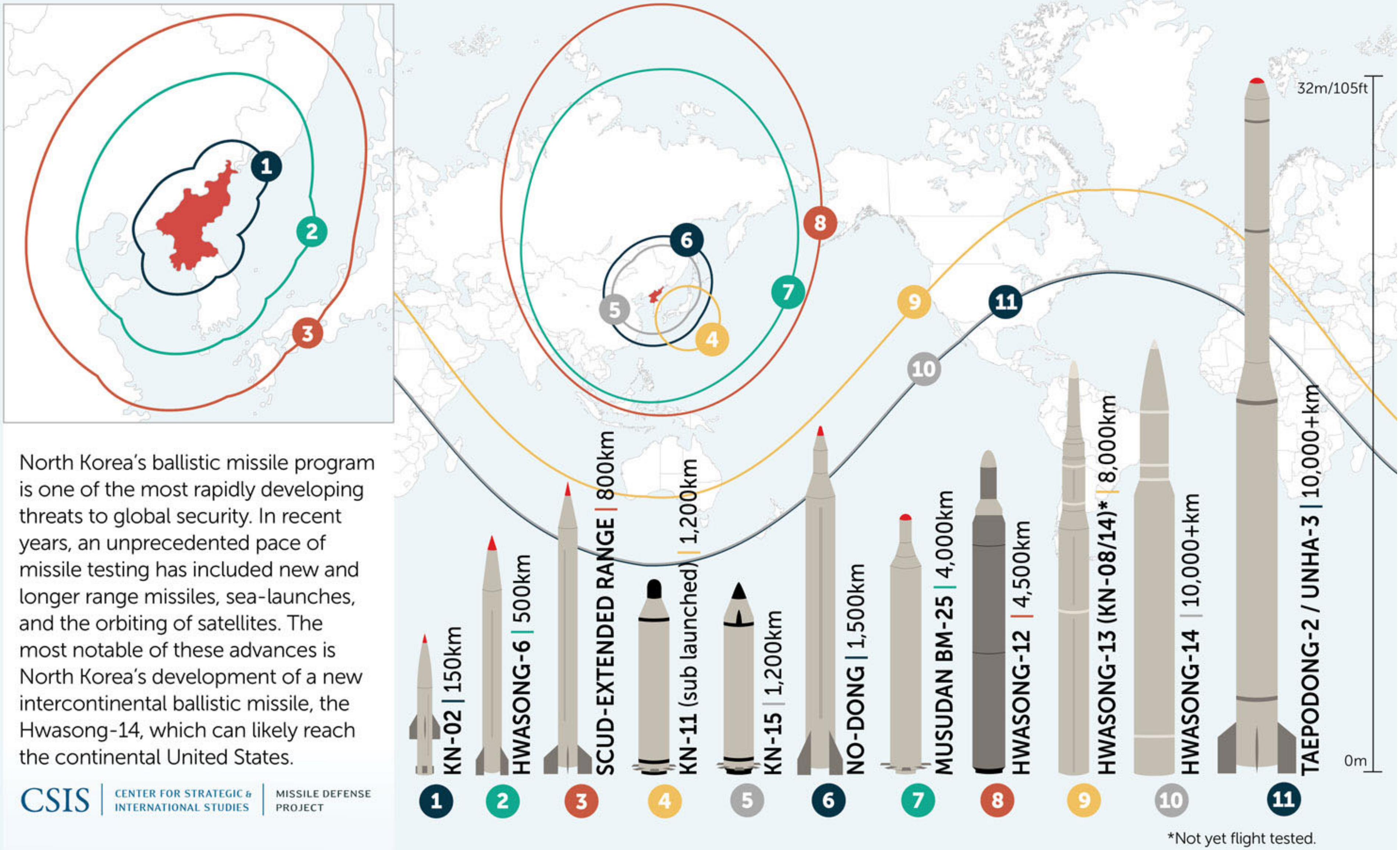
25 million people
15 cities with 100,000 people
Army~1 million (4th largest)
Reserve~ 5.5 million
Submarines ~70 similar to US
Tanks~4000
Artillery ~6500
Rocket launchers ~2500
Aircraft ~1000
Chemical Weapons

RUTGERS

North Korean Nuclear Facilities



NORTH KOREA'S BALLISTIC MISSILES



North Korea's ballistic missile program is one of the most rapidly developing threats to global security. In recent years, an unprecedented pace of missile testing has included new and longer range missiles, sea-launches, and the orbiting of satellites. The most notable of these advances is North Korea's development of a new intercontinental ballistic missile, the Hwasong-14, which can likely reach the continental United States.

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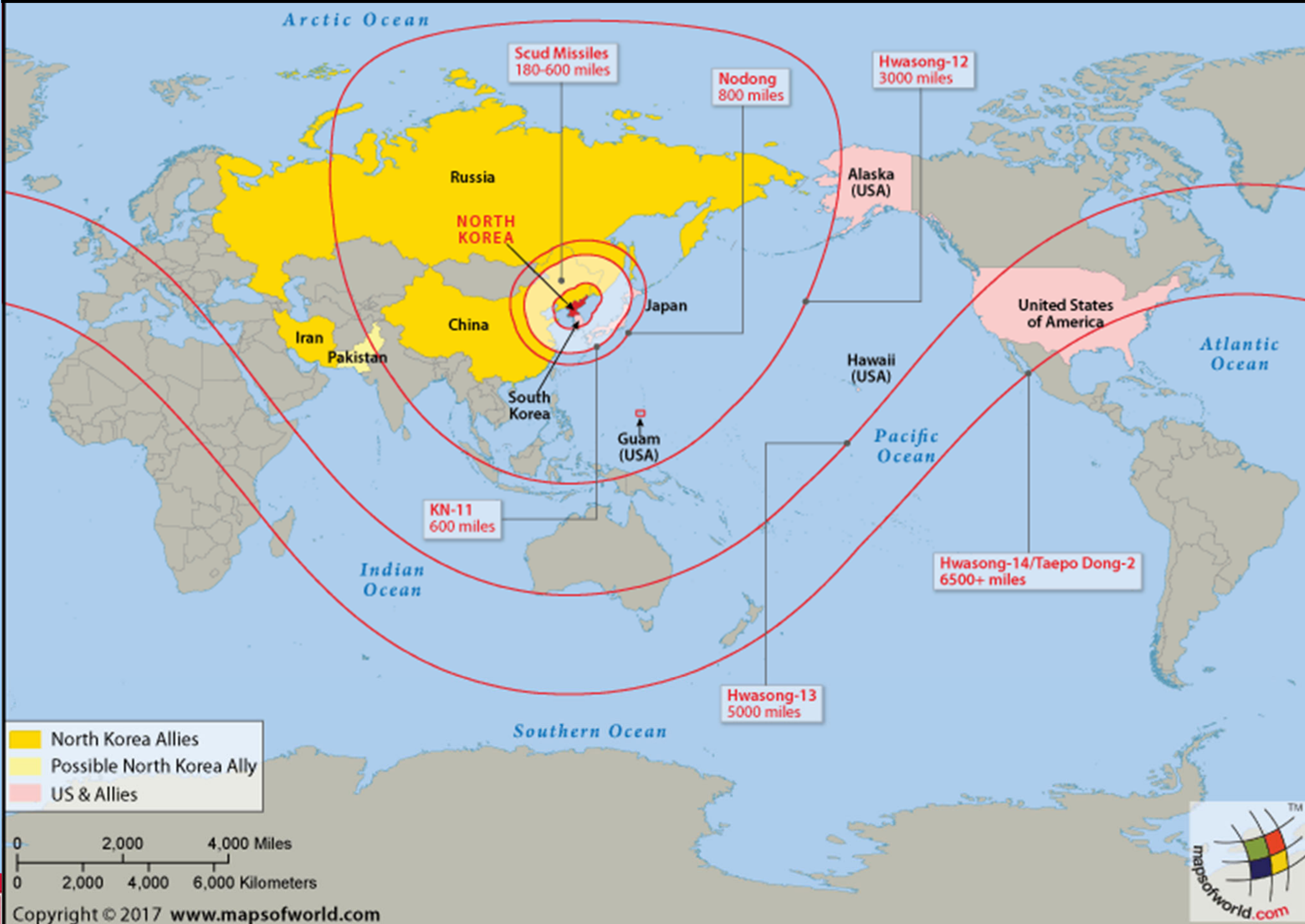
North Korean missile range



One possible scenario:

North Korea sinking a South Korean ship or shelling of an island triggers a reciprocal response. For example, North Korea tests a long range missile and the US and South Korea shoot the missile down. North Korea responds by launching another missile at the THAAD missile base in South Korea. The US launches Tomahawk cruise missiles at North Korean nuclear missile bases and general conventional war breaks out. North Korea barrages Seoul with conventional artillery, and the US and South Korean forces invade North Korea and threaten the defeat of the regime within weeks.

Alan Robock
Department of Environmental Sciences

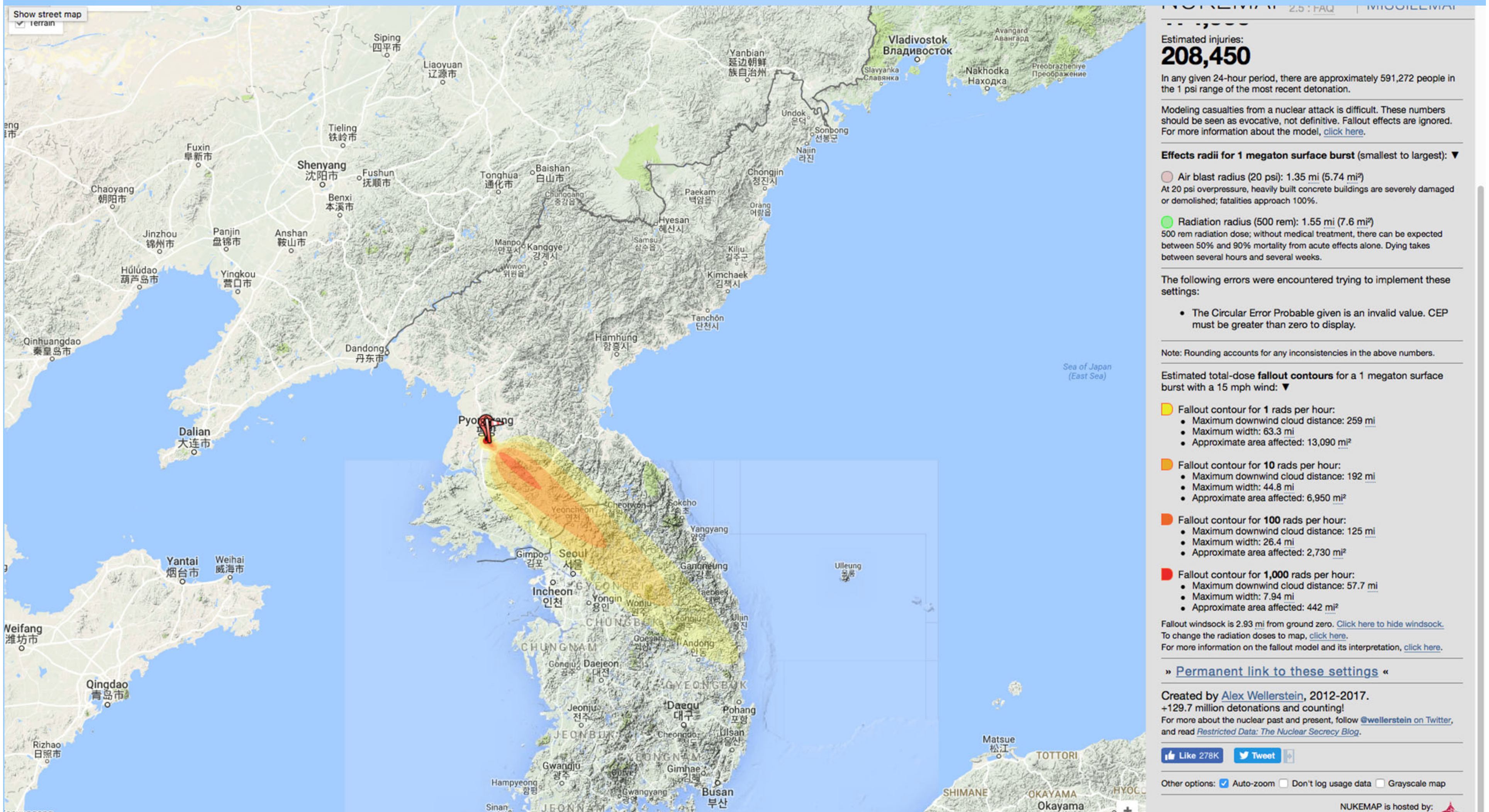
One possible scenario:

The North Koreans reply with their complete nuclear arsenal, 20 weapons with yields of 10-15-kt against US bases in South Korea and Japan, and against South Korean bases, some of which are in cities. The US replies with 80 weapons of 100- or 475-kt against North Korea. Of these 80 weapons, 50 are used against counterforce targets (North Korean military), 20 are used against war-supporting industries, and 10 are used against command and control.

One possible scenario:

North Korean missile shot down by US and South Korea	20 x 10-15 kt 80 x 100-475 kt	20 x 10-15 kt against US and South Korean bases 50 x 100-475 kt against NK counterforce 20 x 100-475 kt against NK war-supporting industries 10 x 100-475 kt against NK command and control

Radiation dose from 1 Mt ground burst



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But what if…

- North Korea has developed hydrogen bombs?
- North Korea can bomb Tokyo and other Japanese cities?
- North Korea can bomb U.S. cities?
- China or Russia get involved, due to an errant missile or fear that a missile going over is a ruse to attack them?

THE STORY OF AN EYEWITNESS

By Jack London

Collier's, the National Weekly

May 5, 1906

Within an hour after the earthquake shock the smoke of San Francisco's burning was a lurid tower visible a hundred miles away. And for three days and nights this lurid tower swayed in the sky, reddening the sun, darkening the day, and filling the land with smoke.

... I watched the vast conflagration from out on the bay. It was dead calm. Not a flicker of wind stirred. Yet from every side wind was pouring in upon the doomed city. East, west, north, and south, strong winds were blowing upon the doomed city. The heated air rising made an enormous suck. Thus did the fire of itself build its own colossal chimney through the atmosphere. Day and night this dead calm continued, and yet, near the flames, the wind was often half a gale, so mighty was the suck.

This photograph, taken from a series of kites five weeks after the great earthquake of April 18, 1906, shows the devastation brought on the city of San Francisco by the quake and subsequent fire. (photo courtesy of Harry Myers)

Church of Our Lady, Dresden, Germany

Destroyed by fire storm created by Allied bombing during WW II

Kurt Vonnegut was a prisoner of war in Dresden when it was firebombed and described the experience in *Slaughterhouse-Five* (1969).

RUTGERS

Slaughterhouse-Five

OR

THE CHILDREN'S CRUSADE

A DUTY-DANCE WITH DEATH

BY

Kurt Vonnegut

A FOURTH-GENERATION GERMAN-AMERICAN
NOW LIVING IN EASY CIRCUMSTANCES
ON CAPE COD
[AND SMOKING TOO MUCH],
WHO, AS AN AMERICAN INFANTRY SCOUT
HORS DE COMBAT,
AS A PRISONER OF WAR,
WITNESSED THE FIRE-BOMBING
OF DRESDEN, GERMANY,
"THE FLORENCE OF THE ELBE,"
A LONG TIME AGO,
AND SURVIVED TO TELL THE TALE.
THIS IS A NOVEL
SOMEWHAT IN THE TELEGRAPHIC SCHIZOPHRENIC
MANNER OF TALES
OF THE PLANET TRALFAMADORE,
WHERE THE FLYING SAUCERS
COME FROM.
PEACE.

He was down in the meat locker on the night Dresden was destroyed. There were sounds like giant footsteps above. Those were sticks of high-explosive bombs. The giants walked and walked. ...

So it goes.

A guard would go to the head of the stairs every so often to see what it was like outside, then he would come down and whisper to the other guards. There was a fire-storm out there. Dresden was one big flame. The one flame ate everything organic, everything that would burn.

It wasn't safe to come out of the shelter until noon the next day. When the Americans and their guards did come out, the sky was black with smoke. The sun was an angry little pinhead. Dresden was like the moon now, nothing but minerals. The stones were hot. Everybody else in the neighborhood was dead.

So it goes.

Slaughterhouse-Five (1969) by Kurt Vonnegut

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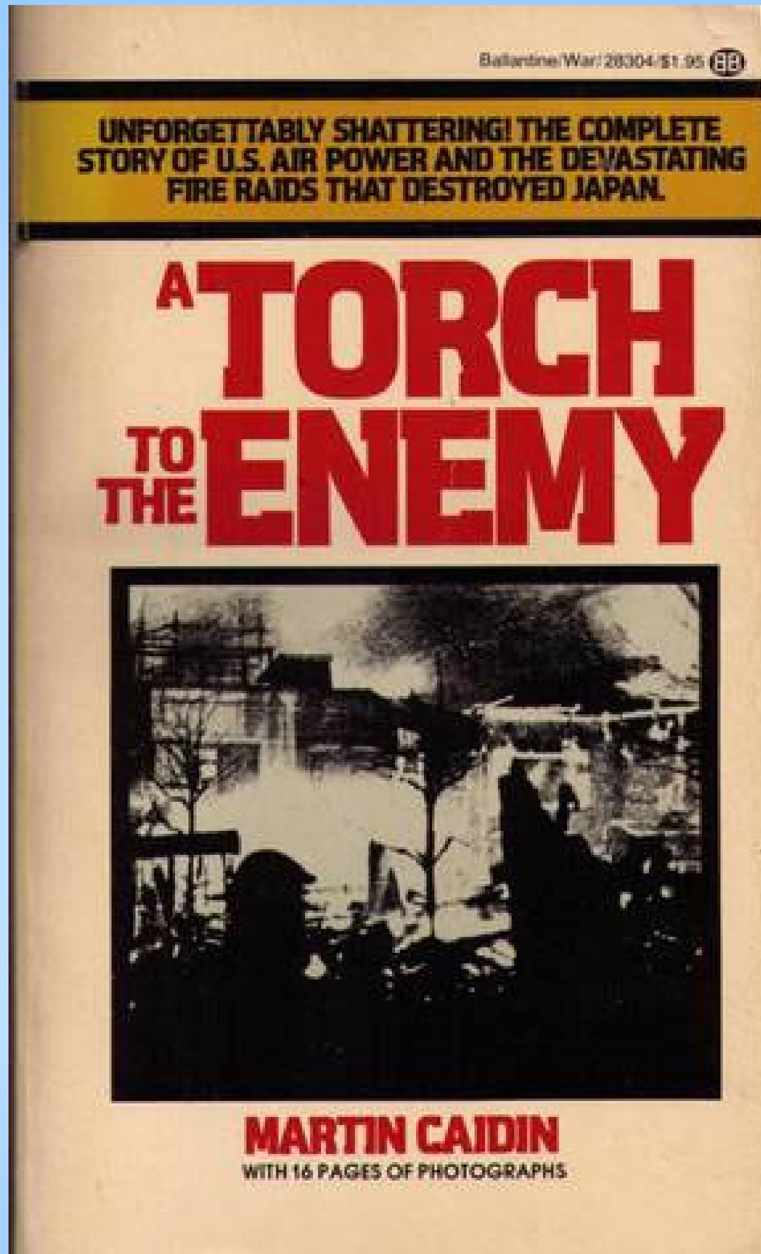
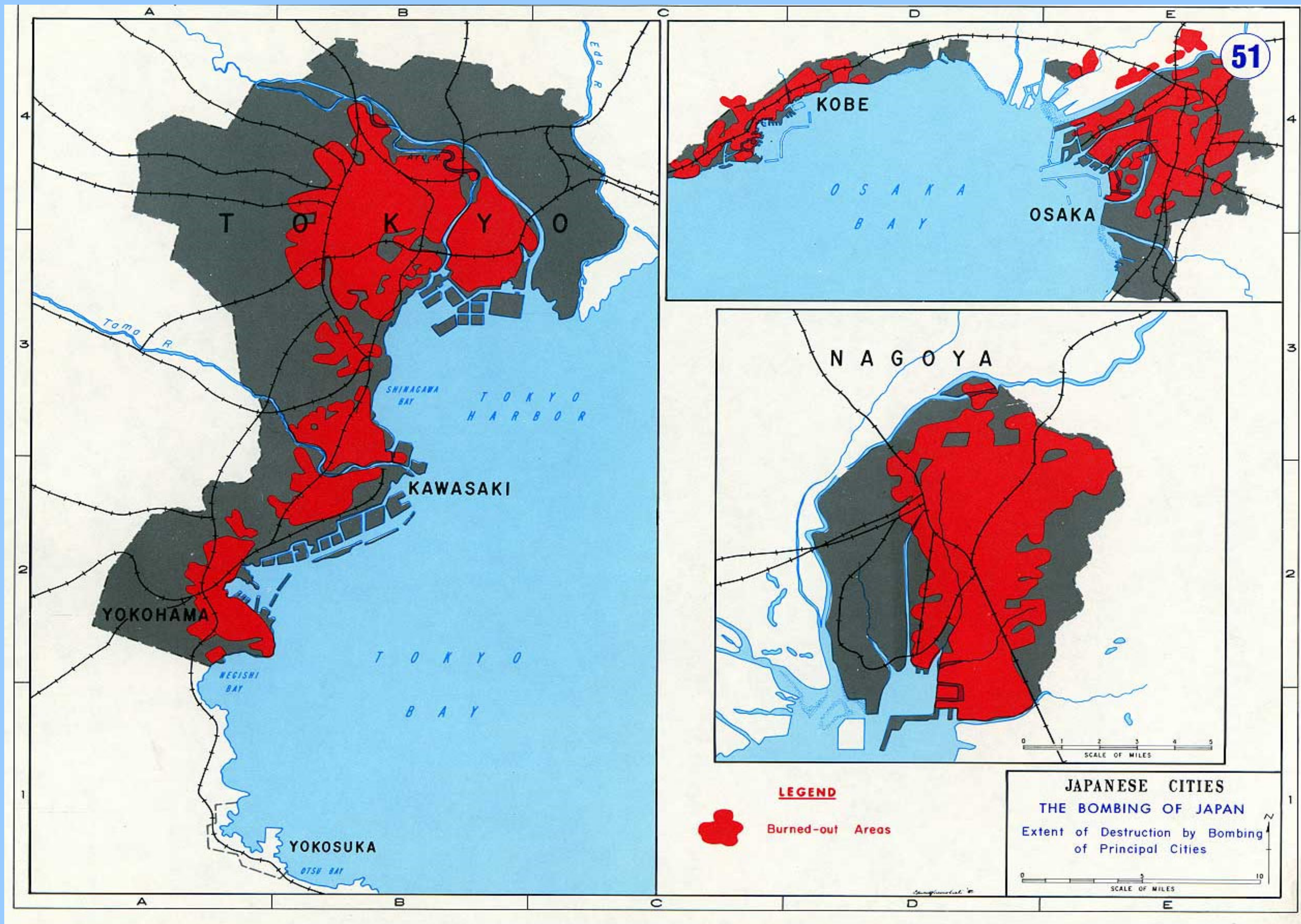
Department of Environmental Sciences

B-29 Superfortress bombers dropping incendiary bombs on Yokohama in May 1945


Ballantine/War/28304/$1.95
UNFORGETTABLY SHATTERING! THE COMPLETE STORY OF U.S. AIR POWER AND THE DEVASTATING FIRE RAIDS THAT DESTROYED JAPAN.
A TORCH TO THE ENEMY
MARTIN CAIDIN
WITH 16 PAGES OF PHOTOGRAPHS



Map from United States Military Academy History Department - http://www.dean.usma.edu/history/Atlases/WorldWarTwo Asia/ww2%20pacific%20%20maps/ww2%20asia%20map%2051.jpg

In Tokyo, Osaka and Nagoya, "the areas leveled (almost 100 square miles (260 km^2)) exceeded the areas destroyed in all German cities by both the American and English air forces (approximately 79 square miles (200 km^2))."

“By the time the atomic bombs had struck-adding *less* than three per cent to the devastated areas-the Superfortresses had gutted a total of 178 square miles [461 km^2] in 69 cities. Affected directly was a Japanese population of more than 21,000,000 people. Cities were being destroyed at the rate of four at a time, with strikes every two or three days.”

Part of Shizuoka after it was firebombed on 19 June 1945

http://www.japanairraids.org/wp-content/uploads/2010/10/A3823.jpg

“In six months of fire bombings, starting with the Tokyo raid on the night of March 10th, civilian casualties were more than twice as great as total Japanese military casualties in forty-five months of war.”

Caidan, Martin, 1960: *A Torch to the Enemy.* (Ballantine, New York), 160 pp.

Alan Robock
Department of Environmental Sciences

"Greatest source of alarm to our flyers were the terrific thermals, or hot-air currents, that rose from the blazing targets and sent our aircraft into a black hell of smoke" [*Caidin*, 1960, p. 154].

"We headed into a great mushroom of boiling, oily smoke, and in a few seconds were tossed 5,000 feet [1,500 m] into the air" [*Caidin*, 1960, pp. 154-155].

Alan Robock
Department of Environmental Sciences

Smoke Emissions

$$M = A\ F\ E\ R\ L$$

M = the total mass of soot injected into the lower stratosphere (kg)

A = the total area burned (m^2)

F = the total fuel per unit area (kg/m^2)

E = the percent of fuel that is emitted as soot into the upper troposphere (%)

R = the fraction that is not rained out (%)

L = the fraction lofted from the upper troposphere into the lower stratosphere, either injected directly or by subsequent solar heating (%)

Smoke Emissions

$$M = A\ F\ E\ R\ L$$

M = the total mass of soot injected into the lower stratosphere (kg)

A = the total area burned (m^2) = 461 km^2

F = the total fuel per unit area (kg/m^2) = 1.6 kg/m^2

E = the percent of fuel that is emitted as soot into the upper troposphere (%) = 1.6%

R = the fraction that is not rained out (%) = 80%

L = the fraction lofted from the upper troposphere into the lower stratosphere, either injected directly or by subsequent solar heating (%) = 50%

Caidan, M. (1960), *A Torch to the Enemy* (Ballantine, New York), 160 pp.

Toon, O. B., R. P. Turco, A. Robock, C. Bardeen, L. Oman, and G. L. Stenchikov (2007), Atmospheric effects and societal consequences of regional scale nuclear conflicts and acts of individual nuclear terrorism, *Atm. Chem. Phys.*, *7*, 1973-2002.

Smoke Emissions

$$M = A\ F\ E\ R\ L \ \boxed{\approx 0.5\ \mathrm{Tg}}$$

M = the total mass of soot injected into the lower stratosphere (kg)

A = the total area burned (m^2) = 461 km^2

F = the total fuel per unit area (kg/m^2) = 1.6 kg/m^2

E = the percent of fuel that is emitted as soot into the upper troposphere (%) = 1.6%

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The Mt. Montezuma, Chile (22°40'S, 68°56'W) solar irradiance observatory. (Smithsonian Institution Archive. Image # 2003-19480.)

The Table Mountain, California (34°22'N, 117°41'W) solar irradiance observatory. (Smithsonian Institution Archive. Image # MAH-21248B.)

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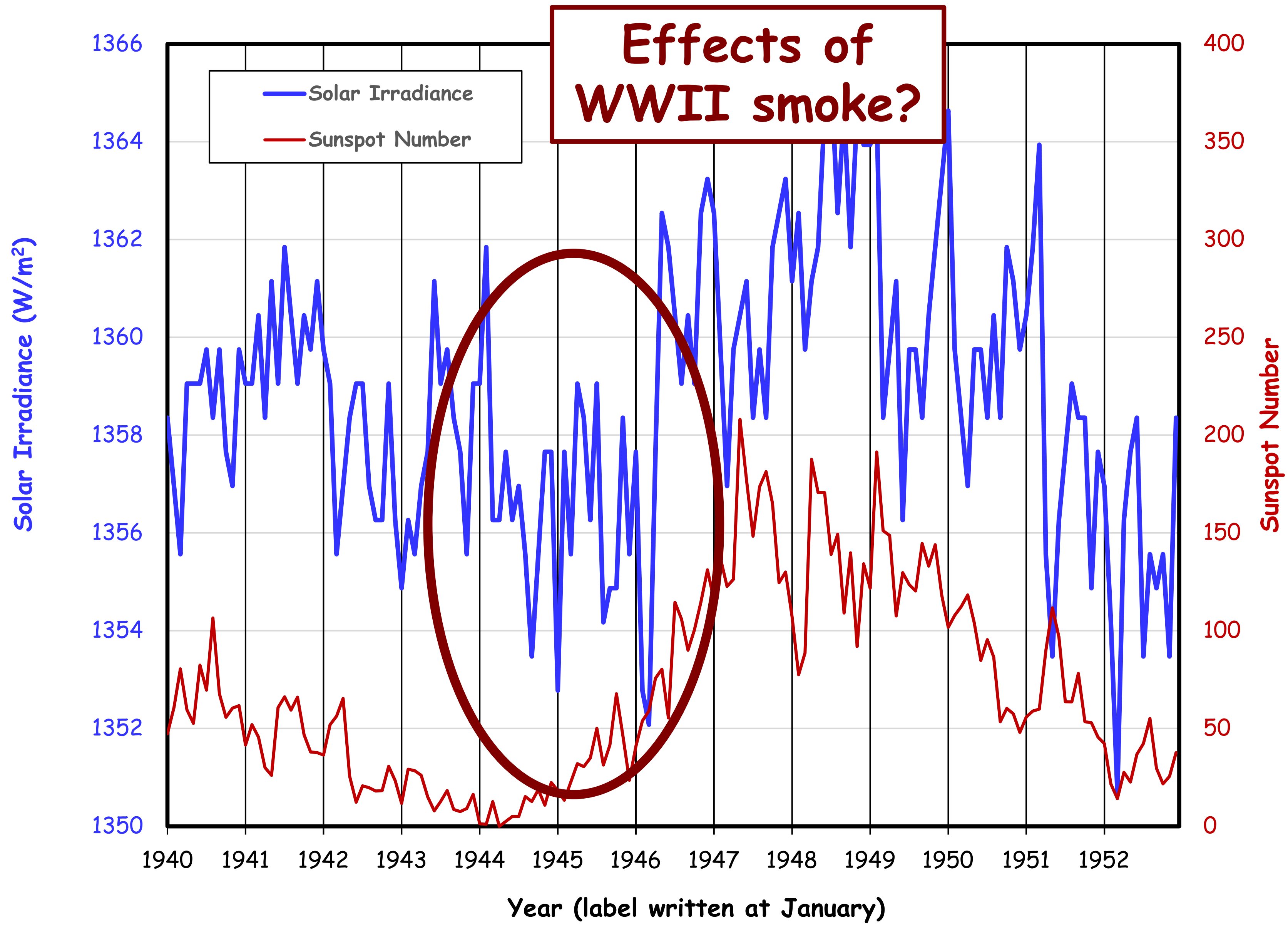
Department of Environmental Sciences

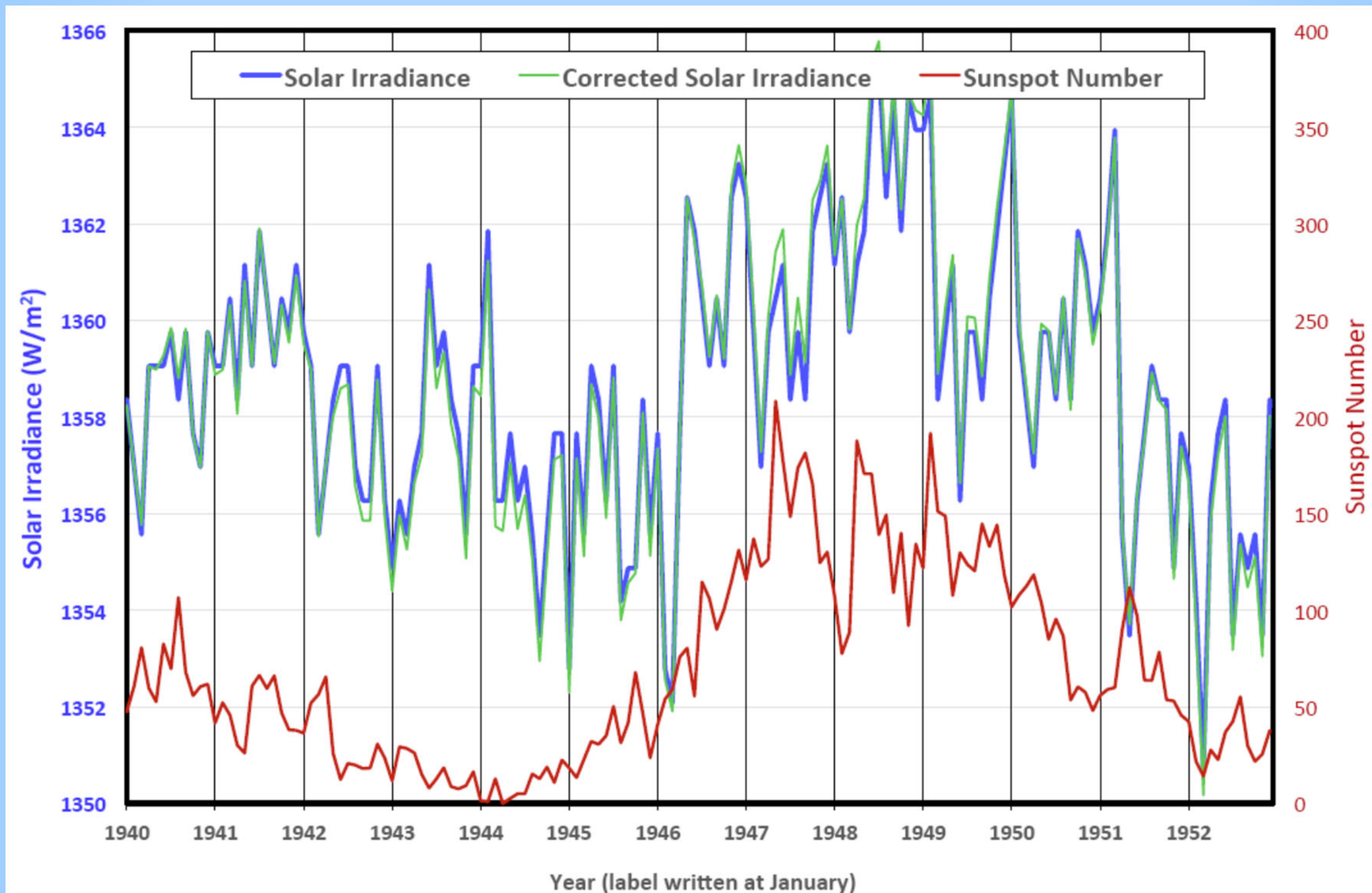


RUTGERS

Aldrich, L. B., and W. H. Hoover (1954), *Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. 7*, (Smithsonian Institution, Washington, D.C.), 184 pp.

Alan Robock
Department of Environmental Sciences

Was it sunspots? No. *Kopp and Lean* [2011], using modern satellite observations of total solar irradiance, found that solar irradiance varies by about 1.6 W m^{-2} between solar maximum and solar minimum.

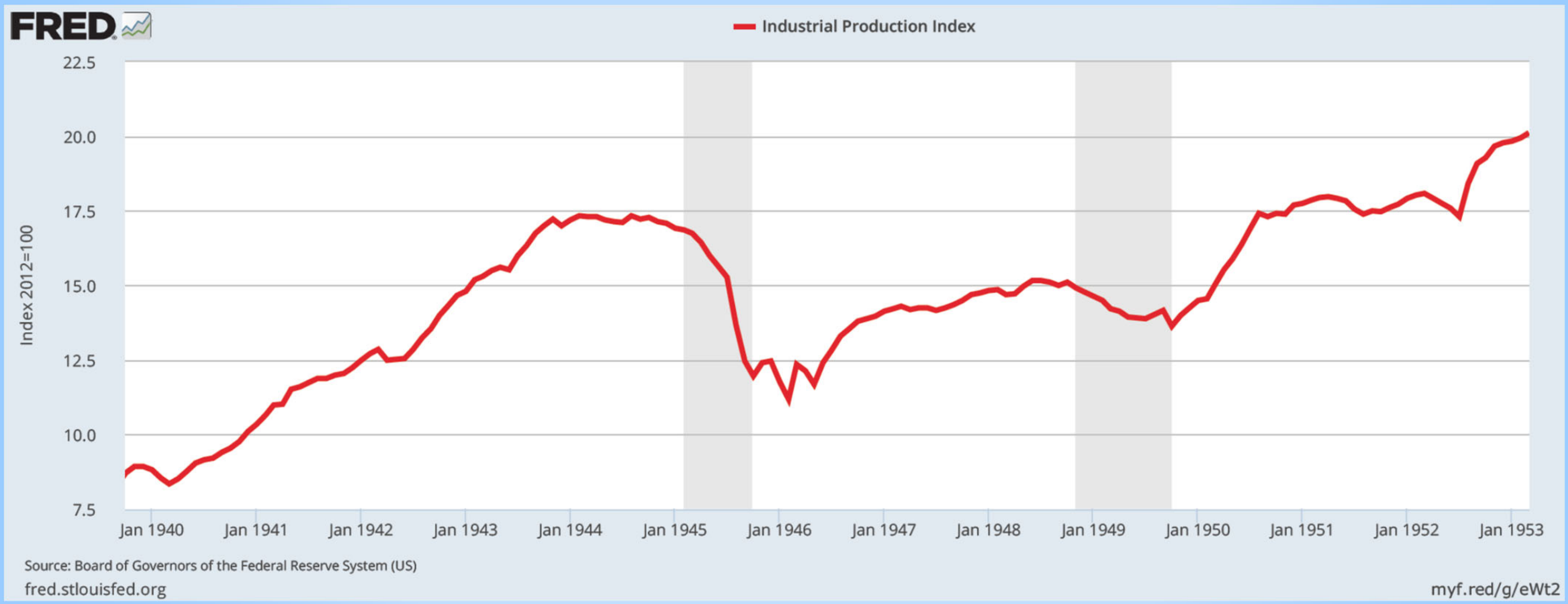


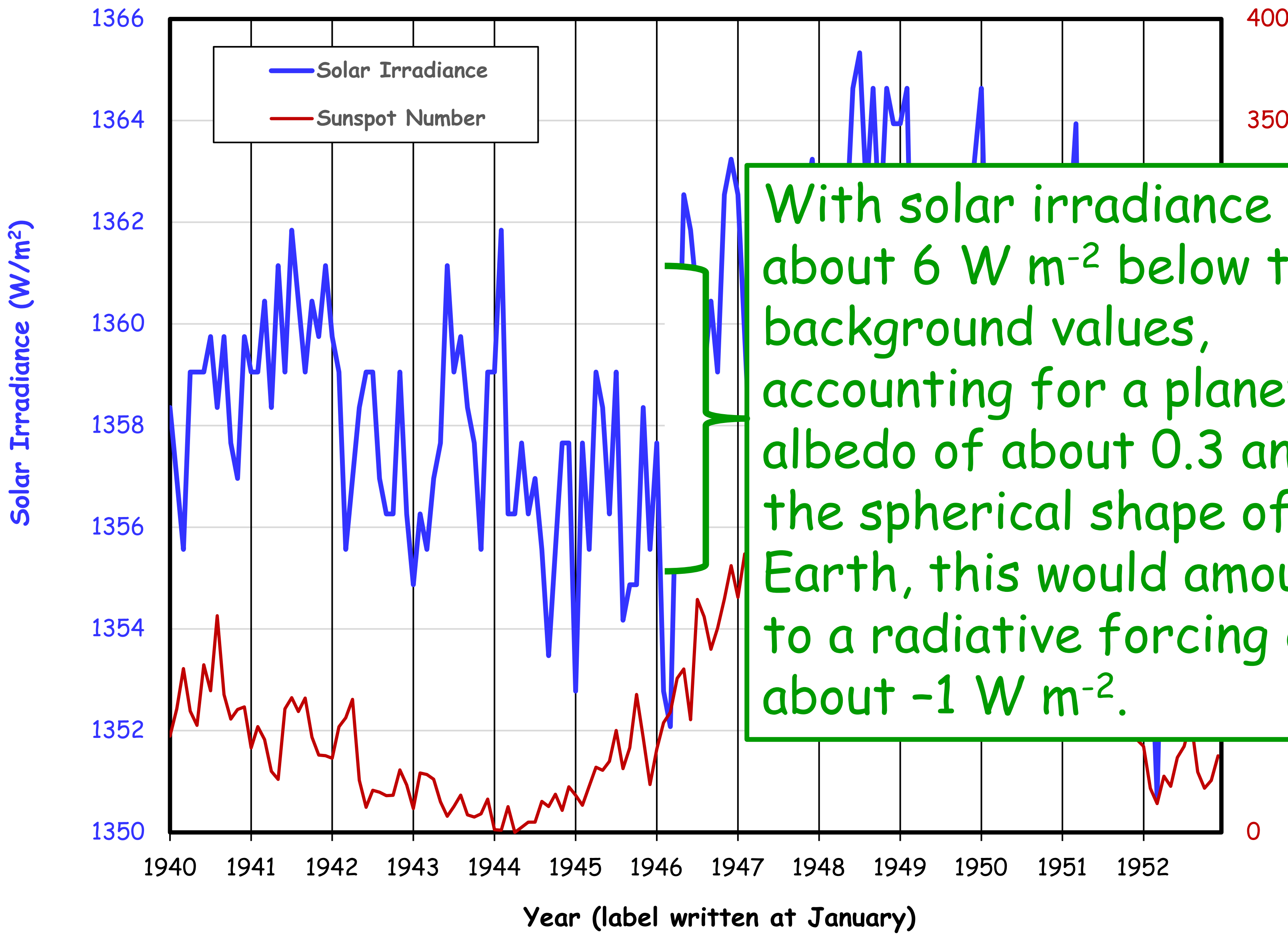
RUTGERS

Kopp, G., and J. L. Lean (2011), A new, lower value of total solar irradiance: Evidence and climate significance, *Geophys. Res. Lett.*, *38*, L01706, doi:10.1029/2010GL045777.

Alan Robock
Department of Environmental Sciences

Was it tropospheric pollution? No. Shaded areas below are recessions.





With solar irradiance about 6 W m^{-2} below the background values, accounting for a planetary albedo of about 0.3 and the spherical shape of Earth, this would amount to a radiative forcing of about –1 W m^{-2}.

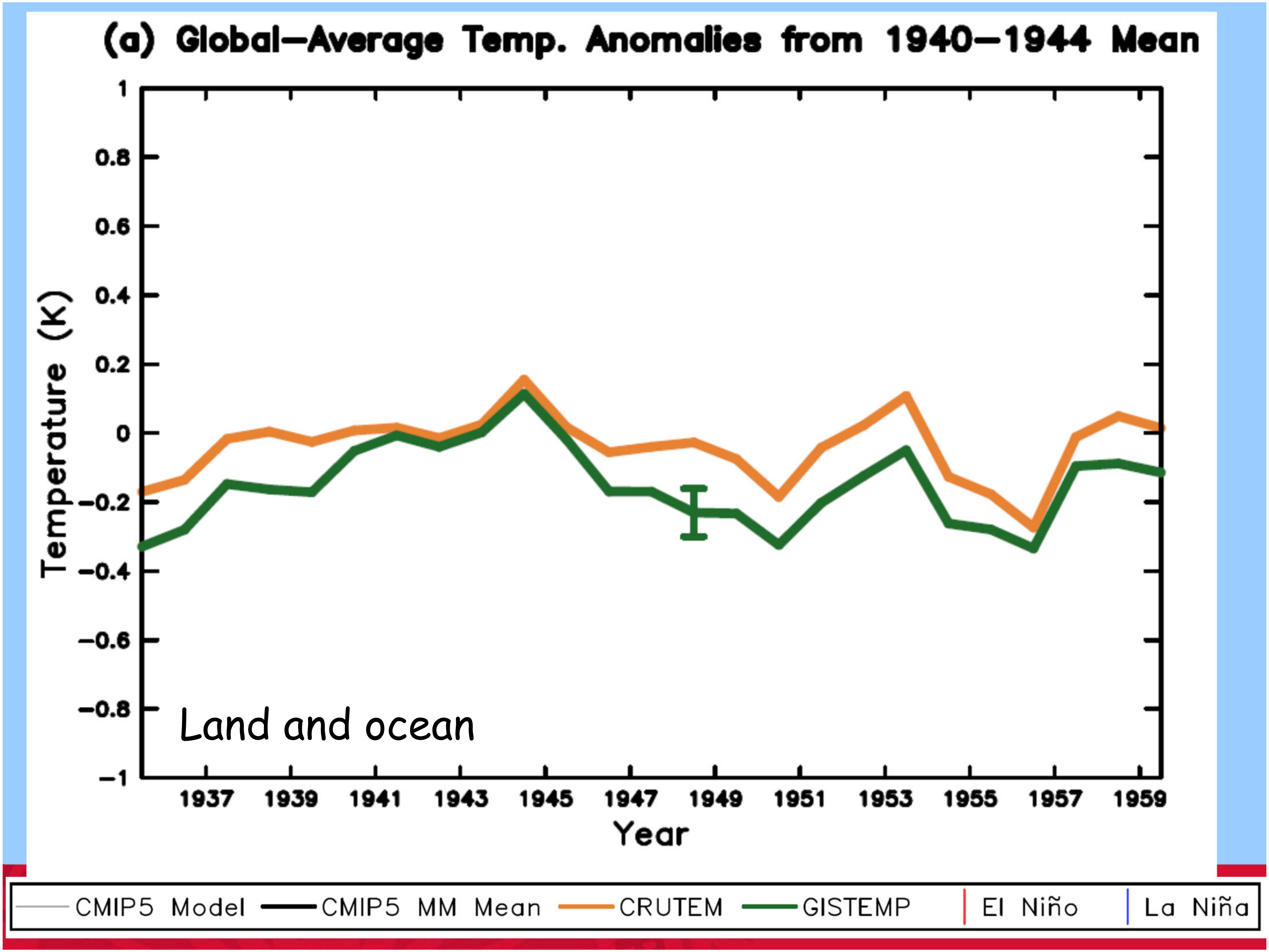
Aldrich, L. B., and W. H. Hoover (1954), *Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. 7*, (Smithsonian Institution, Washington, D.C.), 184 pp.

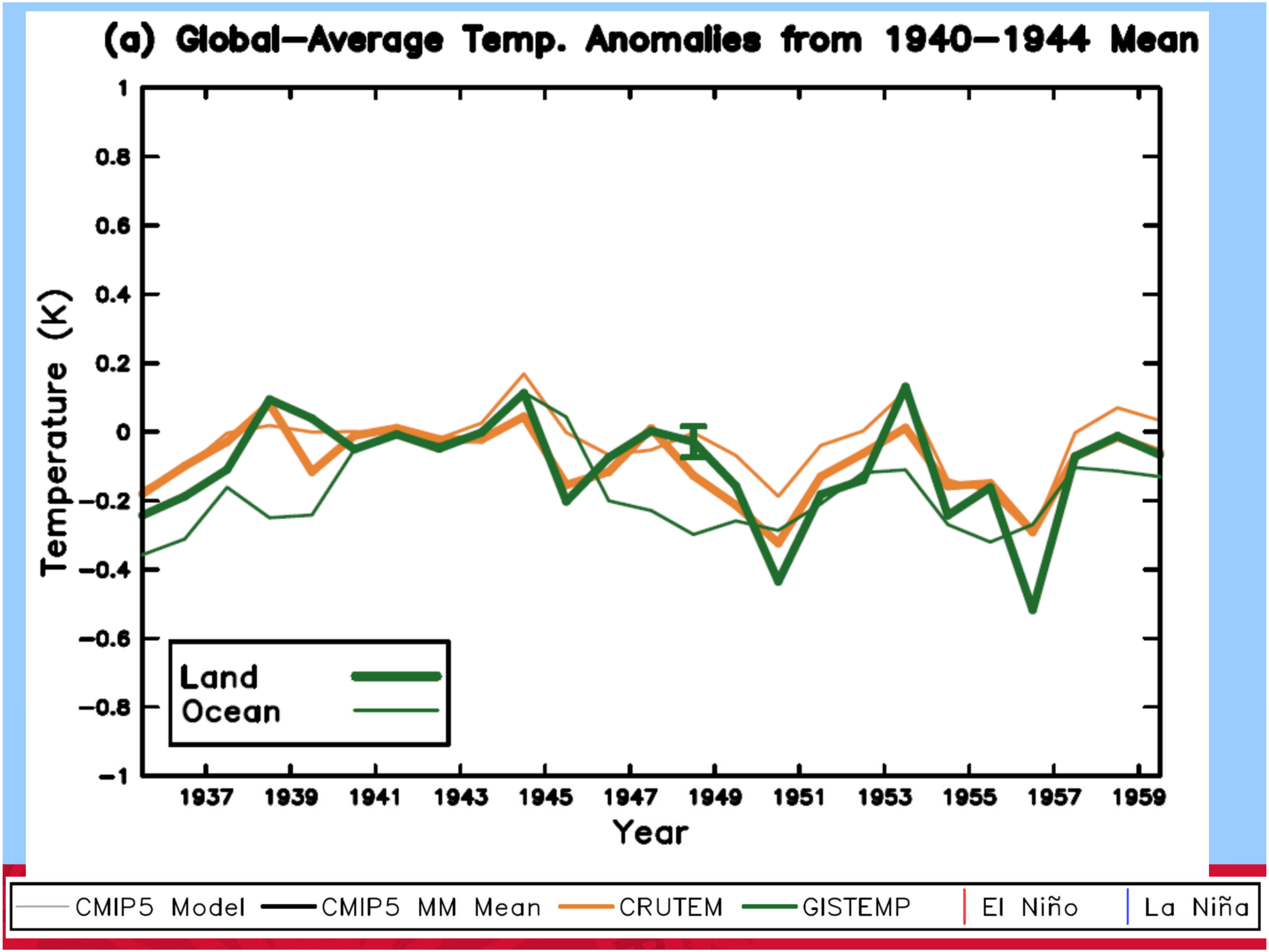
Comparison to climate model simulations

Robock et al. [2007] found a reduction of downward shortwave radiation at the surface of about 13 W m^{-2} one year after an injection of 5 Tg of soot. One tenth of this soot would produce a reduction of about 1.3 W m^{-2}, consistent with observations.

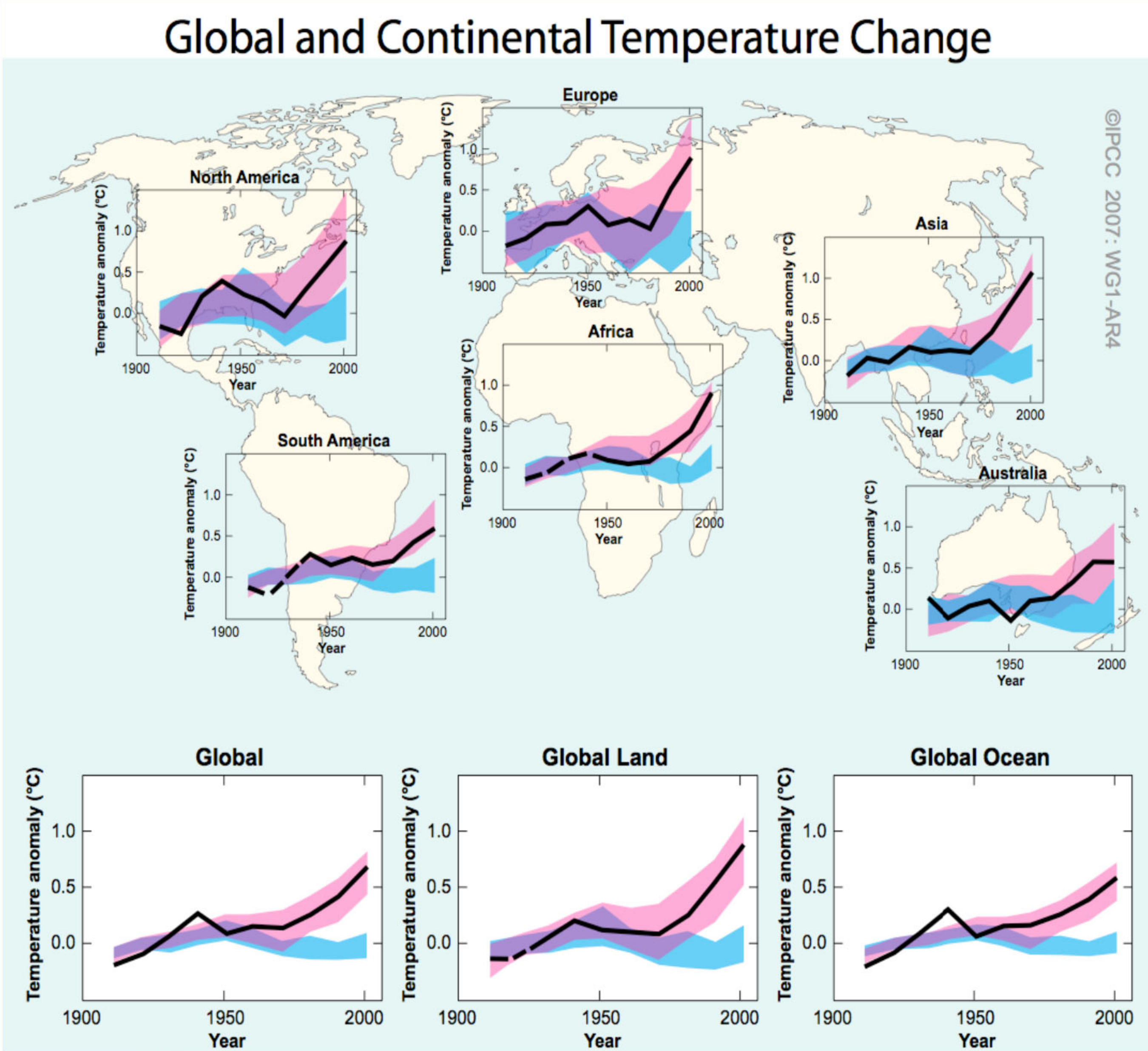
Robock et al. [2007] calculated the impacts of a 5 Tg soot injection into the upper troposphere, and found global average surface air temperature reduction of about 1 K after 1 year, with larger cooling over land. They also simulated an injection of 1 Tg, and found with these low levels of loading, the climate response was essentially linear. Therefore the injection of 0.5-1 Tg of soot into the upper troposphere from city fires during World War II would be expected to produce 0.1-0.2 K global average cooling, with larger cooling over land and over the Northern Hemisphere (because the Northern Hemisphere has a higher fraction of land than the globe).

Robock, A., L. Oman, G. L. Stenchikov, O. B. Toon, C. Bardeen, and R. P. Turco, (2007), Climatic consequences of regional nuclear conflicts, *Atm. Chem. Phys.*, *7*, 2003-2012.


(a) Global–Average Temp. Anomalies from 1940–1944 Mean
Temperature (K)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
Year
Land and ocean
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña



(a) Global-Average Temp. Anomalies from 1940-1944 Mean
Temperature (K)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
Year
Land
Ocean
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña



Observations

As simulated with all forcings

As simulated with only natural forcings

Alan Robock
Department of Environmental Sciences

Problems with SST data during World War II

1. Bucket observations were moved into the cabin at night, producing warm bias.

2. Shipping routes were changed, changing the spatial distribution of observations.

3. Observations were switched from buckets to intake temperatures after WW II, producing warm bias. Done for US ships between 1939 and 1941, but not done for UK ships until a decade later.

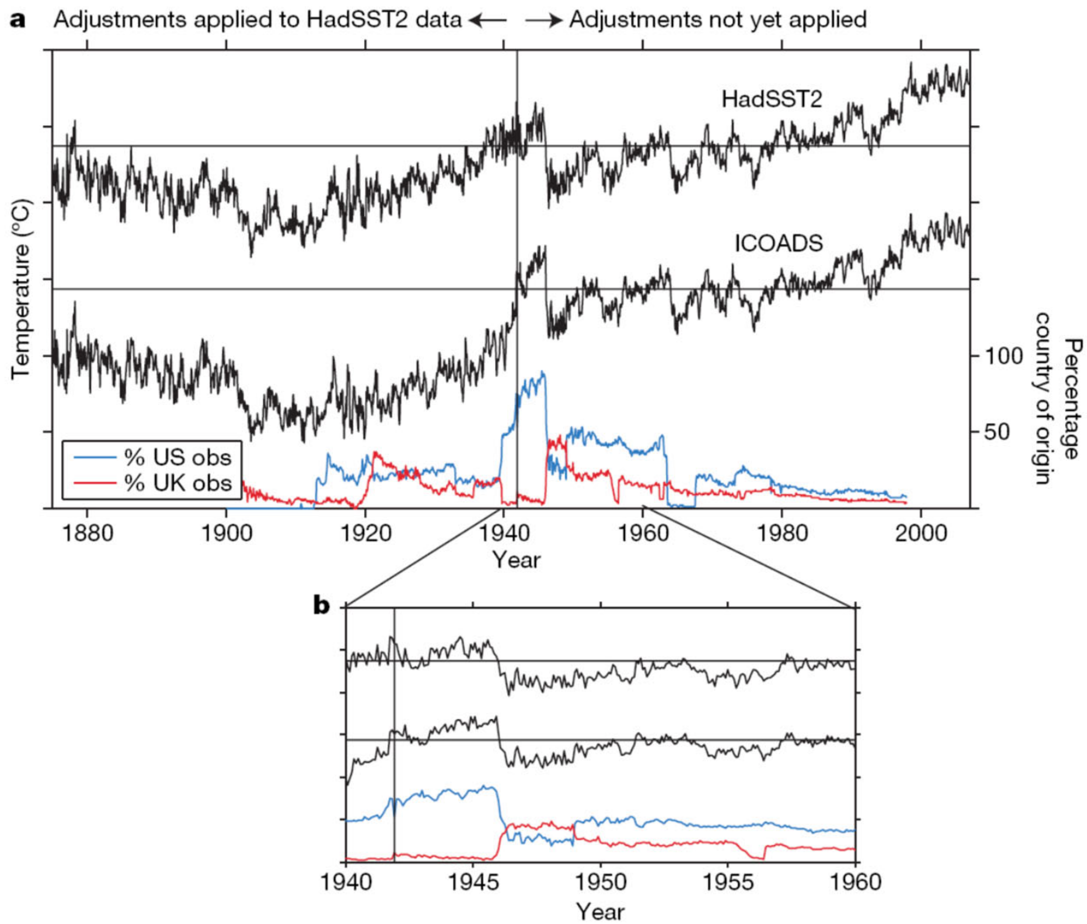
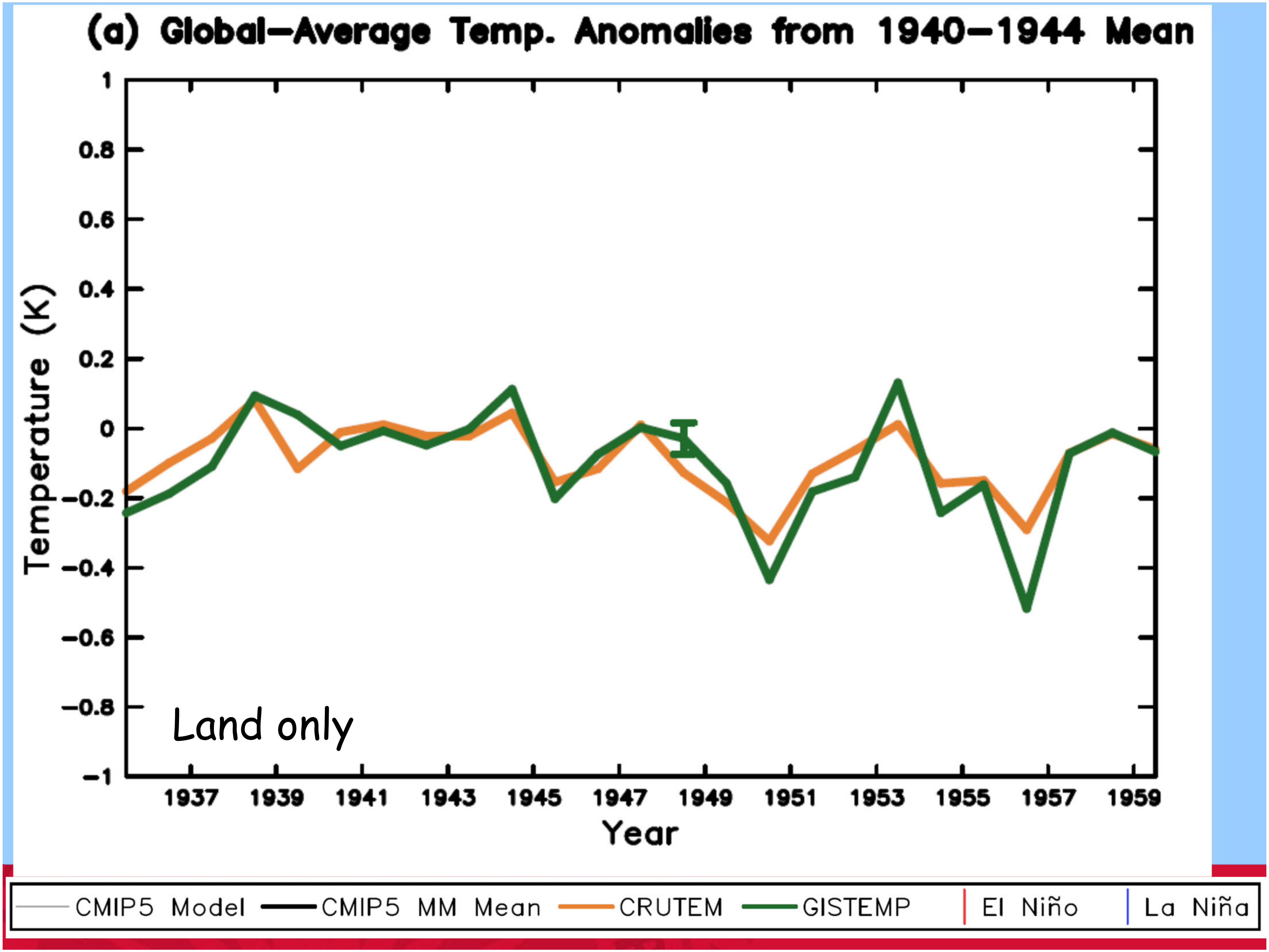


Figure 4 | The HadSST2, ICOADS and country-of-origin time series. a, Top, the ENSO residual global-mean SST time series reproduced from Fig. 3. Middle, as in the top time series but for data from ICOADS. Bottom, the percentage of observations which can be positively identified as coming from US (blue) and UK (red) ships. The vertical line denotes December 1941. Data to the left of the vertical line were corrected in the Met Office Hadley Centre data[6,9]; data to the right of the vertical line have not been adjusted in the HadSST2 data. **b**, As **a** but focused on the period 1940–60. Left vertical axis shows temperature anomalies; tickmarks indicate steps of 0.5 °C. Right vertical axis shows percentage of observations. Horizontal lines in the temperature time series denote the mean for 1961–90.

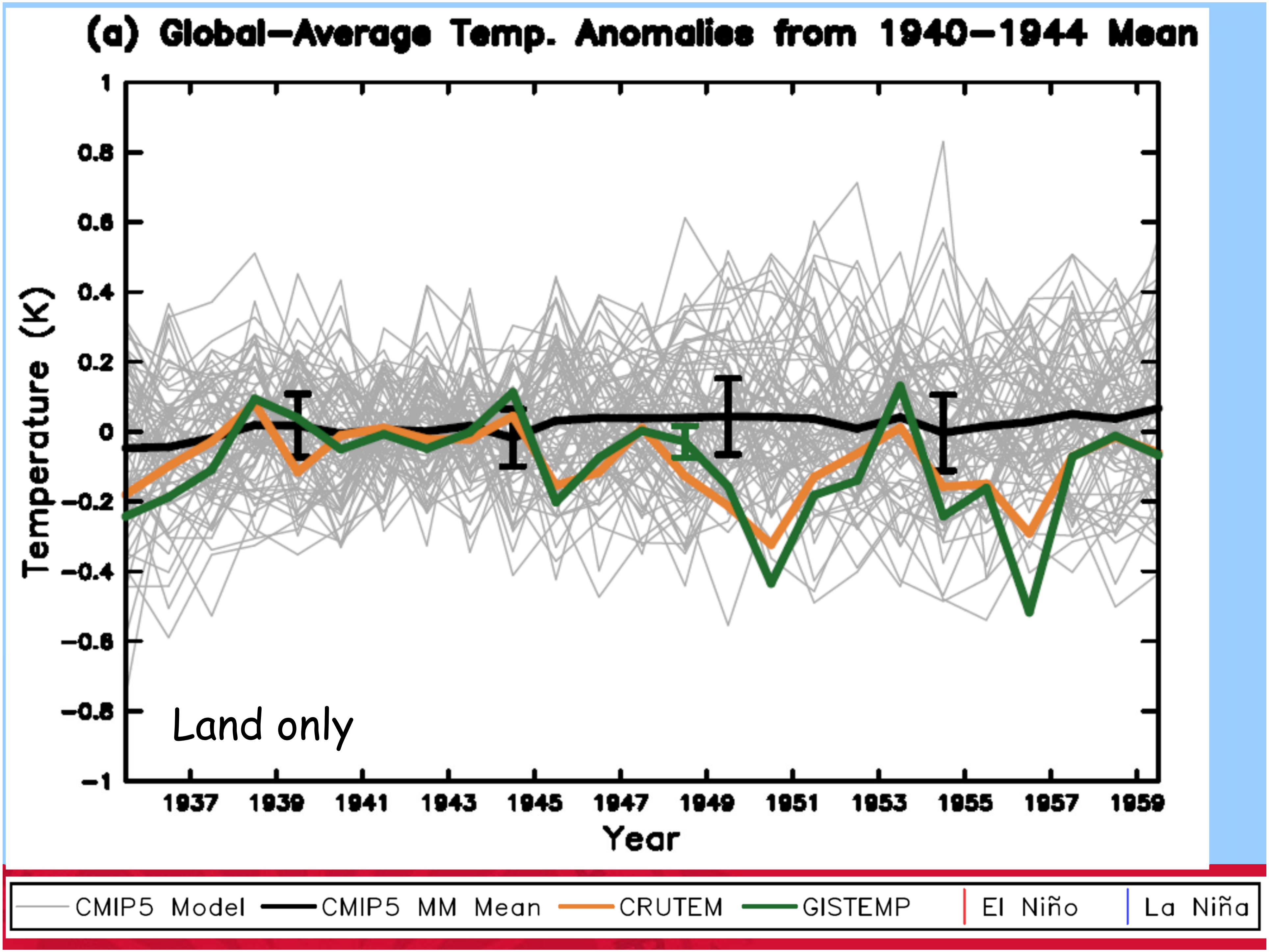
Thompson, D. W. J., J. J. Kennedy, J. M. Wallace, and P. D. Jones (2008), A large discontinuity in the mid-twentieth century in observed global-mean surface temperature, *Nature*, *453*, 646-649, doi:10.1038/nature06982.

Alan Robock
Department of Environmental Sciences


(a) Global-Average Temp. Anomalies from 1940–1944 Mean
Temperature (K)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
Year
Land only
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña

Coupled Model Intercomparison Project 5 historical simulations

Model	Nation	Resolution (°) (lat x lon)	Vertical Levels	Ensemble Members	Reference
ACCESS1-3	Australia	1.25 x 1.875	38	3	Bi et al. [2013]
BCC-CSM1-1	China	2.8 x 2.8	26	3	Wu et al. [2013]
BCC-CSM1-1-M	China	1.11 x 1.125	26	3	Wu et al. [2013]
CanESM2	Canada	2.8 x 2.8	35	5	Chylek et al. [2011]
CESM1-CAM5	US - NCAR	0.94 x 1.25	26	3	Hurrell et al. [2013]
CESM1-FASTCHEM	US - NCAR	0.94 x 1.25	26	3	Hurrell et al. [2013]
CCSM4	US - NCAR	0.94 x 1.25	26	8	Gent et al. [2011]
CNRM-CM5	France	1.4 x 1.4	31	10	Voldoire et al. [2012]
CSIRO-Mk3-6-0	Australia	1.865 x 1.875	18	10	Rotstayn et al. [2010]
GFDL-CM2p1	US - GFDL	2 x 2.5	24	10	Delworth et al. [2006]
GFDL-CM3	US - GFDL	2 x 2.5	48	5	Donner et al. [2011]
GISS-E2-H	US - GISS	2 x 2.5	40	18	Schmidt et al. [2014]
GISS-E2-R	US - GISS	2 x 2.5	40	18	Schmidt et al. [2014]
HadCM3	UK	2.5 x 3.75	19	10	Johns et al. [2003]
HadGEM2-ES	UK	1.25 x 1.875	38	4	Collins et al. [2011]
IPSL-CM5A-LR	France	1.9 x 3.75	39	6	Dufresne et al. [2013]
IPSL-CM5A-MR	France	1.27 x 2.5	39	3	Dufresne et al. [2013]
MIROC-ESM	Japan	2.8 x 2.8125	80	3	Watanabe et al. [2011]
MIROC5	Japan	1.4 x 1.4	40	5	Watanabe et al. [2010]
MPI-ESM-LR	Germany	1.865 x 1.875	47	3	Giorgetta et al. [2013]
MPI-ESM-MR	Germany	1.865 x 1.875	95	3	Giorgetta et al. [2013]
MPI-ESM-P	Germany	1.865 x 1.875	47	2	Giorgetta et al. [2013]
MRI-CGCM3	Japan	1.12 x 1.125	48	5	Yukimoto et al. [2012]
NorESM1-M	Norway	1.9 x 2.5	26	3	Bentsen et al. [2012]


(a) Global-Average Temp. Anomalies from 1940-1944 Mean
Temperature (K)
1
0.8
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0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
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1937
1939
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1959
Year
Land only
CMIP5 Model
CMIP5 MM Mean
CRUTEM
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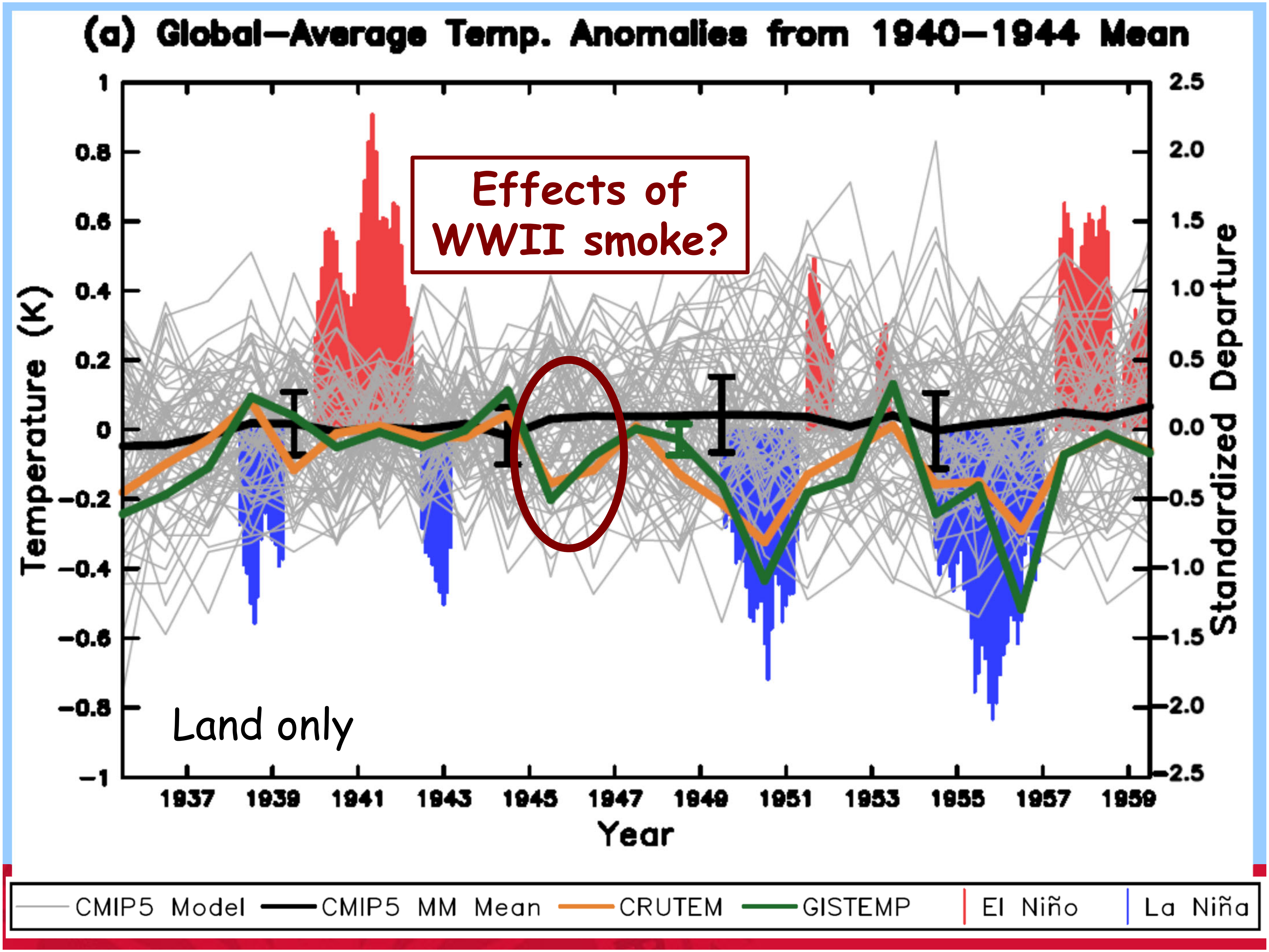
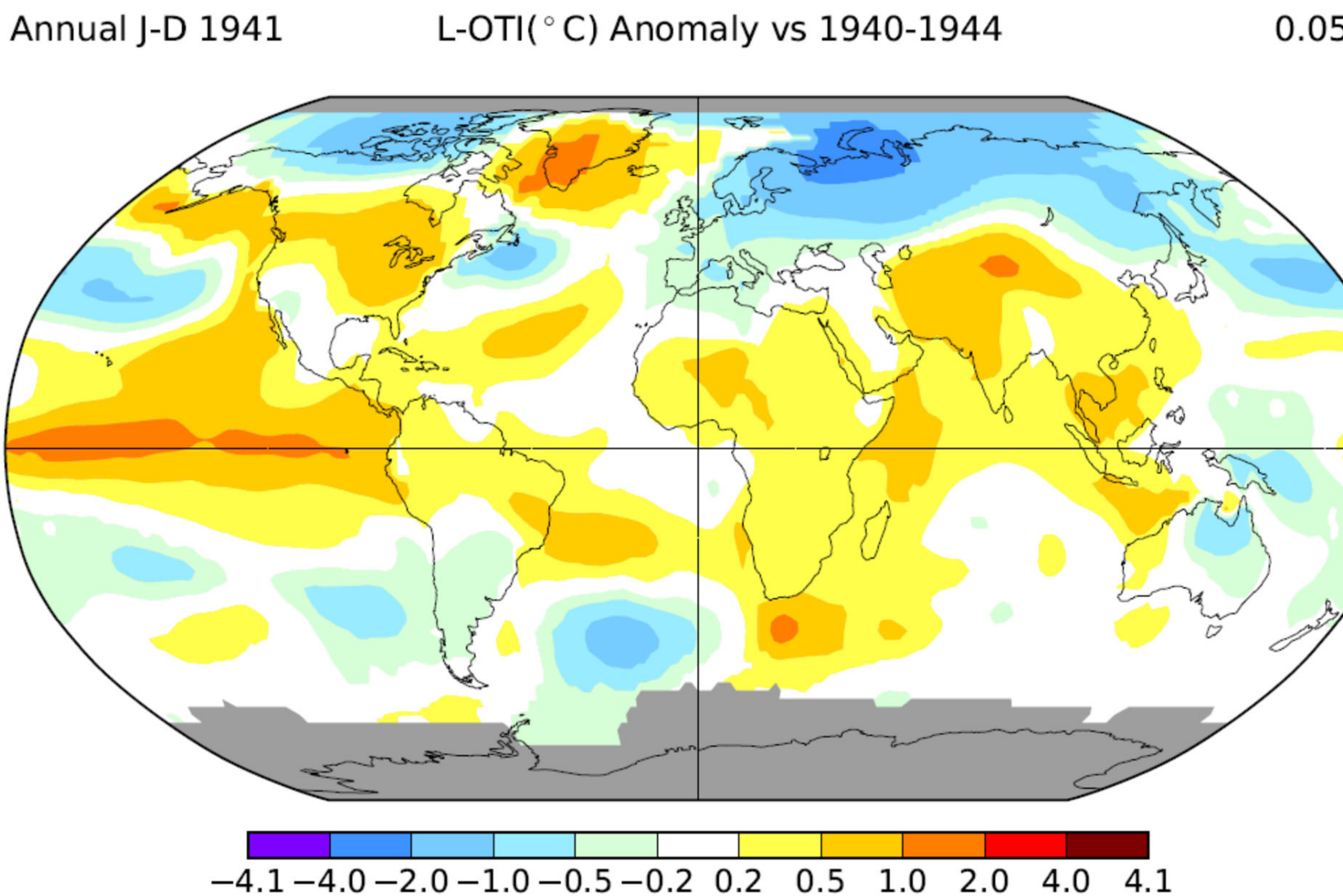
El Niño
La Niña


(a) Global-Average Temp. Anomalies from 1940-1944 Mean
Effects of WWII smoke?
Land only
Temperature (K)
Standardized Departure
Year
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña


Annual J-D 1941
L-OTI(°C) Anomaly vs 1940-1944
0.05
−4.1 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 4.1

"Analysing the data for the past 50 years it becomes clear that not all El Niños show the same features as the one in 1940–42."

Pacific North American (PNA) pattern combined with negative North Atlantic Oscillation (NAO)

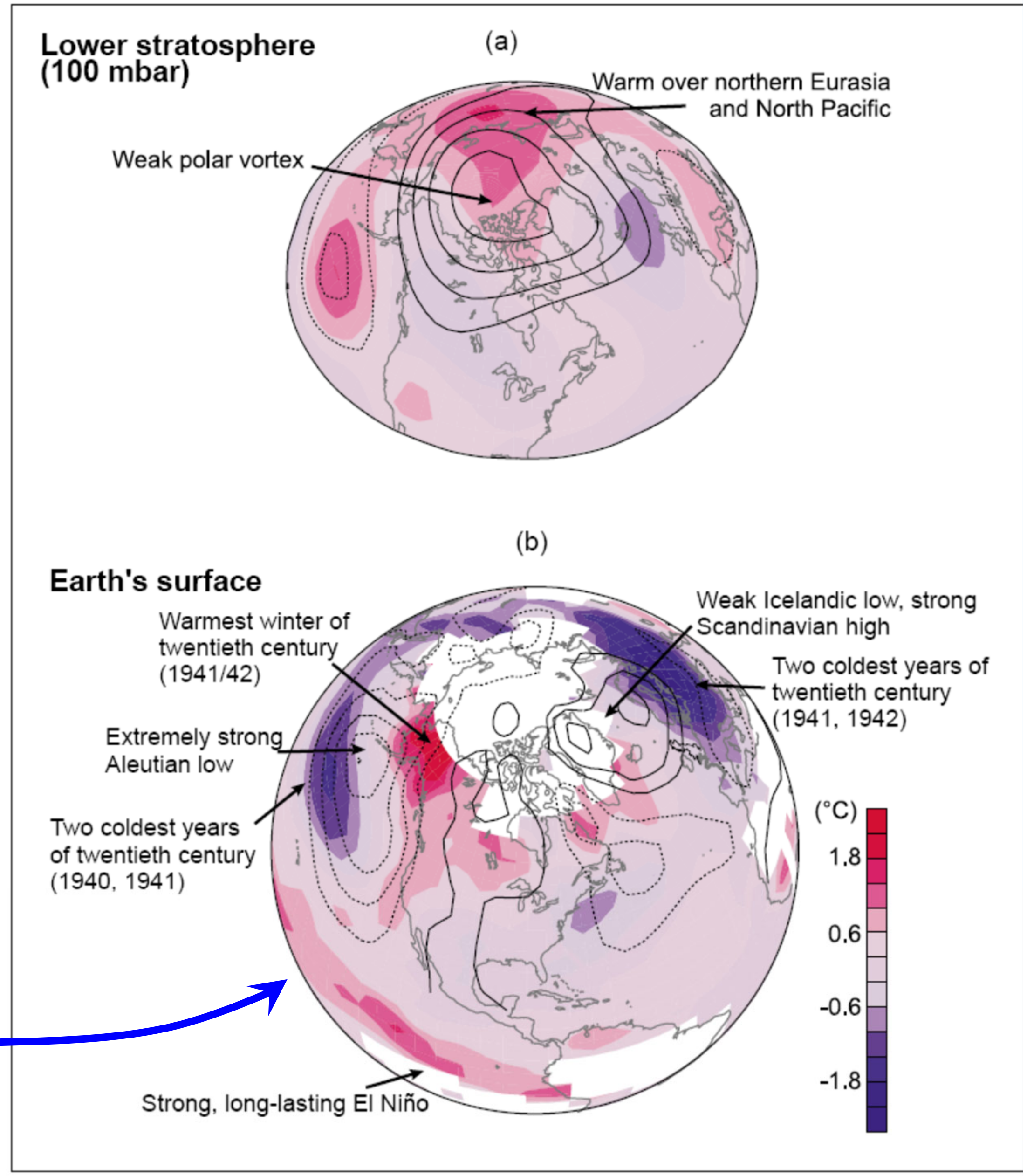
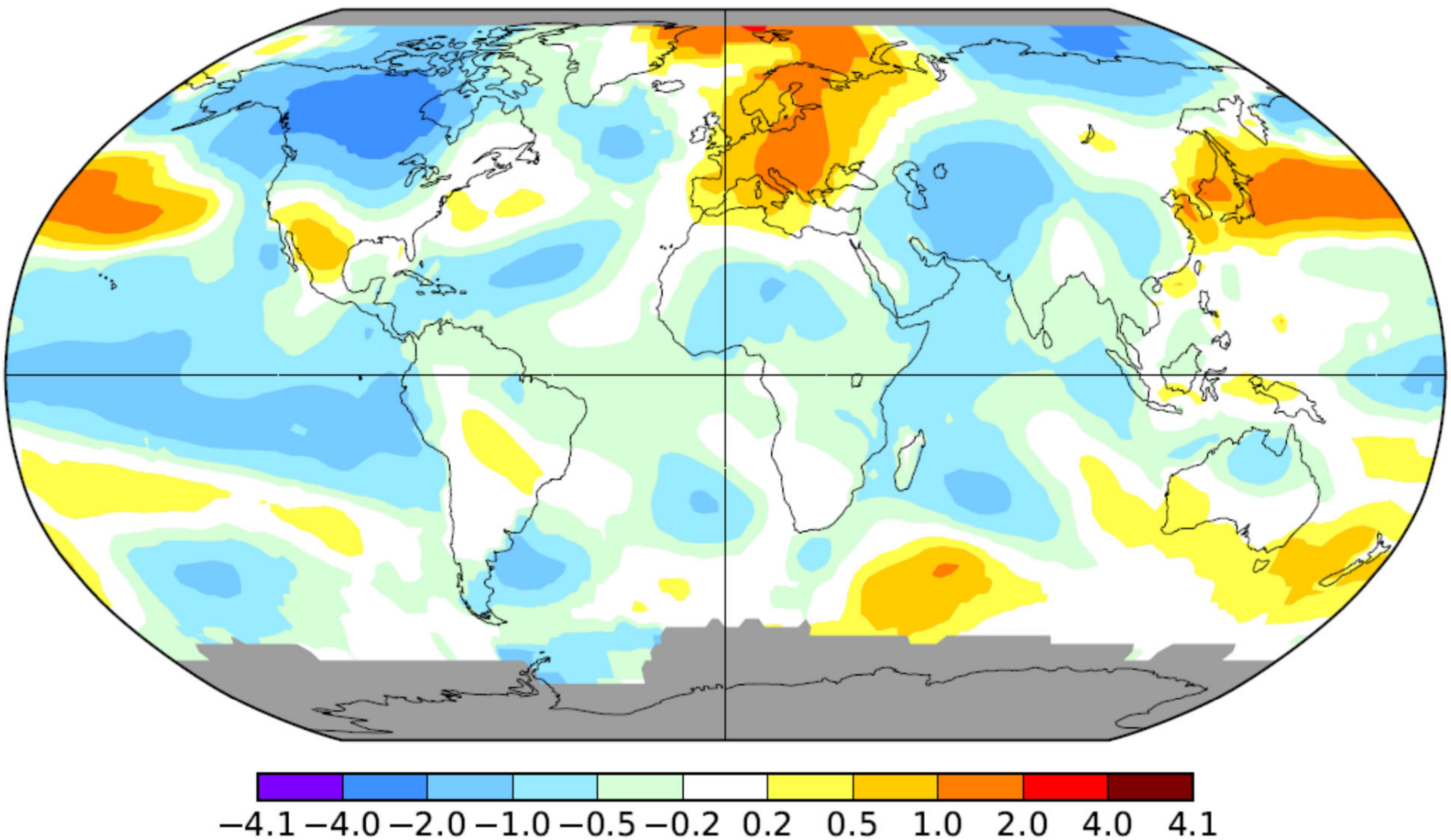


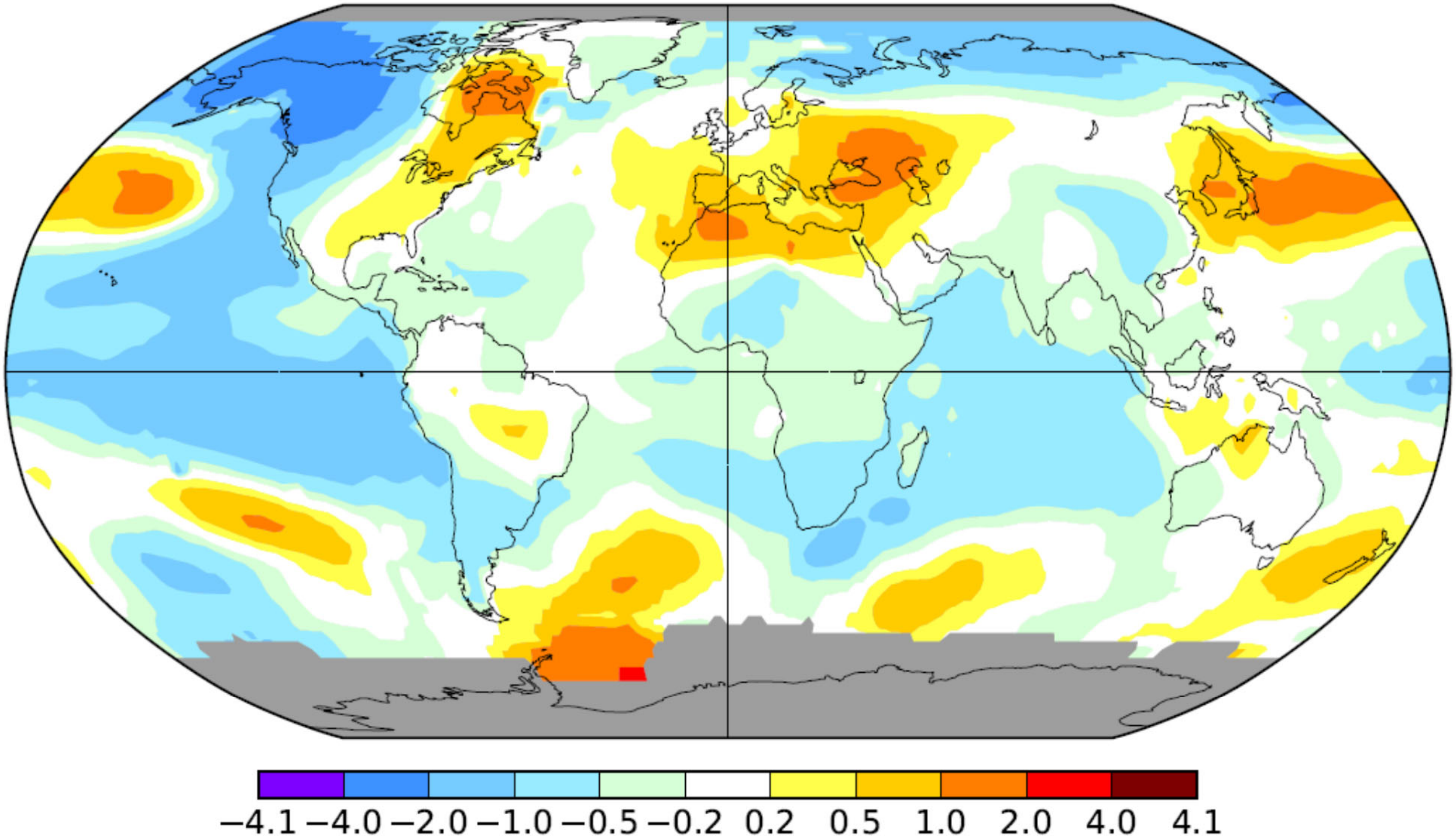
Fig. 7 Averaged anomaly fields (with respect to 1961–1990) from January 1940 to February 1942 of (a) temperature and geopotential height (contours, interval 20 gpm, zero contour not shown) at 100 mbar and (b) surface temperature (HadCRUT2v, Jones and Moberg 2003) and SLP (contours, interval 1 mbar, zero contour not shown, Trenberth and Paolino 1980).

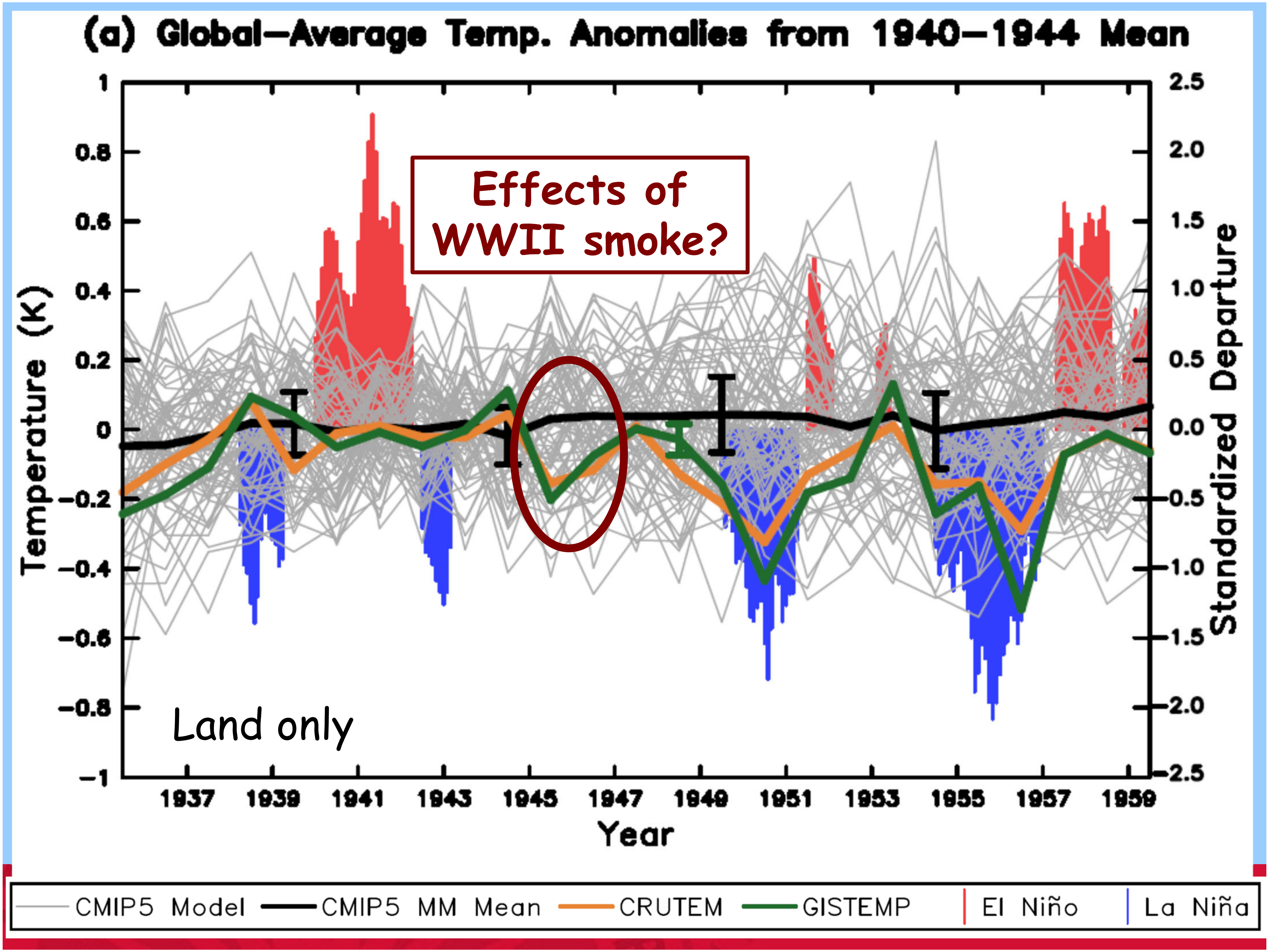
Brönnimann, Stefan, 2005: The global climate anomaly 1940–1942, *Weather*, 60, 336-342, doi: 10.1256/wea.248.04.

Annual J-D 1950 L-OTI(°C) Anomaly vs 1940-1944 -0.30

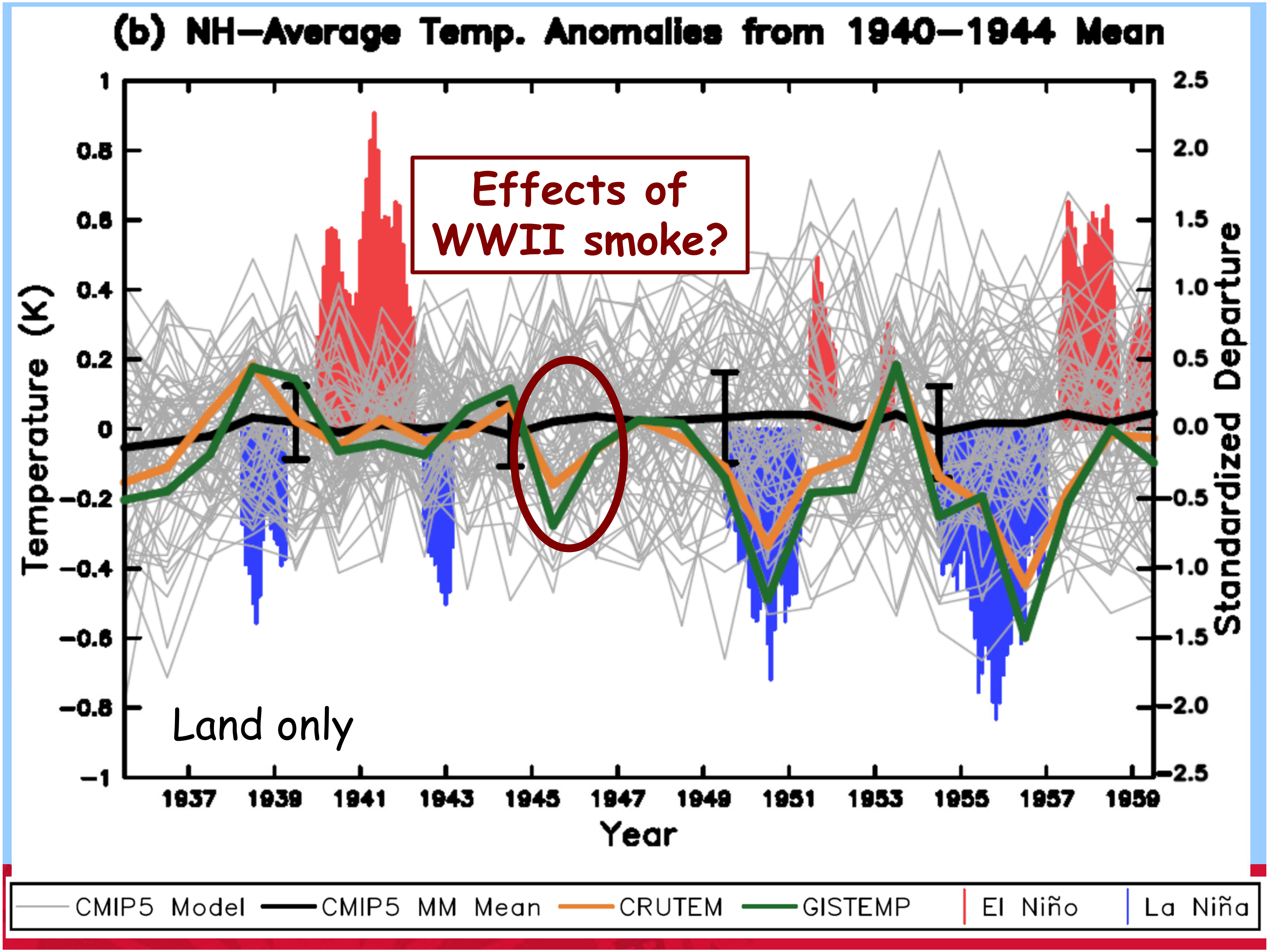


Annual J-D 1955 L-OTI(°C) Anomaly vs 1940-1944 -0.28





(a) Global-Average Temp. Anomalies from 1940–1944 Mean
Effects of WWII smoke?
Land only
Temperature (K)
Standardized Departure
Year
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña

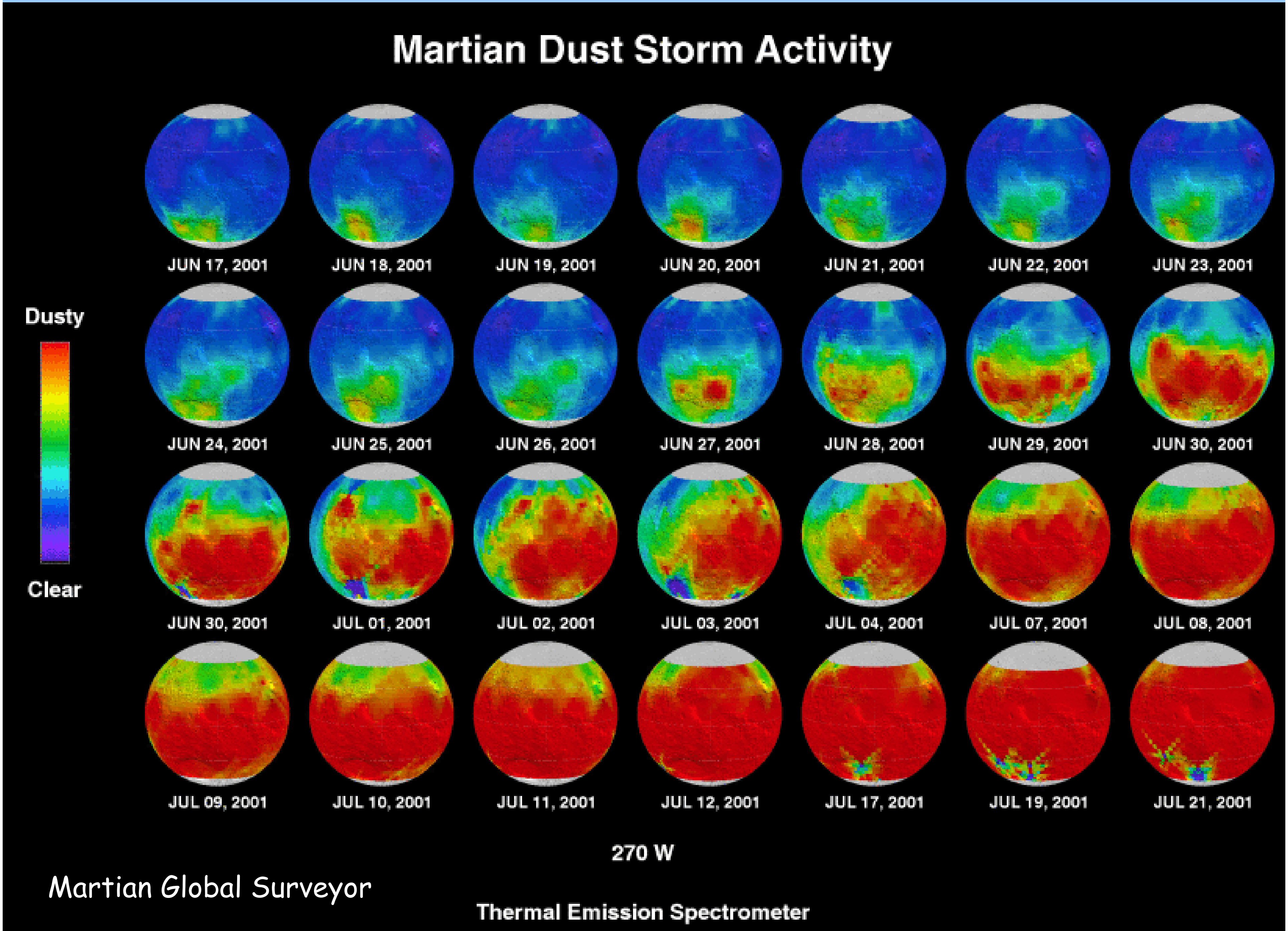

(b) NH–Average Temp. Anomalies from 1940–1944 Mean
Effects of WWII smoke?
Land only
Temperature (K)
Standardized Departure
Year
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
CMIP5 Model
CMIP5 MM Mean
CRUTEM
GISTEMP
El Niño
La Niña

Summary and Conclusions

- Between February 3 and August 9, 1945, an area of 461 km^2 in 69 Japanese cities, including Hiroshima and Nagasaki, was burned in U.S. B-29 Superfortress air raids.
- 1945 global average land surface air temperatures were 0.2 K lower than the average for 1940-1944, and 1946 temps were 0.1 K lower.
- Observations of solar irradiance show reductions consistent with the hypothesis that smoke that was injected into the stratosphere by the city fires.
- Historical simulations from the Coupled Model Intercomparison Project 5, with no smoke in their forcing, showed no post-war cooling.
- **The observed cooling was likely caused by the smoke from the fires.**
- These findings add to previous observations of regional cooling from forest fire smoke, and strengthen observational support for nuclear winter theory.

Robock, Alan, and Brian Zambri, 2017: Did smoke from city fires in World War II cause global cooling? In preparation for submission to *J. Geophys. Res.*

Alan Robock
Department of Environmental Sciences



Martian Global Surveyor

Asteroid impact or massive volcanism wiped out the large dinosaurs 65,000,000 years ago.

This was the beginning of the Age of Mammals.

Yellowstone, June 8, 2007

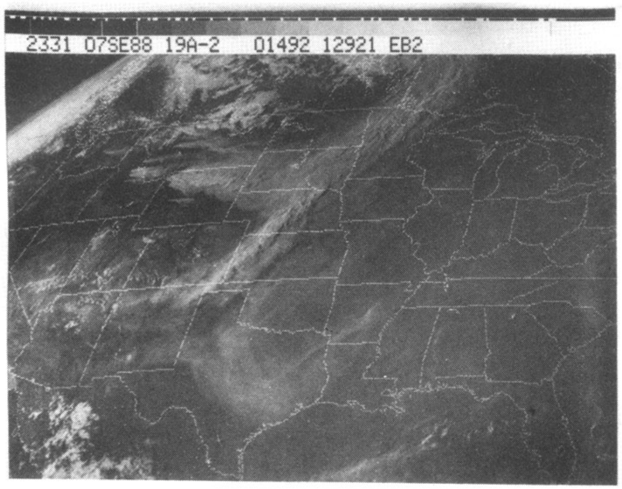


Fig. 13*a*. GOES satellite image in visible wavelengths, September 7, 1988, 2331 UT (1731 LT: mountain daylight time (MDT)) showing smoke from the Yellowstone forest fires.

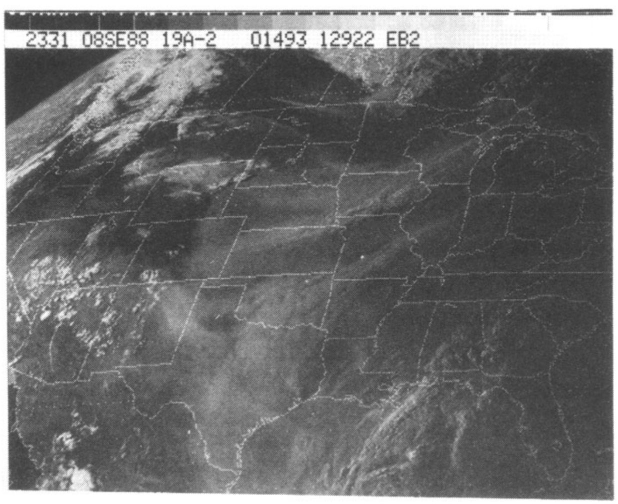


Fig. 13*b*. As in Figure 13*a* for September 8, 1988, at the same time. Note the smoke clouds covering most of the Great Plains. In Colorado the western half of the state is black, indicating no smoke since the Front Range of the Rocky Mountains, which runs north-south through the center of the state, blocks the smoke.

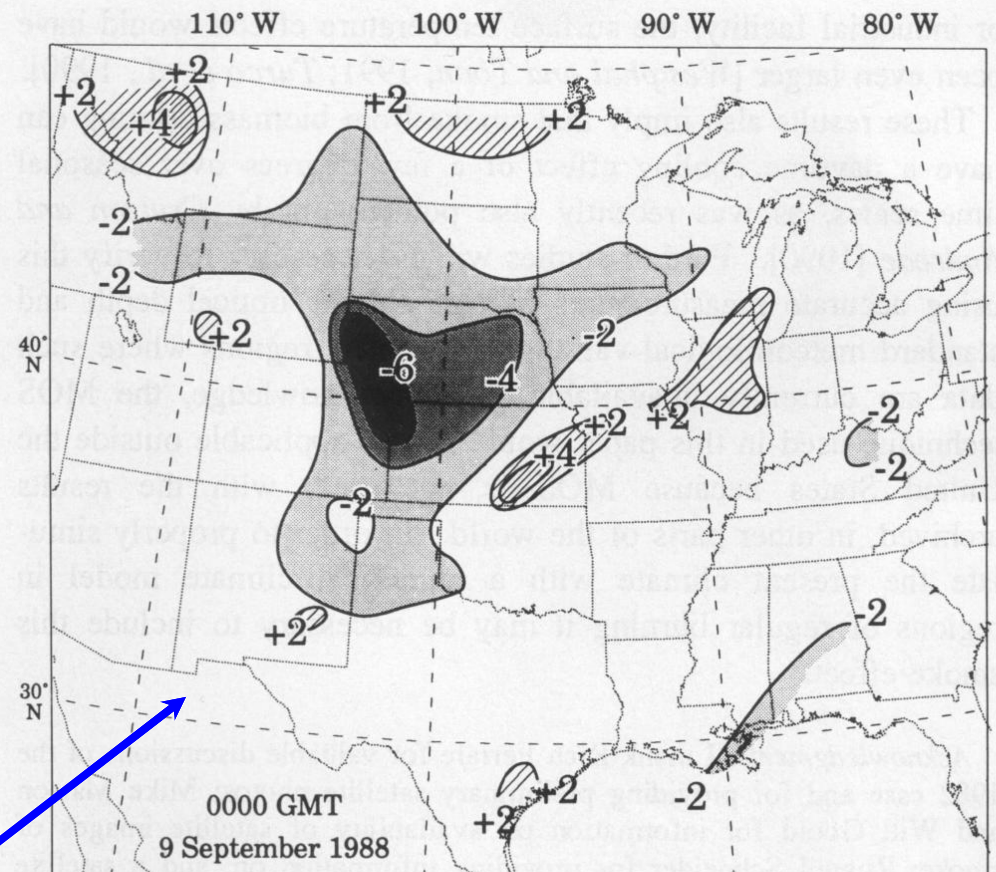


Fig. 15*c*. **As in Figure 15*a* for 0000 UT September 9, 1988 (1800 LT, September 8), only 29 min after the image shown in Figure 13*b*, based on the MOS forecasts made 0000 UT on September 8. Again, note the negative MOS error under the smoke-covered region, indicating the cooling effect of the smoke during the daytime.**

Robock (1991)

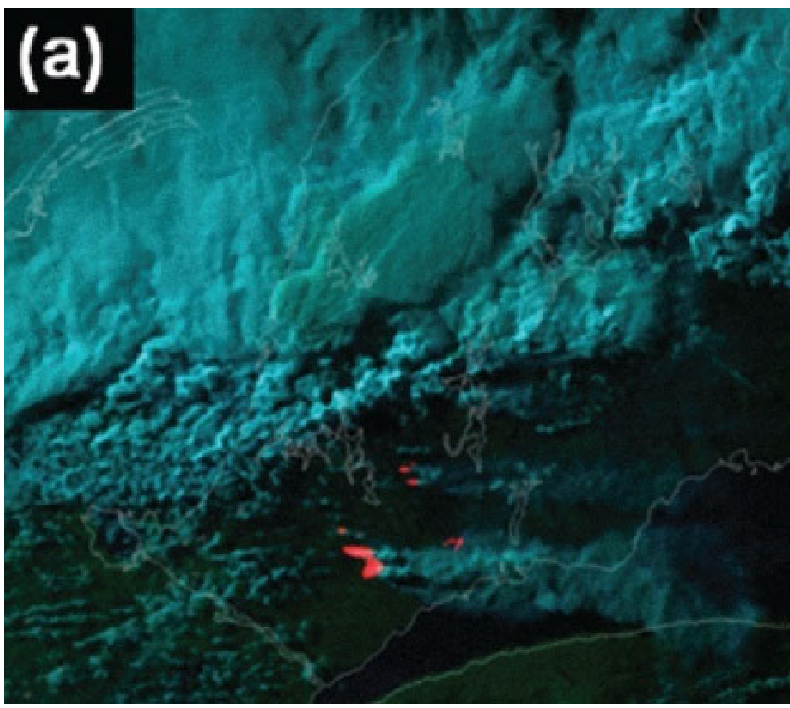
Alan Robock
Department of Environmental Sciences

THE UNTOLD STORY OF PYROCUMULONIMBUS

BY MICHAEL FROMM, DANIEL T. LINDSEY, RENÉ SERVRANCKX, GLENN YUE, THOMAS TRICKL, ROBERT SICA, PAUL DOUCET, AND SOPHIE GODIN-BEEKMANN

BAMS SEPTEMBER 2010

When fires initiate or intensify towering thunderstorms, they can inject aerosols into the lower stratosphere that were once thought to originate only from volcanic plumes.



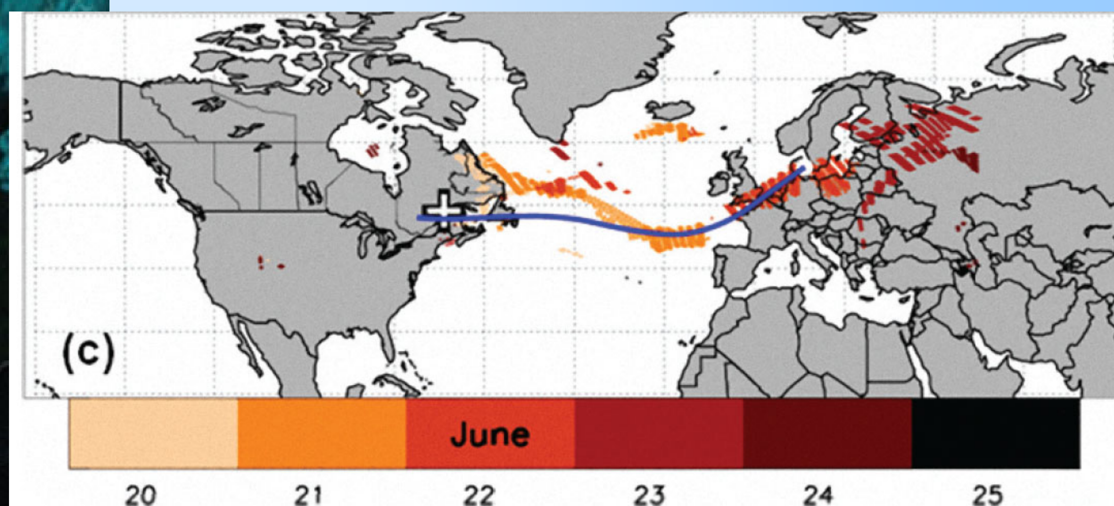


FIG. 4. Composite of AVHRR, AI, SAGE II layer, and trajectory for 1991 Quebec, Canada, pyroCbs. (a) AVHRR RGB image for local evening 19 Jun

Black carbon lofts wildfire smoke high into the stratosphere to form a persistent plume

Pengfei Yu[1,2,3*], Owen B. Toon[4,5], Charles G. Bardeen[6], Yunqian Zhu[5], Karen H. Rosenlof[2], Robert W. Portmann[2], Troy D. Thornberry[1,2], Ru-Shan Gao[2], Sean M. Davis[2], Eric T. Wolf[5,7], Joost de Gouw[1,8], David A. Peterson[9], Michael D. Fromm[10], Alan Robock[11]

Yu *et al.*, *Science* **365**, 587–590 (2019) 9 August 2019

In 2017, western Canadian wildfires injected smoke into the stratosphere that was detectable by satellites for more than 8 months. The smoke plume rose from 12 to 23 kilometers within 2 months owing to solar heating of black carbon, extending the lifetime and latitudinal spread. Comparisons of model simulations to the rate of observed lofting indicate that 2% of the smoke mass was black carbon. The observed smoke lifetime in the stratosphere was 40% shorter than calculated with a standard model that does not consider photochemical loss of organic carbon. Photochemistry is represented by using an empirical ozone-organics reaction probability that matches the observed smoke decay. The observed rapid plume rise, latitudinal spread, and photochemical reactions provide new insights into potential global climate impacts from nuclear war.

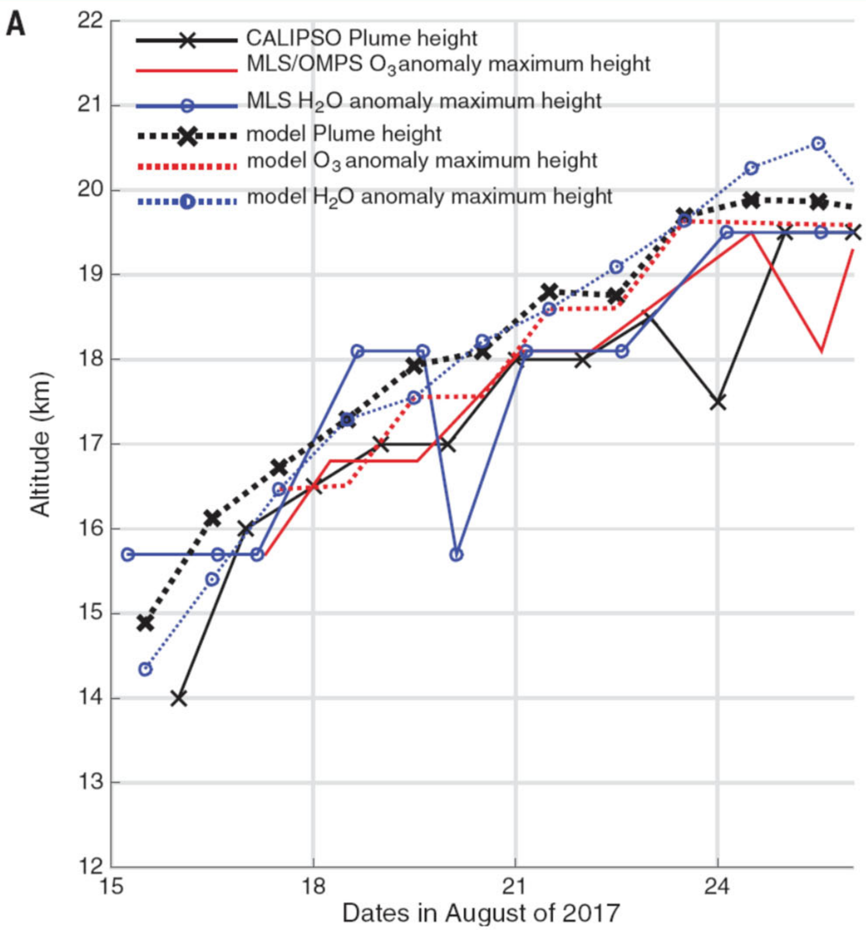


Fig. 3. Observed and modeled smoke transport in August 2017. (**A**) Maximum altitude of observed plume height by CALIOP in the region of interest in black lines with cross symbols; maximum altitude of observed significant O_3 negative anomaly (more negative than −0.3 ppmv) by MLS and OMPS in the region of interest (30° to 70°N, 80°W to 20°E) in red solid line; maximum altitude of observed water vapor positive

Yu *et al.*, *Science* **365**, 587–590 (2019)   9 August 2019

Rapid ascent in first 10 days, observed and modeled.

Atmos. Chem. Phys. Discuss., 6, 9877–9906, 2006
www.atmos-chem-phys-discuss.net/6/9877/2006/

Atmospheric Chemistry and Physics Discussions

Alberta, Canada,
May 28, 2001

The Chisholm firestorm: observed microstruc lightning a

D. Rosenfeld[1], M. Fro
R. Servranckx[5]

Fig. 1. A picture of the pyro-Cb taken to the NW from a fire fighter airplane at 01:30 UTC, shortly after the major explosive growth of the cloud started. Credit: Alberta Government.

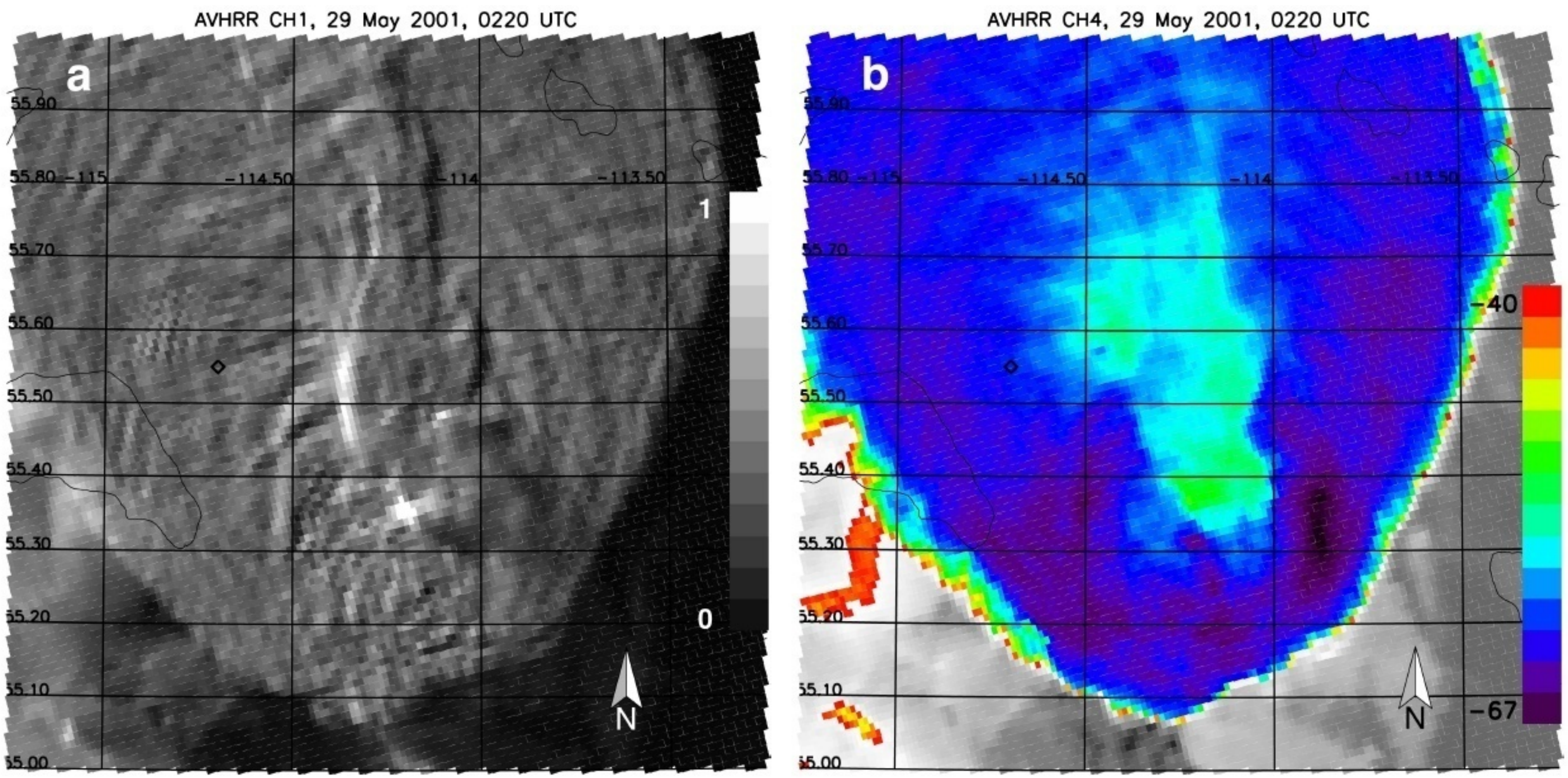
RUTGERS

Atmos. Chem. Phys., 7, 5945–5957, 2007
www.atmos-chem-phys.net/7/5945/2007/

Atmospheric Chemistry and Physics

Small-scale mixing processes enhancing troposphere-to-stratosphere transport by pyro-cumulonimbus storms

G. Luderer[1,*], J. Trentmann[2], K. Hungershöfer[3,**], M. Herzog[4,***], M. Fromm[5], and M. O. Andreae[1]



(a) 0.65 μm reflectance

(b) 10.8 μm brightness temperature

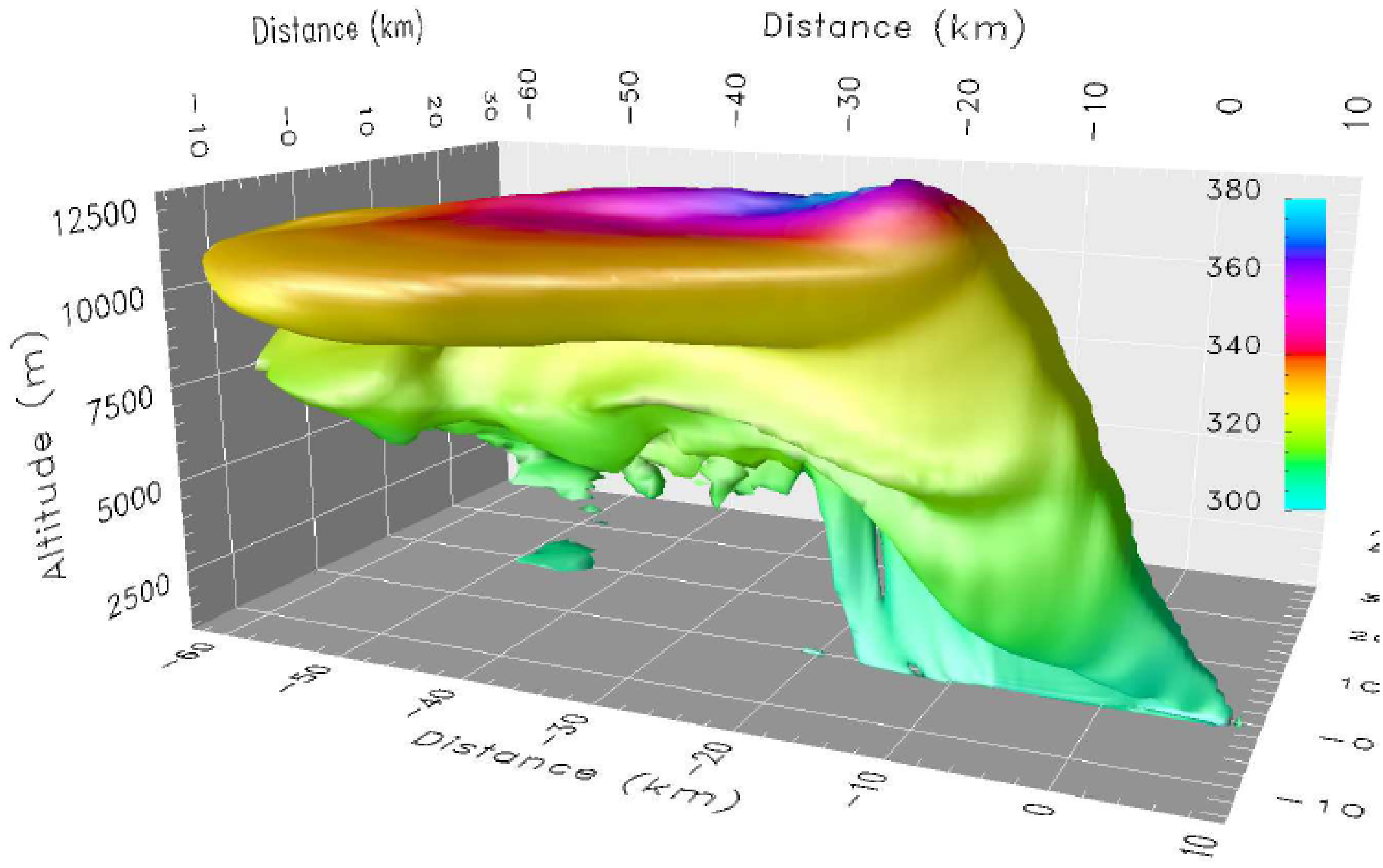
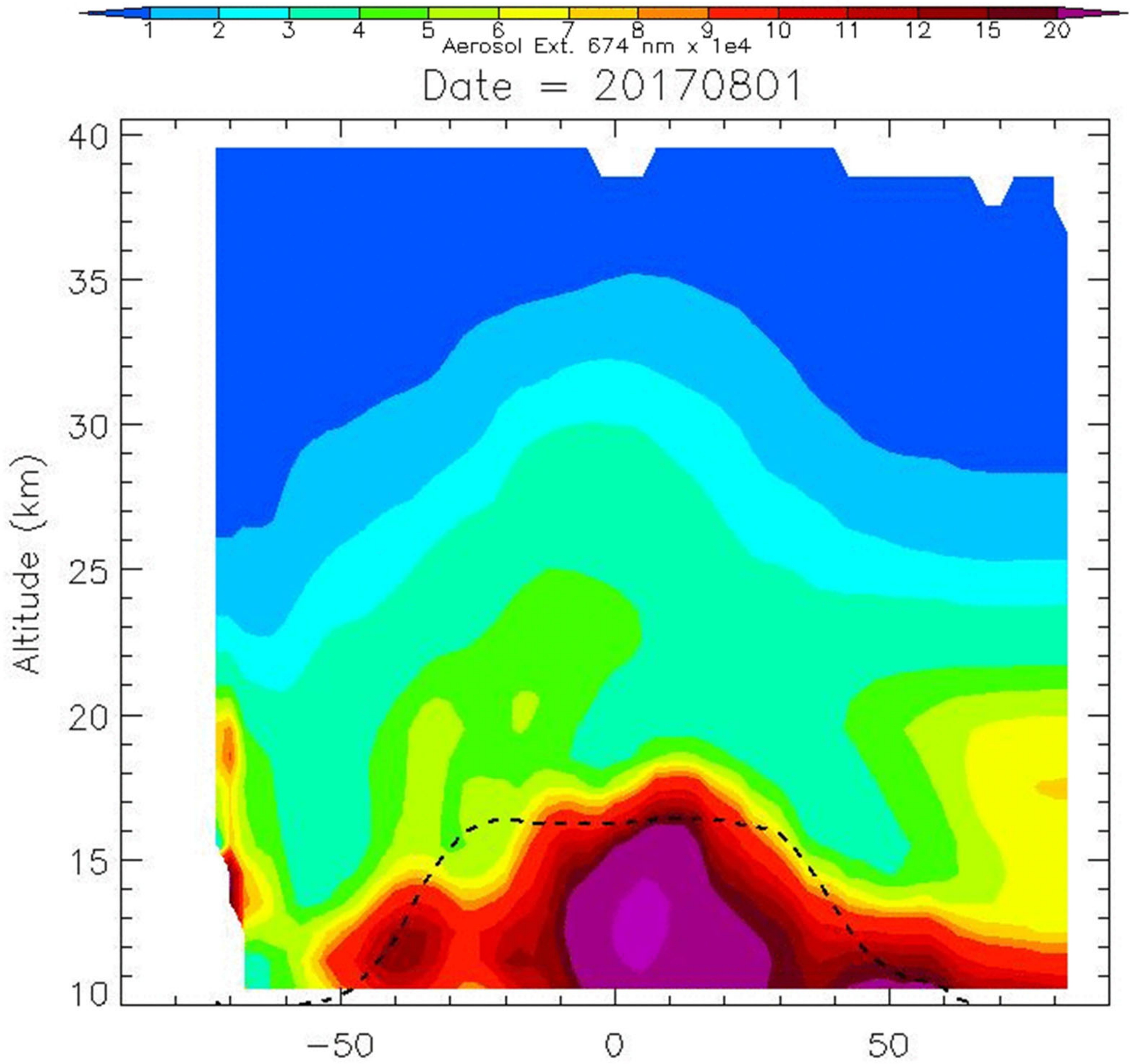


Fig. 3. Three-dimensional representation of the aerosol plume after 40 min simulation time. The 50 $\mu g\,m^{-3}$ isosurface is color-coded with potential temperature in K.

British Columbia (53°N, 123°W) pyroCb

Initial injection:

August 12, 2017 at 13 km of about 0.3 Tg soot



https://avdc.gsfc.nasa.gov/pub/tmp/OMPS_aer/BC_fires/

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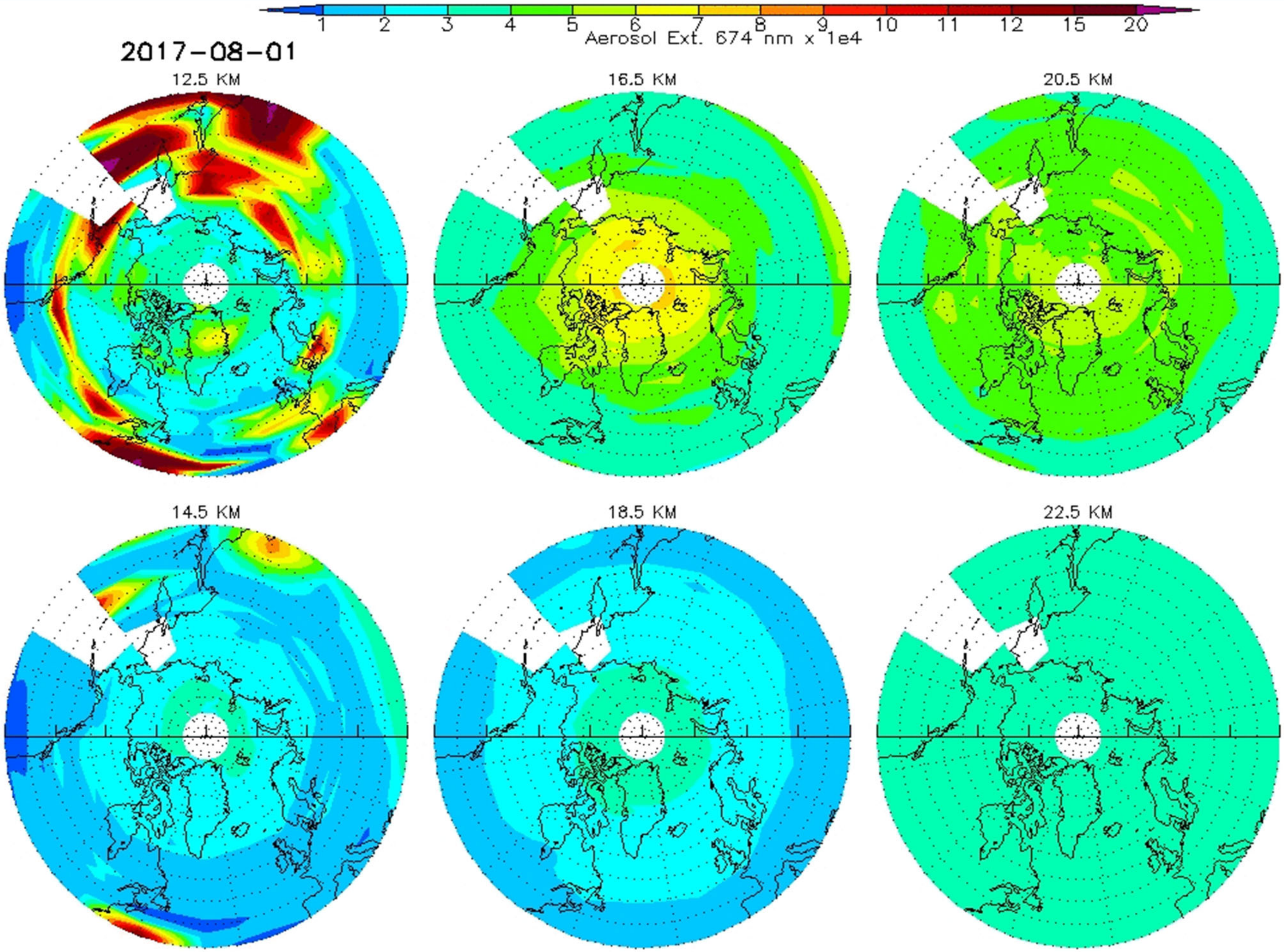


https://avdc.gsfc.nasa.gov/pub/tmp/OMPS_aer/BC_fires/

Alan Robock
Department of Environmental Sciences

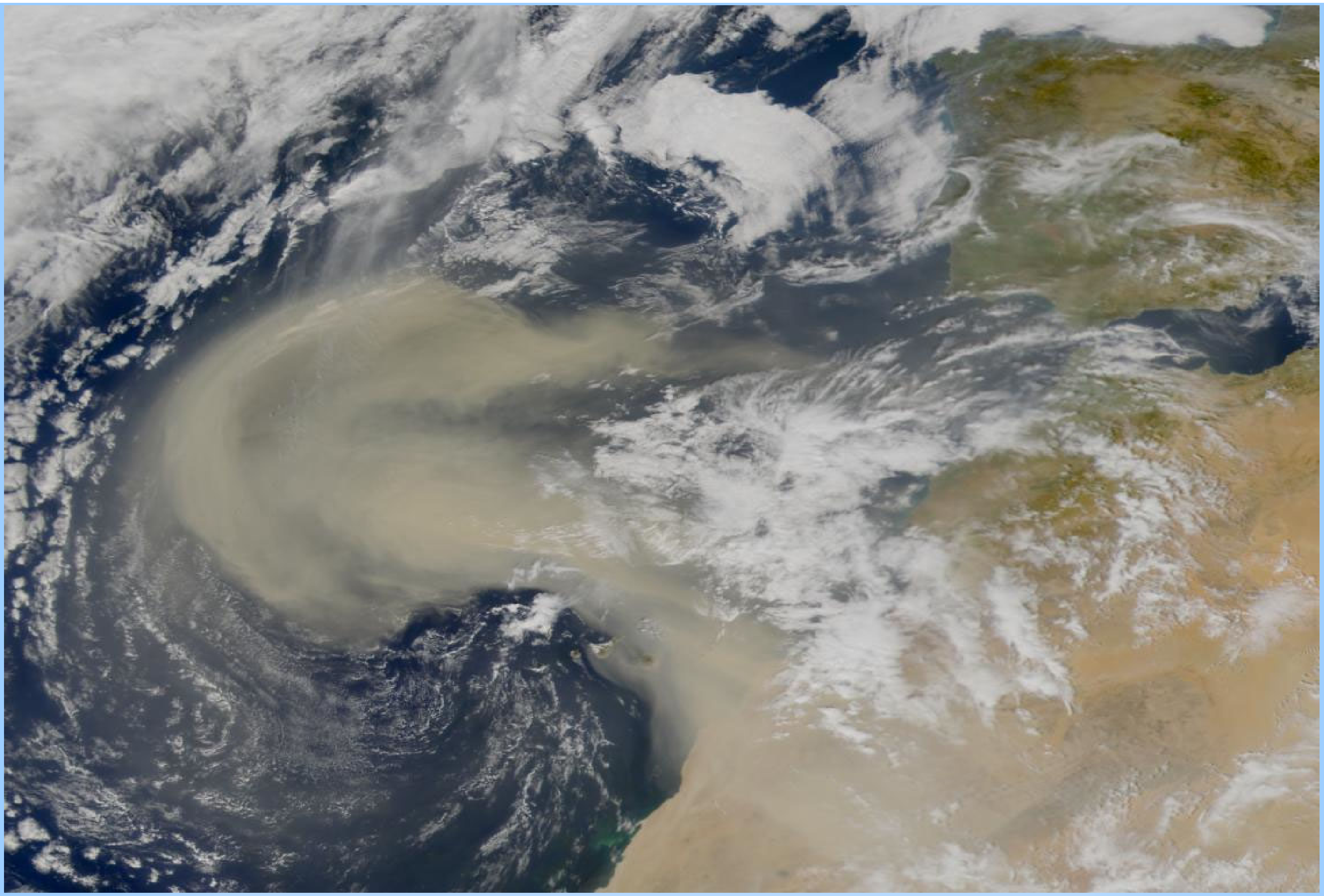
Geophysical Research Letters (2020)

RESEARCH LETTER
10.1029/2020GL090831

Australian New Year's PyroCb Impact on Stratospheric Composition

Michael J. Schwartz[1], Michelle L. Santee[1], Hugh C. Pumphrey[2], Gloria L. Manney[3,4], Alyn Lambert[1], Nathaniel J. Livesey[1], Luis Millán[1], Jessica L. Neu[1], William G. Read[1], and Frank Werner[1]

Plain Language Summary Severe wildfires can trigger vigorous smoke-infused thunderstorms called pyrocumulonimbuses (pyroCbs) that rapidly loft polluted air from the surface, in the most extreme cases depositing it in the lower stratosphere ($\gtrsim$ 14 km altitude). Three times in the past 16 years, long-lived stratospheric plumes from major pyroCbs have been observed in a suite of biomass-burning products measured by the Microwave Limb Sounder on NASA's Aura satellite. Dark smoke in these plumes absorbs sunlight; the plumes rise because they are warmer than the surrounding air. The third, and by far the largest, of these plumes was produced by an extraordinary set of pyroCbs in Australia between 29 December 2019 and 4 January 2020, collectively known as the Australian New Year's event (ANY). The ANY plume core remained remarkably compact, circling the globe twice while rising from ~14 km to ~35 km altitude over a period of 4 months. Record-setting concentrations of five biomass-burning products were measured by MLS throughout the lower stratosphere. Plume fragments tended to move south but do not seem to have influenced ozone-hole chemistry. Differing gas mixtures suggest that several plumes in the first month originated in different pyroCbs. Careful comparison of plume gases requires consideration of the blurriness of the measurements.



Dust storms from the Saharan desert regularly demonstrate long-range tropospheric aerosol transport.

Alan Robock
Department of Environmental Sciences

"The Scream"

Edvard Munch

Painted in 1893 based on Munch's memory of the brilliant sunsets following the 1883 Krakatau eruption.

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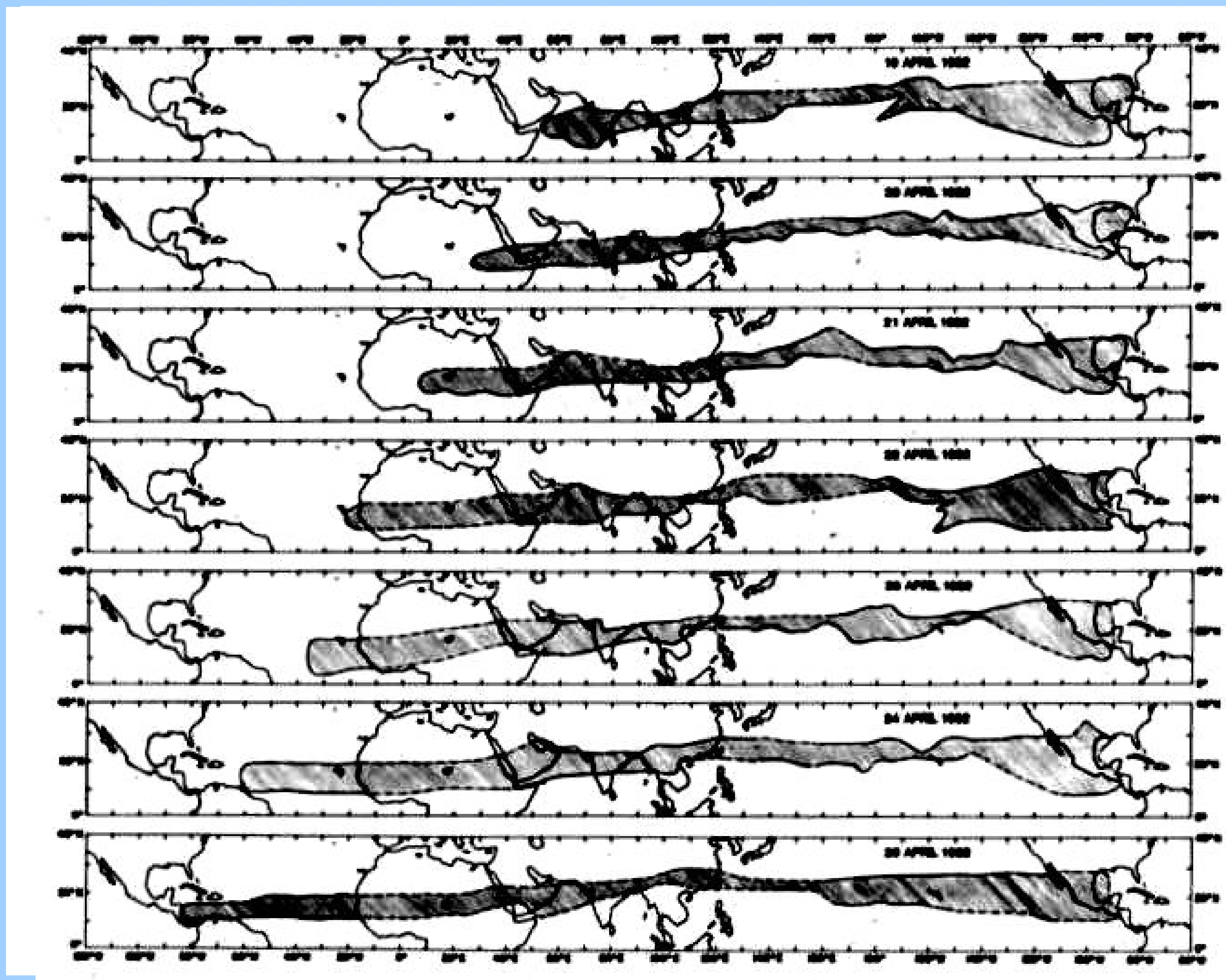
El Chichón, before the 1982 eruptions

Alan Robock
Department of Environmental Sciences

El Chichón, after the 1982 eruptions

El Chichón, 1982



(Robock and Matson, 1983)

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Department of Environmental Sciences

1783-84, The Lakagígar (Laki), Iceland volcano erupted for 8 months, filling the atmosphere with particles, cooling the Eurasian continent and causing a collapse of the African and Indian monsoons.

Constantin-François de Chasseboeuf,
Comte de Volney
Travels through Syria and Egypt, in the years 1783, 1784, and 1785, Vol. I
Dublin, 258 pp. (1788)

"The inundation of 1783 was not sufficient, great part of the lands therefore could not be sown for want of being watered, and another part was in the same predicament for want of seed. In 1784, the Nile again did not rise to the favorable height, and the dearth immediately became excessive. Soon after the end of November, the famine carried off, at Cairo, nearly as many as the plague; the streets, which before were full of beggars, now afforded not a single one: all had perished or deserted the city."

By January 1785, 1/6 of the population of Egypt had either died or left the country in the previous two years.

In addition there was
Famine in India and China in 1783

The Chalisa Famine devastated India as the monsoon failed in the summer of 1783.

The Great Tenmei Famine in Japan in 1783-1787, caused by the collapse of the East Asian monsoon, was locally exacerbated by the Mount Asama eruption of 1783.

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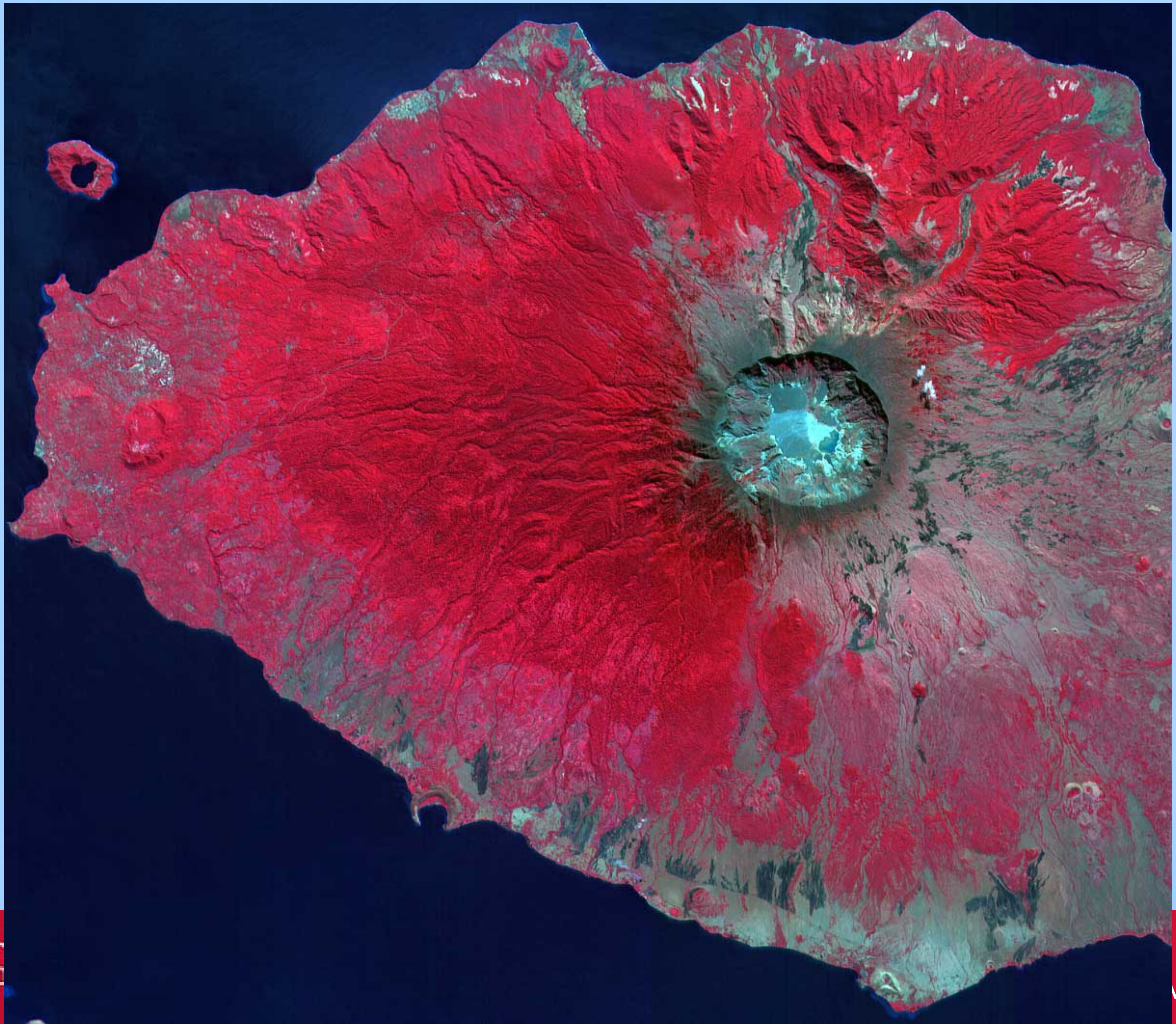
Department of Environmental Sciences

Tambora in 1815, together with an eruption from an unknown volcano in 1809, produced the "Year Without a Summer" (1816)



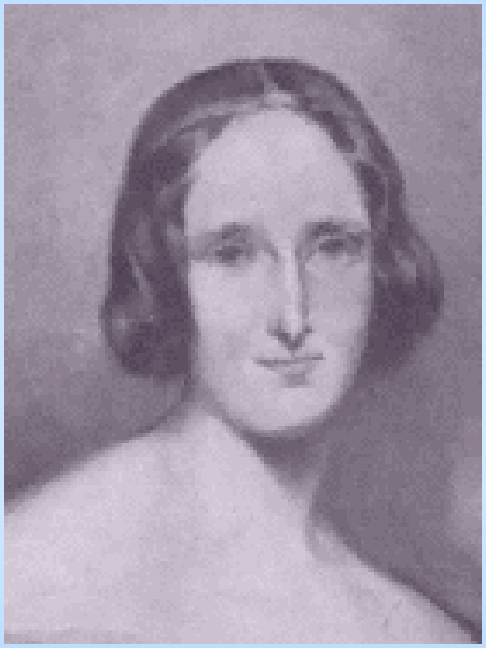
Tambora in 1815, together with an eruption from an unidentified volcano in 1809, produced the "Year Without a Summer" (1816)

Alan Robock
al Sciences

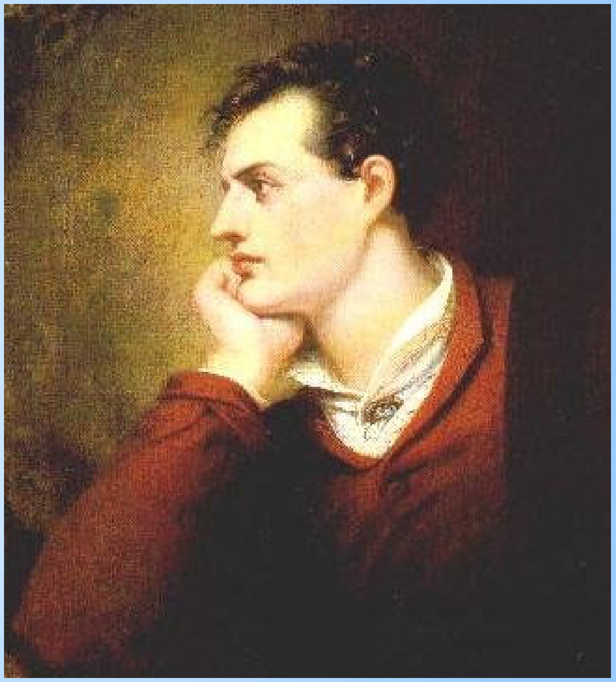
Alan Robock
Department of Environmental Sciences

Tambora, 1815, produced the "Year Without a Summer" (1816)

Percy Bysshe Shelley



Mary Shelley



George Gordon, Lord Byron

Alan Robock
Department of Environmental Sciences


LORD BYRON
POÊTE ANGLAIS
AUTEUR DU
PRISONER of CHILLON
HABITA LA
VILLA DIODATI
EN 1816
YCOMPOSA LE 3me CHANT
DE
CHILDE HAROLD

THE VAMPYRE; A TALE

by John William Polidori
written in 1816, published in 1819

But first on earth, as Vampyre sent,
Thy corpse shall from its tomb be rent;
Then ghastly haunt the native place,
And suck the blood of all thy race;
There from thy daughter, sister, wife,
At midnight drain the stream of life;
Yet loathe the banquet which perforce
Must feed thy livid living corpse,
Thy victims, ere they yet expire,
Shall know the demon for their sire.

The guardians hastened to protect Miss Aubrey; but when they arrived, it was too late. Lord Ruthven had disappeared, and Aubrey's sister had glutted the thirst of a VAMPYRE!

Tambora, 1815, produced the "Year Without a Summer" (1816)

"Darkness"
by Byron

I had a dream, which was not all a dream.
The bright sun was extinguish'd, and the stars
Did wander darkling in the eternal space,
Rayless, and pathless, and the icy earth
Swung blind and blackening in the moonless air;
Morn came and went—and came, and brought no day,
And men forgot their passions in the dread
Of this their desolation; and all hearts
Were chill'd into a selfish prayer for light:
And they did live by watchfires—and the thrones,
The palaces of crowned kings—the huts,
The habitations of all things which dwell,
Were burnt for beacons; cities were consumed,
And men were gather'd round their blazing homes
To look once more into each other's face; . . .

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Conclusions

A nuclear war between any nuclear states, using much less than 1% of the current nuclear arsenal, would produce climate change unprecedented in human history.

Such a "small" nuclear war could reduce food production by 10% to 40% for a decade, with massive increases in ultraviolet radiation.

Nuclear winter theory is correct.

The current arsenal can still produce nuclear winter, producing global famine.

The effects of regional or global nuclear war would last for more than a decade.

Alan Robock
Department of Environmental Sciences

“How does it feel?”

Bob Dylan (1965), *Like a Rolling Stone*

RUTGERS

I'm sorry. This has really been a bummer, and it was not nice of me to present you with such a depressing story.

So what do you do with this information?

The most natural reaction is to try to forget it. As Mark Twain said,

"**Denial ain't just a river in Egypt**."

Alan Robock
Department of Environmental Sciences

History of nuclear weapons treaties

Treaties to limit the testing of weapons

Year signed	Treaty
1963	**Partial Test Ban Treaty**: Prohibited all testing of nuclear weapons except underground.
1974	**Threshold Test Ban Treaty** (TTBT): This treaty between the United States and the Soviet Union established a nuclear threshold through the prohibition of the testing of new or existing nuclear weapons with a yield exceeding 150 kilotons.
1976	**Peaceful Nuclear Explosions Treaty** (PNET): This treaty between the United States and the Soviet Union prohibits peaceful nuclear explosions not covered by the Threshold Test Ban Treaty, and verifies all data exchanges and visits to sites of explosions through national technical means.
1996 not yet in force	**Comprehensive Test Ban Treaty** (CTBT): An international treaty (currently with 181 state signatures and 148 state ratifications) that bans all nuclear explosions in all environments. While the treaty is not in force, Russia has not tested a nuclear weapon since 1990 and the United States has not since 1992.

(from https://en.wikipedia.org/wiki/Nuclear_disarmament and https://www.armscontrol.org/treaties)

History of nuclear weapons treaties. Treaties to limit the number of weapons

Year signed	Treaty
1968 into force 1970 extended indefinitely in 1995	**Nuclear Non-Proliferation Treaty** (NPT): An international treaty (currently with 191 member states) to limit the spread of nuclear weapons. The treaty has three main pillars: nonproliferation, disarmament, and the right to peacefully use nuclear technology. But Article VI, which commits parties to "a treaty on general and complete disarmament" has been ignored.
1972	**Interim Agreement on Offensive Arms** (Strategic Arms Limitation Treaty - SALT I): The Soviet Union and the United States agreed to a freeze in the number of intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) that they would deploy.
1972 U.S. withdrew 2002	**Anti-Ballistic Missile Treaty** (ABM): The United States and Soviet Union could deploy ABM interceptors at two sites, each with up to 100 ground-based launchers for ABM interceptor missiles. In a 1974 Protocol, the US and Soviet Union agreed to only deploy an ABM system to one site, so they could not be used as a nation-wide defense.
1979	**Strategic Arms Limitation Treaty** (SALT II): Replacing SALT I, SALT II limited both the Soviet Union and the United States to an equal number of ICBM launchers, SLBM launchers, and heavy bombers. Also placed limits on Multiple Independent Reentry Vehicles (MIRVs).
1987 U.S. withdrew 2019	**Intermediate-Range Nuclear Forces Treaty** (INF): Created a ban on short- and long-range nuclear weapons systems, as well as an intrusive verification regime for the U.S. and Soviet Union.
1991 ratified 1994	**Strategic Arms Reduction Treaty** (START I): Limited long-range nuclear forces in the United States and the newly independent states of the former Soviet Union to 6,000 attributed warheads on 1,600 ballistic missiles and bombers.
1992 U.S. withdrew 2020	**Open Skies Treaty**: Establishes a regime of unarmed aerial observation flights over state territories and enhances mutual understanding of and increase transparency in military forces and activities.
1993 never put into force	**Strategic Arms Reduction Treaty II** (START II): START II was a bilateral agreement between the US and Russia which attempted to commit each side to deploy no more than 3,000 to 3,500 warheads by December 2007 and also included a prohibition against deploying MIRVs on ICBMs
2002 into force 2003	**Strategic Offensive Reductions Treaty** (SORT or Moscow Treaty): A very loose treaty that is often criticized by arms control advocates for its ambiguity and lack of depth, Russia and the United States agreed to reduce their "strategic nuclear warheads" (a term that remained undefined in the treaty) to between 1,700 and 2,200 by 2012. Was superseded by New Start Treaty in 2010.
2010 into force 2011	**New Strategic Arms Reduction Treaty** (New START): Replaces SORT treaty, reduces deployed nuclear warheads by about half, will remain in force until at least 2026.

(from https://en.wikipedia.org/wiki/Nuclear_disarmament and https://www.armscontrol.org/treaties)

Alan Robock
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1972 U.S. withdrew 2002	**Anti-Ballistic Missile Treaty** (ABM): The United States and Soviet Union could deploy ABM interceptors at two sites, each with up to 100 ground-based launchers for ABM interceptor missiles. In a 1974 Protocol, the US and Soviet Union agreed to only deploy an ABM system to one site, so they could not be used as a nation-wide defense.
1979	**Strategic Arms Limitation Treaty** (SALT II): Replacing SALT I, SALT II limited both the Soviet Union and the United States to an equal number of ICBM launchers, SLBM launchers, and heavy bombers. Also placed limits on Multiple Independent Reentry Vehicles (MIRVs).
1987 U.S. withdrew 2019	**Intermediate-Range Nuclear Forces Treaty** (INF): Created a ban on short- and long-range nuclear weapons systems, as well as an intrusive verification regime for the U.S. and Soviet Union.
1991 ratified 1994	**Strategic Arms Reduction Treaty** (START I): Limited long-range nuclear forces in the United States and the newly independent states of the former Soviet Union to 6,000 attributed warheads on 1,600 ballistic missiles and bombers.
1992 U.S. withdrew 2020	**Open Skies Treaty**: Establishes a regime of unarmed aerial observation flights over state territories and enhances mutual understanding of and increase transparency in military forces and activities.
1993 never put into force	**Strategic Arms Reduction Treaty II** (START II): START II was a bilateral agreement between the US and Russia which attempted to commit each side to deploy no more than 3,000 to 3,500 warheads by December 2007 and also included a prohibition against deploying MIRVs on ICBMs
2002 into force 2003	**Strategic Offensive Reductions Treaty** (SORT or Moscow Treaty): A very loose treaty that is often criticized by arms control advocates for its ambiguity and lack of depth, Russia and the United States agreed to reduce their "strategic nuclear warheads" (a term that remained undefined in the treaty) to between 1,700 and 2,200 by 2012. Was superseded by New Start Treaty in 2010.
2010 into force 2011	**New Strategic Arms Reduction Treaty** (New START): Replaces SORT treaty, reduces deployed nuclear warheads by about half, will remain in force until at least 2026.

RUTGERS

(from https://en.wikipedia.org/wiki/Nuclear_disarmament and https://www.armscontrol.org/treaties)

Alan Robock
Department of Environmental Sciences

Text of the Treaty Between the United States of America and the Russian Federation on Strategic Offensive Reductions (SORT treaty)

May 24, 2002

Article I

Each Party shall reduce and limit strategic nuclear warheads, as stated by the President of the United States of America on November 13, 2001 and as stated by the President of the Russian Federation on November 13, 2001 and December 13, 2001 respectively, so that by December 31, 2012 the aggregate number of such warheads does not exceed 1700-2200 for each Party. Each Party shall determine for itself the composition and structure of its strategic offensive arms, based on the established aggregate limit for the number of such warheads.

http://www.armscontrol.org/documents/sort.asp

Alan Robock
Department of Environmental Sciences

President Barack Obama and President Dmitry Medvedev of Russia sign the New START Treaty during a ceremony at Prague Castle in Prague, Czech Republic, April 8, 2010.

(Official White House Photo by Chuck Kennedy)
[Downloaded from http://www. whitehouse.gov/photos-and-video/photogallery/new-start-treaty-0 on July 5, 2010.]

Alan Robock
Department of Environmental Sciences

New START requires each side, within 7 years of the treaty coming into force, to reduce deployed strategic warheads to a maximum of 1550 per side, but each long-range bomber counts as one warhead no matter how many it has.

Expires Feb. 21, 2026, having just been extended by 5 years.

But 4000 nuclear warheads (in the arsenals of Russia and the US under this treaty) are enough to produce nuclear winter.

Alan Robock
Department of Environmental Sciences

Policy Implications of the Use of Nuclear Weapons

Only nuclear disarmament will prevent the possibility of a nuclear environmental catastrophe.

Continuing American and Russian reductions set an example for the world, maintain the nuclear deterrence of each, and dramatically lower the chances of nuclear winter, but are not enough.

WEAPONS ALREADY BANNED

There are already international conventions prohibiting biological weapons, chemical weapons, land mines and cluster munitions, but no comparable treaty – as yet – for nuclear weapons. The international community must address this legal anomaly. As with the negotiating processes that resulted in treaties banning land mines and cluster munitions, likeminded governments should work in close partnership with civil society to bring about a nuclear weapons ban regardless of resistance from states possessing the weapons.

✗ BIOLOGICAL WEAPONS

Banned under the Biological Weapons Convention

1972

✗ CHEMICAL WEAPONS

Banned under the Chemical Weapons Convention

1993

✗ LAND MINES

Banned under the Anti-Personnel Mine Ban Treaty

1997

✗ CLUSTER MUNITIONS

Banned under the Convention on Cluster Munitions

2008

NUCLEAR WEAPONS

NOT YET BANNED BY TREATY

RUTGERS

Alan Robock
Department of Environmental Sciences

WEAPONS ALREADY BANNED

There are already international conventions prohibiting biological weapons, chemical weapons, land mines and cluster munitions, but no comparable treaty – as yet – for nuclear weapons. The international community must address this legal anomaly. As with the negotiating processes that resulted in treaties banning land mines and cluster munitions, likeminded governments should work in close partnership with civil society to bring about a nuclear weapons ban regardless of resistance from states possessing the weapons.

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Banned under the Anti-Personnel Mine Ban Treaty

1997

✗ CLUSTER MUNITIONS

Banned under the Convention on Cluster Munitions

2008

NUCLEAR WEAPONS

NOT YET BANNED BY TREATY

TPNW

Comes into force on January 22, 2021!

RUTGERS

Alan Robock
Department of Environmental Sciences

History of nuclear weapons treaties.

Treaties to ban nuclear weapons in certain places.

Year signed	Treaty
1961	**Antarctic Treaty**: Prohibits any measures of a military nature, including basing or testing nuclear weapons, in Antarctica
1967	**Latin America Nuclear Weapons Free Zone Treaty** (Treaty of Tlatelolco): Prohibits Latin American states from not only acquiring and possessing nuclear weapons, but also from allowing the storage or deployment of nuclear weapons on their territories by other states.
1967	**Outer Space Treaty**: Prevented states from placing nuclear weapons or other weapons of mass destruction into Earth's orbit, and prohibited states from installing such weapons on the Moon or celestial bodies or stationing them in outer space in any other manner.
1971	**Seabed Arms Control Treaty**: This treaty prevents the introduction of international conflict and nuclear weapons in areas already free of them.
1985 in force 1986	**South Pacific Nuclear Weapons Free Zone Treaty** (Treaty of Rarotonga): Prohibits the manufacture, possession, or control of nuclear explosives, the dumping of radioactive wastes at sea within the defined zone, and the testing or stationing nuclear explosive devices within state territories.
1995 in force 1997	**Southeast Asia Nuclear-Weapon-Free Zone Treaty** (Bangkok Treaty): Prohibits nuclear weapons in Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.
1996	**African Nuclear-Weapons-Free Zone Treaty** (Treaty of Pelindaba): Ensures the denuclearization of Africa.
2006 in force 2009	**Central Asia Nuclear-Weapon-Free-Zone Treaty** (CANWFZ): Prohibits nuclear weapons in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan.
2017 in force 2021	**Treaty on the Prohibition of Nuclear Weapons**: Prohibits possession, manufacture, development, and testing of nuclear weapons, stationing and installment of nuclear weapons or assistance in such activities, by its parties.

(from https://en.wikipedia.org/wiki/Nuclear_disarmament and https://www.armscontrol.org/treaties)

Alan Robock
Department of Environmental Sciences

The **Treaty of Tlatelolco** is the conventional name given to the **Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean**. It is embodied in the **OPANAL** (Spanish: *Organismo para la Proscripción de las Armas Nucleares en la América Latina y el Caribe*, English: the Agency for the Prohibition of Nuclear Weapons in Latin America and the Caribbean).

Treaty of Tlatelolco

Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean

Signed	14 February 1967
Location	Mexico City
Effective	22 April 1968
Condition	Deposit of ratifications (Art. 29) / waiver according to Article 29
Parties	33

Contents [hide]

1 Provisions
2 History
3 External links
4 References

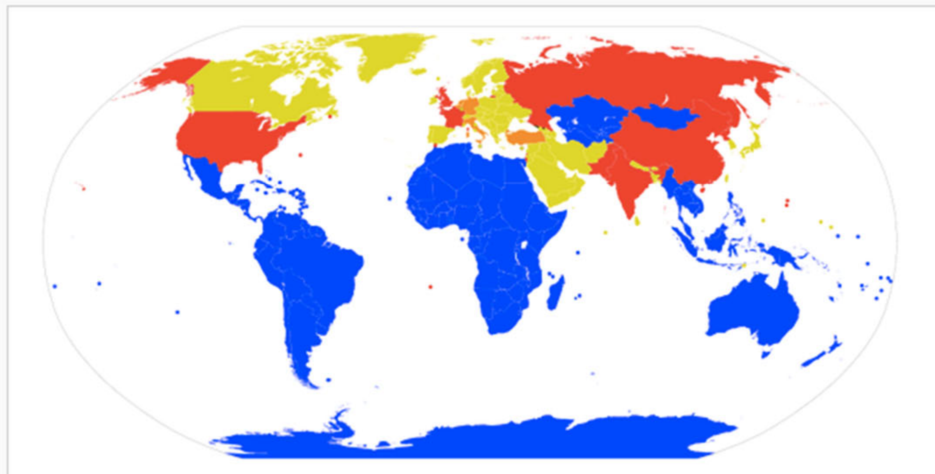
1982 Nobel Peace Prize to Alfonso García Robles

Provisions [edit]

Under the treaty, the states parties agree to prohibit and prevent the "testing, use, manufacture, production or acquisition by any means whatsoever of any nuclear weapons" and the "receipt, storage, installation, deployment and any form of possession of any nuclear weapons."

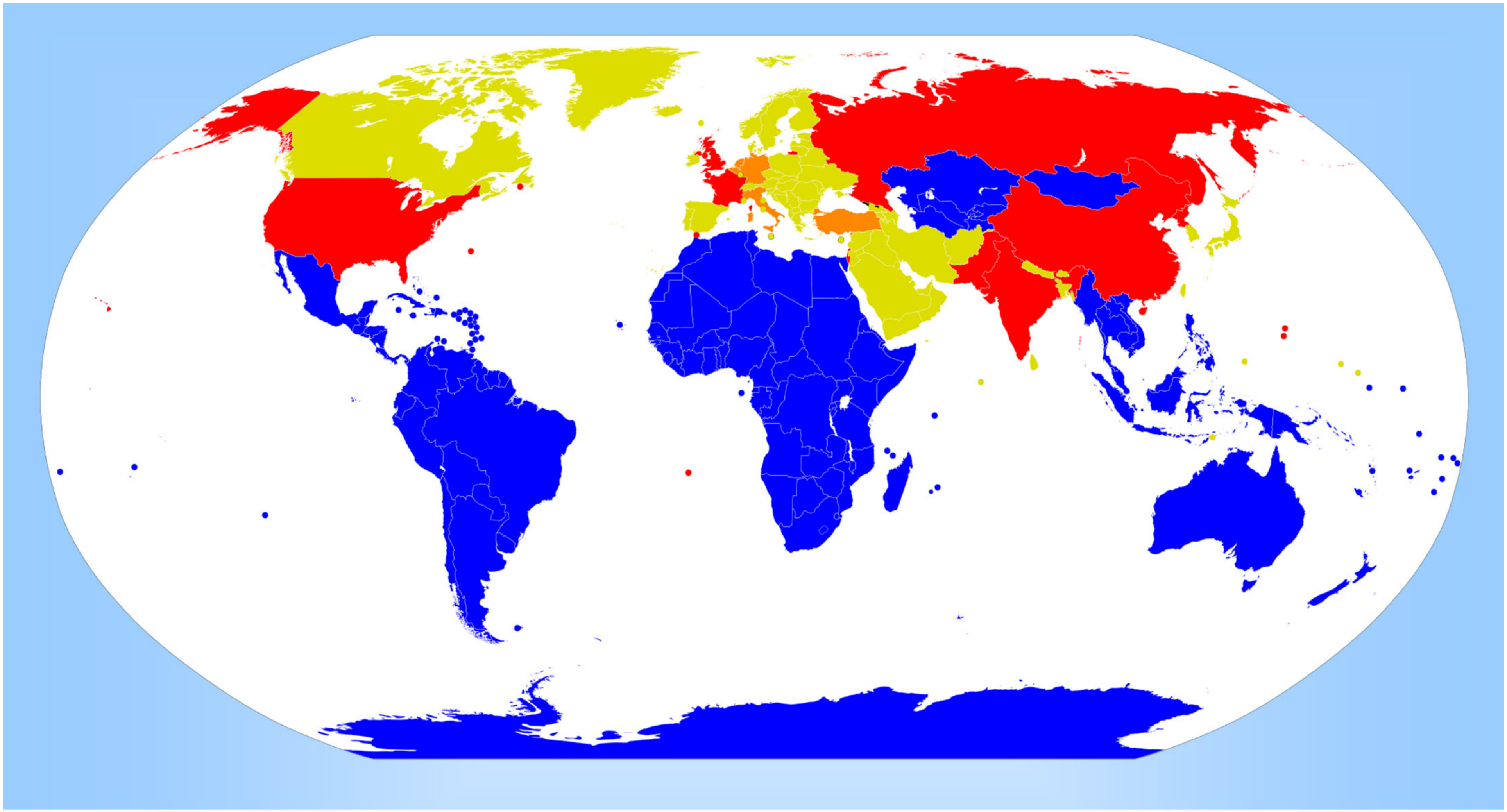
There are two additional protocols to the treaty:

Protocol I binds those overseas countries with



Nuclear-Weapon-Free Zones NW states Nuclear sharing NPT only

https://en.wikipedia.org/wiki/Treaty_of_Tlatelolco



	Nuclear-weapon-free zones by international treaty, including territories that belong to a Nuclear Weapons State that has agreed the territory is subject to a zone
	Nuclear weapons states and territories belonging to them that are not in any NWFZ
	Nuclear sharing (US nuclear arsenal stationed there for host country use in wartime)
	None of the above (but party to the Non Proliferation Treaty (NPT))

Alan Robock
Department of Environmental Sciences

History of nuclear weapons treaties.

Treaties to ban nuclear weapons in certain places.

Year signed	Treaty
1961	**Antarctic Treaty**: Prohibits any measures of a military nature, including basing or testing nuclear weapons, in Antarctica
1967	**Latin America Nuclear Weapons Free Zone Treaty** (Treaty of Tlatelolco): Prohibits Latin American states from not only acquiring and possessing nuclear weapons, but also from allowing the storage or deployment of nuclear weapons on their territories by other states.
1967	**Outer Space Treaty**: Prevented states from placing nuclear weapons or other weapons of mass destruction into Earth's orbit, and prohibited states from installing such weapons on the Moon or celestial bodies or stationing them in outer space in any other manner.
1971	**Seabed Arms Control Treaty**: This treaty prevents the introduction of international conflict and nuclear weapons in areas already free of them.
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2006 in force 2009	**Central Asia Nuclear-Weapon-Free-Zone Treaty** (CANWFZ): Prohibits nuclear weapons in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan.
2017 in force 2021	**Treaty on the Prohibition of Nuclear Weapons**: Prohibits possession, manufacture, development, and testing of nuclear weapons, stationing and installment of nuclear weapons or assistance in such activities, by its parties.

RUTGERS

(from https://en.wikipedia.org/wiki/Nuclear_disarmament and https://www.armscontrol.org/treaties)

Alan Robock
Department of Environmental Sciences

Go to http://www.globalzero.org/ to join the movement.

GLOBAL ZERO

A WORLD WITHOUT NUCLEAR WEAPONS

Go to http://www.icanw.org to join the movement.

ican

international campaign to abolish nuclear weapons

Al Gore

Nobel Peace Prize address
Dec. 10, 2007

"More than two decades ago, scientists calculated that nuclear war could throw so much debris and smoke into the air that it would block life-giving sunlight from our atmosphere, causing a 'nuclear winter.' Their eloquent warnings here in Oslo helped galvanize the world's resolve to halt the nuclear arms race."

Alan Robock
Department of Environmental Sciences

Bulletin of the Atomic Scientists

IT IS 5 MINUTES TO MIDNIGHT

Feature

Bulletin of the Atomic Scientists
68(5) 66–74

DOI: 10.1177/0096340212459127
http://thebulletin.sagepub.com
SAGE

Self-assured destruction: The climate impacts of nuclear war

Alan Robock and Owen Brian Toon

http://climate.envsci.rutgers.edu/pdf/RobockToonSAD.pdf

Nuclear states claim they maintain their arsenals not to use them, but for deterrence.

Clearly, nuclear weapons do not deter attacks by terrorists or cyberwarfare, or attacks on nuclear nations by conventional weapons. Examples (nuclear nation in red):

Soviet takeover of Eastern Europe: US

Six-Day War: Israel, Egypt, Jordan, and Syria

Malvinas [Falkland Islands] War: UK, Argentina

Afghanistan: USSR

Afghanistan: US

Vietnam: US

Alan Robock
Department of Environmental Sciences

Nuclear states claim they maintain their arsenals not to use them, but for deterrence.

But do nuclear weapons deter attacks by other nuclear states? There has been no major war between nuclear powers since World War II. Why?

Significant contributors:

- General decline in violence
- Growth in international commerce
- Increase in number of democracies
- NATO, UN, EU, acceptance of national boundaries

It is impossible to know the role of nuclear deterrence, but if it is important, the real question is:

Will deterrence last forever?

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

Severity Index

1-Very slight alarm, quickly resolved.

2-More serious incident with general risk, quickly resolved.

3-Specific, serious risk possibly leading to escalation with other state. Requires more complex resolution.

4-Serious risk to wider public; has potential to cause widespread casualties and damage beyond military personnel and property, or to cause escalation in conflict.

5-Nuclear devices detonate and cause casualties, or confrontation nearly leads to the use of nuclear devices.

https://www.wagingpeace.org/nuclear-close-calls/

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

November 10, 1950—Plane accidentally drops nuclear weapon
American plane in Canada, Severity: 4
A B-50 bomber experiencing mechanical failure drops its Mark 4 atomic bomb over Quebec. Its conventional explosives detonate when it lands in a river, scattering nearly 100 pounds of uranium.

March 11, 1958—B-47 bomber accidentally drops a Mark 6 atomic bomb into backyard in South Carolina
United States, Severity: 4

October 15, 1959—B-52 with nuclear weapons on board collision over Hardinsberg, Kentucky with refueling aircraft
United States, Severity: 4

January 24, 1961—Plane crash drops two nuclear bombs into Goldsboro, NC
United States, Severity: 4

October 25, 1962—False alarm of sabotage (actually a bear entering a Wisconsin base) almost leads to attack
United States, Severity: 4

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

October 27, 1962 is now commonly referred to as "Black Saturday" as it was the most dangerous day of the Cuban Missile Crisis, when both the United States and the Soviet Union came close to initiating nuclear attack multiple times.

Cruise missiles pointed at the United States
Soviet base in Cuba, Severity: 4
In the early morning of October 27, the Soviets deploy nuclear cruise missiles in firing position to within 15 miles of the U.S. naval base at Guantanamo Bay. The U.S. remains completely unaware.

Wartime radio frequencies signal war
Soviet Union, Severity: 4

U2 spy plane enters Soviet air space
United States, Severity: 4
Meanwhile, an American U2 spy plane enters Soviet air space, attracting the attention of Soviet MIG interceptors, which are ordered to shoot the plane down. American fighter planes loaded with nuclear missiles and ordered to shoot at their own discretion are sent to escort the U2 plane back to American ground.

U2 spy plane shot down over Cuba
United States, Severity: 5

Submarine almost launches nuclear torpedo
Soviet Union, Severity: 5
Perhaps most seriously, eleven U.S. Navy destroyers and aircraft carrier U.S.S. Randolph corner a nuclear-armed Soviet submarine near Cuba. Authorized to launch nuclear torpedoes without express permission from Moscow, two of the three submarine officers onboard vote to launch. The third officer, Vasili Arkhipov, refuses to authorize the launch. Had any other officer been in Arkhipov's place—whether one who agreed with the two other officers, or one who was more easily pressured by the other officers to authorize the launch—nuclear war likely would have occurred.

https://www.wagingpeace.org/nuclear-close-calls/

THE FUTURE OF LIFE AWARD

Celebrating the Unsung Heroes of our Time

https://futureoflife.org/future-of-life-award/

2017 Winner

Vasili Arkhipov

Vasili Arkhipov single-handedly prevented nuclear war during the height of the Cuban Missile Crisis. Arkhipov's submarine captain, thinking their sub was under attack by American forces, wanted to launch a nuclear weapon at the ships above. Arkhipov, with the power of veto, said no, thus averting nuclear war.

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

November 2, 1962—Captured secret agent gives false alarm of nuclear attack
United Kingdom, Severity: 4

January 17, 1966— B-52 bomber collides with a plane refueling it mid-air spewing radioactive material
American plane in Spain, Severity: 4
Seven crew members are killed in the crash, and American military crew brought in to clean up after the crash show high rates of radiation-related illnesses today. Spanish people from the area also contracted cancer and other illnesses at higher rates, and sections of Palomares remain highly radioactive today.

January 21, 1968—American B-52 bomber crash spews radioactive material
American base in Greenland, Severity: 4
The plane crashes into sea ice, causing all four bombs to detonate and radioactive material to be spewed into the ocean. Had the plane hit Thule Air Base, American Strategic Air Command would likely have assumed attack and retaliated.

November 15, 1969—American and Soviet submarines collide
Barents Sea, Severity: 4

November 9, 1979—False alarm nearly leads to nuclear strike
United States, Severity: 4
Someone mistakenly placed military exercise tapes in the operational missile detection computer system.

September 18, 1980—Fire at a Titan II ICBM nuclear missile silo in Damascus, Arkansas
United States, Severity: 4
A missile repairman drops a wrench. The fuel explodes, killing an airman, and catapults the warhead out of the silo

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

September 26, 1983—Radar malfunction warns of missile attack
Soviet Union, Severity: 4
The Soviet soldier on duty, Stanislav Petrov, suspects a malfunction and does not call for a retaliatory Soviet strike. (Documented in the movie, "The Man Who Saved the World," available on Amazon Prime)

November 2-11, 1983—NATO military exercise Able Archer 83 interpreted as attack
Soviet Union, Severity: 4

August 19-21, 1991—Coup leaders confiscate nuclear briefcases from Gorbachev
Soviet Union, Severity: 4

January 25, 1995—Scientific rocket launch from Norway interpreted as nuclear missile
Russia, Severity: 4

May-June, 1999—Conflict almost includes nuclear weapons
India and Pakistan, Severity: 5
The incident escalates until both sides threaten to use nuclear weapons. The crisis is temporarily defused by mediation from President Clinton.

May 23, 2008—Fire in missile silo burns unnoticed
United States, Severity: 4

August 5, 2014—Nuclear power plant sabotaged
Belgium, Severity: 4

https://www.wagingpeace.org/nuclear-close-calls/

THE FUTURE OF LIFE AWARD

Celebrating the Unsung Heroes of our Time

https://futureoflife.org/future-of-life-award/

2018 Winner

Stanislav Petrov

One of the closest calls occurred thirty-five years ago, on September 26, 1983, when Stanislav Petrov chose to ignore the Soviet early-warning detection system that had erroneously indicated five incoming American nuclear missiles. With his decision to ignore algorithms and instead follow his gut instinct, Petrov helped prevent an all-out US-Russian nuclear war, as detailed in the documentary film "The Man Who Saved the World".

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

November 10, 1950—Plane accidentally drops nuclear weapon
American plane in Canada, Severity: 4
A B-50 bomber experiencing mechanical failure drops its Mark 4 atomic bomb over Quebec. Its conventional explosives detonate when it lands in a river, scattering nearly 100 pounds of uranium.

March 10, 1956—Plane carrying nuclear weapons disappears
United States, Severity: 3
A B-47 carrying two types of nuclear capsules from Florida to a base overseas loses contact over the Mediterranean, and is never found.

July 27, 1956—Plane crashes into bomb storage
American base in United Kingdom, Severity: 3
A B-47 bomber skids off the runway on landing and rips into a storage igloo containing Mark 6 atomic bombs before exploding. The bombs do not detonate.

November 5, 1956—False alarm of Soviet attack (flight of swans) during Suez Crisis
United States, Soviet Union, United Kingdom, and France, Severity: 3

January 31, 1958—Plane fire on runway turns bomb into an 8,000 pound block of radioactive metal.
American base in Morocco, Severity: 3

February 5, 1958—Plane collision drops nuclear weapon over water and the bomb is never found
United States, Severity: 3

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

March 11, 1958—B-47 bomber accidentally drops a Mark 6 atomic bomb into backyard in South Carolina
United States, Severity: 4

November 4, 1958—B-47 bomber crash into a field near Abilene, Texas with Mark 39 hydrogen bombs on board
United States, Severity: 3

October 15, 1959—B-52 with nuclear weapons on board collision over Hardinsberg, Kentucky with refueling aircraft
United States, Severity: 4

October 5, 1960—False alarm (radar misinterprets moonrise over Norway as missiles) suggests attack
American base in Greenland, Severity: 3

January 19, 1961—B-52 bomber crash over Monticello, Utah with nuclear weapons on board
United States, Severity: 3

January 24, 1961—Plane crash drops two nuclear bombs into Goldsboro, NC
United States, Severity: 4

November 24, 1961—Communications failure (actually lines down in Colorado) suggests enemy attack
United States, Severity: 3

August 23, 1962—Navigational error of nuclear B-52 into Soviet airspace
United States, Severity: 3

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

October 1962
Throughout the Cuban Missile Crisis of October 1962, miscommunications due to the chaotic nature of the issue at hand as well as sheer carelessness led to multiple near-nuclear confrontations.

Miscommunication possibly signals attack
United States and European allies, Severity: 3

Prolonged UK exercise possibly signals attack
United Kingdom, Severity: 3

October 24, 1962—Satellite explosion misinterpreted as attack
Soviet Union, Severity: 3

October 25, 1962—False alarm of sabotage (actually a bear entering a Wisconsin base) almost leads to attack
United States, Severity: 4

October 26, 1962—Unannounced missile test possibly signals attack to Soviets
United States, Severity: 3

October 26, 1962—Unannounced missile test causes false alarm of attack to Americans
United States, Severity: 3

October 26, 1962—Nuclear missile left alone with launch codes
United States, Severity: 3
A single operator could have singlehandedly launched a nuclear-armed missile.

Alan Robock
Department of Environmental Sciences

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

October 27, 1962 is now commonly referred to as "Black Saturday" as it was the most dangerous day of the Cuban Missile Crisis, when both the United States and the Soviet Union came close to initiating nuclear attack multiple times.

Cruise missiles pointed at the United States
Soviet base in Cuba, Severity: 4
In the early morning of October 27, the Soviets deploy nuclear cruise missiles in firing position to within 15 miles of the U.S. naval base at Guantanamo Bay. The U.S. remains completely unaware.

Wartime radio frequencies signal war
Soviet Union, Severity: 4

U2 spy plane enters Soviet air space
United States, Severity: 4
Meanwhile, an American U2 spy plane enters Soviet air space, attracting the attention of Soviet MIG interceptors, which are ordered to shoot the plane down. American fighter planes loaded with nuclear missiles and ordered to shoot at their own discretion are sent to escort the U2 plane back to American ground.

U2 spy plane shot down over Cuba
United States, Severity: 5

Submarine almost launches nuclear torpedo
Soviet Union, Severity: 5
Perhaps most seriously, eleven U.S. Navy destroyers and aircraft carrier U.S.S. Randolph corner a nuclear-armed Soviet submarine near Cuba. Authorized to launch nuclear torpedoes without express permission from Moscow, two of the three submarine officers onboard vote to launch. The third officer, Vasili Arkhipov, refuses to authorize the launch. Had any other officer been in Arkhipov's place—whether one who agreed with the two other officers, or one who was more easily pressured by the other officers to authorize the launch—nuclear war likely would have occurred.

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

October 28, 1962—Misplaced simulation tape interpreted as attack from Cuba
United States, Severity: 4

October 28, 1962—False alarm and miscommunication suggest missile attack
United States, Severity: 3

November 2, 1962—Captured secret agent gives false alarm of nuclear attack
United Kingdom, Severity: 4

November 9, 1965—Alarm failure announces nuclear attack
United States, Severity: 2

December 5, 1965—Plane falls off the deck of the U.S.S. Ticonderoga aircraft carrier
American plane over the Pacific Ocean, Severity: 3
A bomber carrying a nuclear weapon rolls into the ocean. Pilot, plane, and weapon are never found.

January 17, 1966— B-52 bomber collides with a plane refueling it mid-air spewing radioactive material
American plane in Spain, Severity: 4
Seven crew members are killed in the crash, and American military crew brought in to clean up after the crash show high rates of radiation-related illnesses today. Spanish people from the area also contracted cancer and other illnesses at higher rates, and sections of Palomares remain highly radioactive today.

May 23, 1967—Communications failure suggests nuclear attack
United States, Severity: 3
Multiple early warning radar sites around the world go offline, leading the U.S. to again fear that the Soviets have disabled American radar in the first stage of a nuclear attack. Nuclear bombers prepare to take flight until it is determined that a solar flare knocked out the radar systems.

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

January 21, 1968—American B-52 bomber crash spews radioactive material
American base in Greenland, Severity: 4
The plane crashes into sea ice, causing all four bombs to detonate and radioactive material to be spewed into the ocean. Had the plane hit Thule Air Base, American Strategic Air Command would likely have assumed attack and retaliated.

April 11, 1968—Nuclear submarine sinks
Soviet submarine in Pacific Ocean, Severity: 3

November 15, 1969—American and Soviet submarines collide
Barents Sea, Severity: 4

October 24-25, 1973—False alarm signals nuclear attack during Arab-Israeli War
United States, Severity: 3

August 1, 1974—Unfit president holds power to launch nuclear attack
United States, Severity: 3
In his last weeks in office during the Watergate Crisis, Nixon is depressed, drinking heavily, and extremely unstable.

November 9, 1979—False alarm nearly leads to nuclear strike
United States, Severity: 4
Someone mistakenly placed military exercise tapes in the operational missile detection computer system.

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

March 15, 1980—Training exercise interpreted as attack
United States, Severity: 2

June 3 & 6, 1980—Faulty computer chip announces missile attack
United States, Severity: 3

September 18, 1980—Fire at a Titan II ICBM nuclear missile silo in Damascus, Arkansas
United States, Severity: 4
A missile repairman drops a wrench. The fuel explodes, killing an airman, and catapults the warhead out of the silo

September 26, 1983—Radar malfunction warns of missile attack
Soviet Union, Severity: 3
The Soviet soldier on duty, Stanislav Petrov, suspects a malfunction and does not call for a retaliatory Soviet strike.

November 2-11, 1983—NATO military exercise Able Archer 83 interpreted as attack
Soviet Union, Severity: 4

January 10, 1984—Malfunction causes nuclear-armed missile to almost launch
United States, Severity: 3

August 19-21, 1991—Coup leaders confiscate nuclear briefcases from Gorbachev
Soviet Union, Severity: 4

January 25, 1995—Scientific rocket launch from Norway interpreted as nuclear missile
Russia, Severity: 4

Nuclear Close Calls

by Sarah Witmer, August 31, 2017

May-June, 1999—Conflict almost includes nuclear weapons
India and Pakistan, Severity: 5
The incident escalates until both sides threaten to use nuclear weapons. The crisis is temporarily defused by mediation from President Clinton.

December 2001-October 2002—Conflict almost includes nuclear weapons
Pakistan, Severity: 3

August 2006—Nuclear missile fuses accidentally shipped to Taiwan
United States, Severity: 2

August 29-30, 2007—Nuclear missiles accidentally loaded onto plane
United States, Severity: 3

May 23, 2008—Fire in missile silo burns unnoticed
United States, Severity: 4

October 23, 2010—Communications failure leads to lost contact with nuclear missiles
United States, Severity: 2

July 28, 2012—Activists break into top-secret uranium production plant
United States, Severity: 3

August 5, 2014—Nuclear power plant sabotaged
Belgium, Severity: 4

https://www.wagingpeace.org/nuclear-close-calls/

How many other incidents were there that were kept secret?

How much longer will our luck hold out?

Alan Robock
Department of Environmental Sciences

Box 8.3 | Volcanic Eruptions as Analogues

Volcanic eruptions provide a natural experiment of a stratospheric aerosol cloud that can serve to inform us of the impacts of the proposed production of such a cloud as a means to control the climate, which is one method of geoengineering (Rasch et al., 2008); see Section 7.7. For example, Trenberth and Dai (2007) showed that the Asian and African summer monsoon, as well as the global hydrological cycle, was weaker for the year following the 1991 Mt Pinatubo eruption, which is consistent with climate model simulations (Robock et al., 2008). MacMynowski et al. (2011) showed that because the climate system response of the hydrological cycle is rapid, forcing from volcanic eruptions, which typically last about a year, can serve as good analogues for longer-lived forcing. The formation of sulphate aerosols, their transport and removal, their impacts on ozone chemistry, their RF, and the impacts on whitening skies all also serve as good analogues for geoengineering proposals. Volcanic impacts on the carbon cycle because of more diffuse radiation (Mercado et al., 2009) and on remote sensing can also be useful analogues, and the impacts of contrail-generated sub-visual cirrus (Long et al., 2009) can be used to test the long-term impacts of a permanent stratospheric cloud.

Smoke from fires generated by nuclear explosions on cities and industrial areas, which could be lofted into the stratosphere, would cause surface cooling and a reduction of stratospheric ozone (Mills et al., 2008). Volcanic eruptions that produce substantial stratospheric aerosol clouds also serve as an analogue that supports climate model simulations of the transport and removal of stratospheric aerosols, their impacts on ozone chemistry, their RF, and the climate response. The use of the current global nuclear arsenal still has the potential to produce nuclear winter, with continental temperatures below freezing in summer (Robock et al., 2007a; Toon et al., 2008), and the use of only 100 nuclear weapons could produce climate change unprecedented in recorded human history (Robock et al., 2007b), with significant impacts on global agriculture (Ozdogan et al., 2013; Xia and Robock, 2013).

Intergovernmental Panel on Climate Change (IPCC)
Working Group I, Fifth Assessment Report

Alan Robock Become a fan

Distinguished Professor of Climatology, Rutgers University; director, Rutgers Undergraduate Meteorology Program

Ban Nuclear Weapons; Saving Money and Saving the World

Posted: 02/20/2014 5:13 pm EST | Updated: 02/20/2014 5:59 pm EST

MORE: Nuclear Power, Nuclear War, Nuclear Weapons, Nuclear Power, Nuclear Warfare, Politics News

Co-authored by Owen Brian Toon, Professor in the Department of Atmospheric and Oceanic Sciences at the University of Colorado, Boulder, btoon@lasp.colorado.edu

Nuclear winter - still possible but preventable: Alan Robock at TEDxHoboken

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Alan Robock
Department of Environmental Sciences

I've studied nuclear war for 35 years -- you should be worried. | Brian Toon | TEDxMileHigh

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Edit profile

Alan Robock ☮

@AlanRobock

Climate scientist, working on nuclear winter, volcanic eruptions and climate, geoengineering, and global warming. envsci.rutgers.edu/~robock

Manasquan, NJ, USA climate.envsci.rutgers.edu/nuclear/
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Former World Leaders Urge Ratification of Nuclear Arms Ban Treaty

Former World Leaders Urge Ratification of Nuclear Arms Ban Treaty

In an open letter, the onetime leaders implored their own governments to embrace an arms treaty negotiated at the U.N. three years ago. It is...

nytimes.com

Bulletin of the Atomic Scientists

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Home › An open letter to President-elect Trump about nuclear weapons and nuclear winter

An open letter to President-elect Trump about nuclear weapons and nuclear winter

11 NOVEMBER 2016

Alan Robock, Department of Environmental Sciences, Rutgers University

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Nuclear Notebook

An open letter to President-elect Trump about nuclear weapons and nuclear winter

11 NOVEMBER 2016

Alan Robock, Department of Environmental Sciences, Rutgers University

There are several first steps you can take to make the world safer.

You can change our nuclear policy to one of no first use of nuclear weapons. There are no circumstances in which we should use nuclear weapons to attack anyone. We can defend the Unnited States with our modern, precision-guided weapons, which do not require wholesale slaughter of innocent civilians.

You can take US land-based missiles off of hair-trigger alert. Any use of nuclear weapons requires deliberate thought, not immediate reaction during a time of panic and possible misinformation. What a message of peace taking US missiles off high-alert status will be to the world.

You can stand down our land-based missiles and begin to dismantle them as part of a rapid reduction of our nuclear arsenal. No treaty with Russia is needed, and President George H. W. Bush set a precedent for this by reducing our nuclear arsenal as the Soviet Union was coming apart. This unilateral action will have the two-fold effect of making accidental nuclear war much less likely and setting the world on a path to reducing the threat of global nuclear war and nuclear winter.

Your presidency is an unprecedented opportunity for positive change in the world. Reducing the threat of nuclear war and nuclear winter will make the United States safer and richer, and cement your status as a world leader. Please take advantage of this chance to be a real winner.

An Open Letter to President-Elect Trump about Nuclear Weapons and Nuclear Winter

01/10/2017 11:07 am

Alan Robock
Distinguished

Dear President-E

5. There are several first steps you can take to make the world safer.

A. You can change our nuclear policy to one of **no first use of nuclear weapons**. There are no circumstances in which we should use nuclear weapons to attack anyone. We can defend the United States with our modern, precision-guided weapons, which do not require wholesale slaughter of innocent civilians.

B. You can **take U.S. land-based missiles off of hair-trigger alert**. Any use of nuclear weapons requires deliberate thought, not immediate reaction during a time of panic and possible misinformation. What a message of peace this will be to the world.

C. You can **stand down our land-based missiles** and begin to dismantle them as part of a rapid reduction of our nuclear arsenal. No treaty with Russia is needed, and President George H. W. Bush set a precedent for this by reducing our nuclear arsenal as the Soviet Union was coming apart. This unilateral action will have the two-fold effect of making accidental nuclear war much less likely and setting the world on a path to reducing the threat of global nuclear war and nuclear winter.

RUTGE

nj.com True Jersey.

Opinion

Dear President-Elect Biden, please start with the easiest problem to solve | Opinion

Updated Oct 30, 2020; Posted Oct 18, 2020

Dr. Alan Robock was one of the scientists who helped to discover in the 1980s that a nuclear war between the U.S. and the Soviet Union smoke from fires ignited by nuclear explosions would block out the Sun, turning the Earth cold, dark and dry, killing plants and preventing agriculture for at least a year, producing global famine. The Doomsday Clock is now 100 seconds to midnight, the closest it has ever been.

By Star-Ledger Guest Columnist

By Alan Robock

https://www.nj.com/opinion/2020/10/dear-president-elect-biden-please-start-with-the-easiest-problem-to-solve-opinion.html

Ru

Robock
Sciences

We are lucky that for the past 75 years there has not been a second nuclear war. Here are the immediate steps you can take to make this even less likely:

1. Take U.S. land-based missiles off hair-trigger alert.
2. Give up the sole presidential authority to launch nuclear weapons.
3. Extend the New START Treaty with Russia for another five years.
4. Change our nuclear policy to one of no first use of nuclear weapons.
5. Stand down our land-based missiles and begin to dismantle them as part of a rapid reduction of our nuclear arsenal.

Alan Robock
Department of Environmental Sciences

Five Myths About Nuclear Weapons

Ward Wilson, *New York Times*, January 13, 2013

1. Nuclear weapons altered the course of World War II. (66 Japanese cities were destroyed by conventional weapons. Two more did not make a difference.)
2. Decisive destruction. (Mass destruction doesn't win wars; killing soldiers does.)
3. Nuclear deterrence. (Did not stop Falklands War, Yom Kippur War, or Soviets after World War II. Who won the wars in Afghanistan and Vietnam?)
4. Nuclear weapons have "kept the peace." (Absence of nuclear war since 1945 does not prove this.)
5. Irreversibility. (Technology cannot be uninvented, but it fades when no longer useful.)

Alan Robock
Department of Environmental Sciences

BAN NUCLEAR WEAPONS NOW

http://www.icanw.org

ican
international campaign to abolish nuclear weapons

Alan Robock
Department of Environmental Sciences

Mexico hosted the **Second Conference on the Humanitarian Impact of Nuclear Weapons** in Nayarit, February, 2014, attended by 146 nations, the United Nations, Red Cross, Red Crescent, and civil society.

In October 2015, states decided to hold a second OEWG to address concrete effective legal measures, legal provisions, and norms that will need to be concluded to attain and maintain a world without nuclear weapons. It operated as a subsidiary body of the General Assembly.

First session: February 22-26, 2016

Second session: May 2-4, 9-13, 2016

Third session: August 5, 16, 17, and 19, 2016

On 27 October 2016, the First Committee of the UN General Assembly, acting on the key recommendation of the OEWG, adopted resolution L41 to convene "a United Nations conference to negotiate a legally binding instrument to prohibit nuclear weapons, leading towards their total elimination" to be held March 27-31 and June 15 to July 7, 2017 "with the participation and contribution of international organizations and civil society representatives."

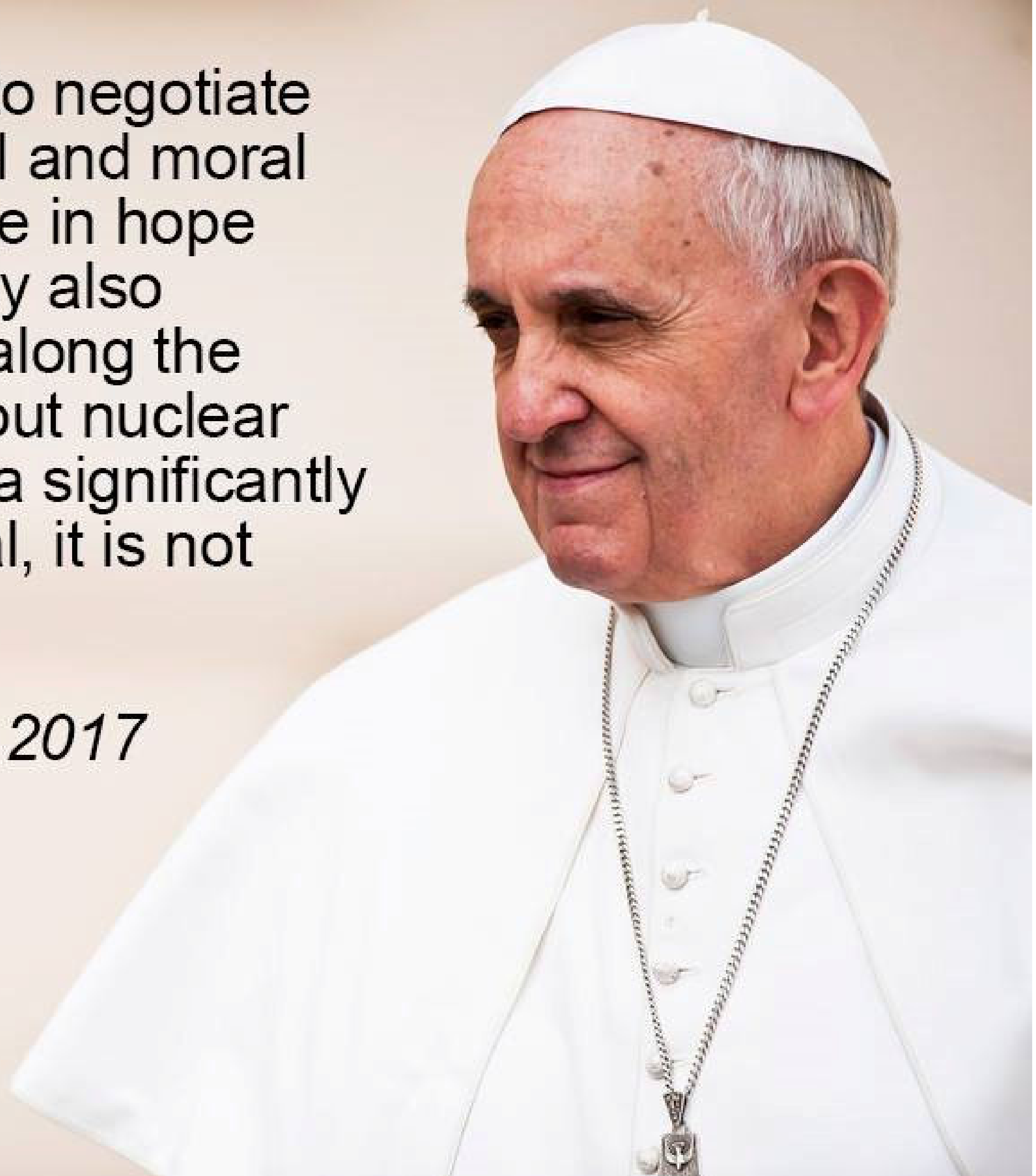
The voting result was **123** nations in favor and **38** against, with **16** abstentions. Of the 9 nuclear nations, North Korea voted in favor; China, Pakistan, and India abstained; and the US, UK, France, Russia, and Israel voted against.

The Full UN General Assembly voted to approve the recommendation on December 23, 2016.

Alan Robock
Department of Environmental Sciences

"This Conference intends to negotiate a Treaty inspired by ethical and moral arguments. It is an exercise in hope and it is my wish that it may also constitute a decisive step along the road towards a world without nuclear weapons. Although this is a significantly complex and longterm goal, it is not beyond our reach."

- Pope Francis, March 22, 2017



ican
international campaign to abolish nuclear weapons

First week of Ban negotiations at UN, March 27-31, 2017

Alan Robock
Department of Environmental Sciences


I'M BANNING NUCLEAR WEAPONS THIS WEEK.
BEAT THAT.

The New York Times | https://nyti.ms/2uRgH4p

AMERICAS

A Treaty Is Reached to Ban Nuclear Arms. Now Comes the Hard Part.

By RICK GLADSTONE JULY 7, 2017

UN Treaty on the Prohibition of Nuclear Weapons

What the Treaty Does

Comprehensively bans nuclear weapons and related activity. It will be illegal for parties to undertake any activities related to nuclear weapons. It bans the use, development, testing, production, manufacturing, acquiring, possession, stockpiling, transferring, receiving, threatening to use, stationing, installation, or deploying of nuclear weapons. [Article 1]

Bans any assistance with prohibited acts. The treaty bans assistance with prohibited acts, and should be interpreted as prohibiting states from engaging in military preparations and planning to use nuclear weapons, financing their development and manufacture, or permitting the transit of them through territorial waters or airspace. [Article 1]

UN Treaty on the Prohibition of Nuclear Weapons

What the Treaty Does

Creates a path for nuclear states which join to eliminate weapons, stockpiles, and programs. It requires states with nuclear weapons that join the treaty to remove them from operational status and destroy them and their programs, all according to plans they would submit for approval. It also requires states which have other country's weapons on their territory to have them removed. [Article 4]

Verifies and safeguards that states meet their obligations. The treaty requires a verifiable, time-bound, transparent, and irreversible destruction of nuclear weapons and programs and requires the maintenance and/or implementation of international safeguards agreements. The treaty permits safeguards to become stronger over time and prohibits weakening of the safeguard regime. [Articles 3 and 4]

Alan Robock
Department of Environmental Sciences

UN Treaty on the Prohibition of Nuclear Weapons

What the Treaty Does

Requires victim and international assistance and environmental remediation. The treaty requires states to assist victims of nuclear weapons use and testing, and requires environmental remediation of contaminated areas. The treaty also obliges states to provide international assistance to support the implementation of the treaty. The text requires states to join the Treaty, and to encourage others to join, as well as to meet regularly to review progress. [Articles 6, 7, and 8]

Adoption. Friday 7 July 2017.

UN Treaty on the Prohibition of Nuclear Weapons

Next Steps

Opening for signature. The treaty will be open for signature on 20 September 2017 at the United Nations in New York. [Article 13]

Entry into force. Fifty states are required to ratify the treaty for it to enter into force. At a national level, the process of ratification varies, but usually requires parliamentary approval and the development of national legislation to turn prohibitions into national legislation. This process is also an opportunity to elaborate additional measures, such as prohibiting the financing of nuclear weapons. [Article 15]

First meeting of States Parties. The first Meeting of States Parties will take place within a year after the entry into force of the Convention. [Article 8]

UN Treaty on the Prohibition of Nuclear Weapons

Significance and Impact of the Treaty

Delegitimizes nuclear weapons. This treaty is a clear indication that the majority of the world no longer accepts nuclear weapons and do not consider them legitimate weapons, creating the foundation of a new norm of international behavior.

Changes party and non-party behavior. As has been true with previous weapon prohibition treaties, changing international norms leads to concrete changes in policies and behaviors, even in states not party to the treaty. This is true for treaties ranging from those banning cluster munitions and land mines to the Convention on the law of the sea. The prohibition on assistance will play a significant role in changing behaviour given the impact it may have on financing and military planning and preparation for their use.

Alan Robock
Department of Environmental Sciences

UN Treaty on the Prohibition of Nuclear Weapons

Significance and Impact of the Treaty

Completes the prohibitions on weapons of mass destruction. The treaty completes work begun in the 1970s, when chemical weapons were banned, and the 1990s when biological weapons were banned.

Strengthens International Humanitarian Law ("Laws of War"). Nuclear weapons are intended to kill millions of civilians – non-combatants – a gross violation of International Humanitarian Law. Few would argue that the mass slaughter of civilians is acceptable and there is no way to use a nuclear weapon in line with international law. The treaty strengthens these bodies of law and norms.

Removes the prestige associated with proliferation. Countries often seek nuclear weapons for the prestige of being seen as part of an important club. By more clearly making nuclear weapons an object of scorn rather than achievement, their spread can be deterred.

Alan Robock
Department of Environmental Sciences

The New York Times

Treaty to Prohibit Nuclear Weapons Passes Important Threshold

Fifty countries have now ratified the treaty, so it will become international law. The United States and the eight other nuclear-armed powers reject it but have failed to stop its advance.

António Guterres, the United Nations secretary general, with papers second from right, at the signing of the Treaty on the Prohibition of Nuclear Weapons in 2017. Don Emmert/Agence France-Presse — Getty Images

https://www.nytimes.com/2020/10/25/world/americas/nuclear-weapons-prohibition-treaty.html

By Rick Gladstone

Oct. 25, 2020

The 50th ratification occurred on October 24, 2020, the 75th anniversary of the founding of the United Nations.

It came into force on January 22, 2021.

Alan Robock
Department of Environmental Sciences

Alan Robock
Department of Environmental Sciences

ON SEPTEMBER 20, 2017

50 NATIONS OF EARTH RATIFIED

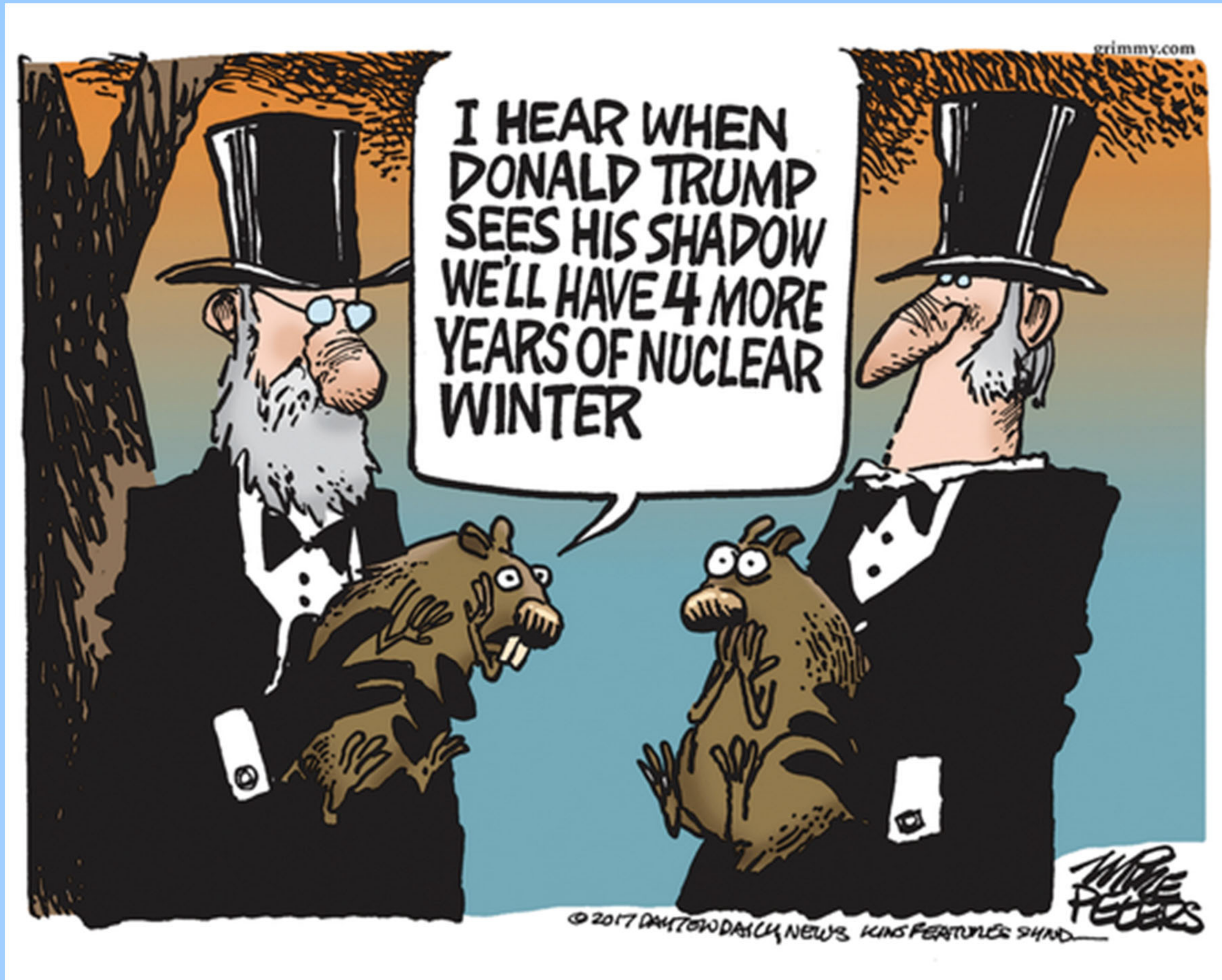
AN HISTORIC, LEGALLY BINDING TREATY

ON THE PROHIBITION OF

NUCLEAR WEAPONS

We are saying to our children,
YES, it is possible to inherit a world
free from nuclear weapons.

WHYTE GOMEZ
President, U.N. Nuclear Weapons Ban Conference



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Alan Robock
Department of Environmental Sciences

THE HUFFINGTON POST

THE BLOG

An Open Letter to President-Elect Trump about Nuclear Weapons and Nuclear Winter

01/10/2017 11:07 am ET

Alan Robock
Distinguished Professor of Climate Science, Rutgers University

Dear President-Elect Trump,

Slaughterhouse-Five (1969) by Kurt Vonnegut

It was a movie about American bombers in the Second World War and the gallant men who flew them. Seen backwards by Billy, the story went like this:

American planes, full of holes and wounded men and corpses took off backwards from an airfield in England. Over France, a few German fighter planes flew at them backwards, sucked bullets and shell fragments from some of the planes and crewmen. They did the same for wrecked American bombers on the ground, and those planes flew up backwards to join the formation.

The formation flew backwards over a German city that was in flames. The bombers opened their bomb bay doors, exerted a miraculous magnetism which shrunk the fires, gathered them into cylindrical steel containers, and lifted the containers into the bellies of the planes. The containers were stored neatly in racks. The Germans below had miraculous devices of their own, which were long steel tubes. They used them to suck more fragments

Slaughterhouse-Five (1969) by Kurt Vonnegut

from the crewmen and planes. But there were still a few wounded Americans, though and some of the bombers were in bad repair. Over France, though, German fighters came up again, and made everything and everybody as good as new.

When the bombers got back to their base, the steel cylinders were taken from the racks and shipped back to the United States of America, where factories were operating night and day, dismantling the cylinders, separating the dangerous contents into minerals. Touchingly, it was mainly women who did this work. The minerals were then shipped to specialists in remote areas. It was their business to put them in to the ground, to hide them cleverly, so they would never hurt anybody ever again.

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

1. What are the likeliest scenarios of nuclear war? How many weapons, of what size, would be used on what targets?
2. What is the inventory of flammable material in potential target zones? How much soot would be produced from fires and firestorms after nuclear attack? Would multiple discrete fires in a large megacity coalesce into a larger firestorm, which would produce more soot than assumed by the recent studies? What fraction of the soot would be placed in the upper atmosphere where it can produce global climate change?

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

3. How do soot particles get transported and modified by the atmosphere? What can we learn from the observed behavior of soot from forest fires? How would chemical and physical processes alter the particles in the stratosphere, and how would this affect their lifetimes and effects on radiation and climate? How sensitive are the amount and properties of the smoke to prevailing winds, season of the conflict, and duration of the conflict?

Alan Robock
Department of Environmental Sciences

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

4. What would be the climate response to a variety of nuclear conflict scenarios? How does the effect vary with different combatant groups and different attack scenarios? How would temperature, precipitation, sunlight, and ultraviolet radiation change? Are the preliminary results described above robust when tested with different climate models?
5. How would agricultural production, water resources, and the ocean food chain change in response to the resulting climatic disruption and enhanced ultraviolet radiation?
6. How would the availability of food and water in each nation, including the United States, change as global markets and distribution systems react?

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

Our team:

Principal Investigators: Alan Robock (Rutgers University) and Brian Toon (University of Colorado)

Co-Investigators: Yunping Xi, Julie Lundquist, Nicole Lovenduski, and Cheryl Harrison (University of Colorado), Charles Bardeen (University of Colorado and NCAR), Michael Mills (NCAR), Eric Jensen (NASA), Joshua Elliott and Ian Foster (University of Chicago), Lili Xia and Gal Hochman (Rutgers University), 1 postdoc, 8 graduate students

Invited experts: Bruce Blair (Princeton), Ira Helfand (PSR), Matthew McKinzie (NRDC), Feroz Khan (Naval Postgraduate School), Ted Postol (MIT), Hans M. Kristensen (FAS), Daniel Ellsberg (retired)

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Environmental and Human Impacts of Nuclear War: A New Research Program

Alan Robock

Department of Environmental Sciences
Rutgers University, New Brunswick, New Jersey USA

robock@envsci.rutgers.edu

http://envsci.rutgers.edu/~robock

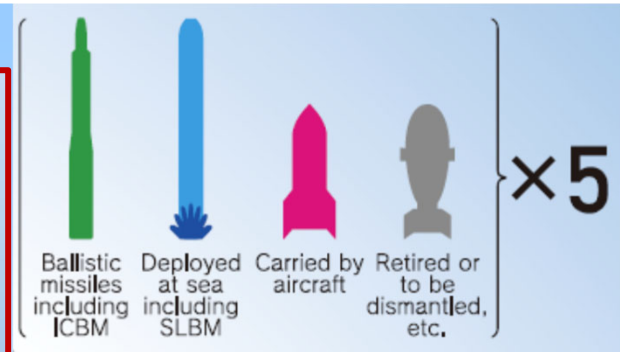
The World's Nuclear Warheads Count June 2017

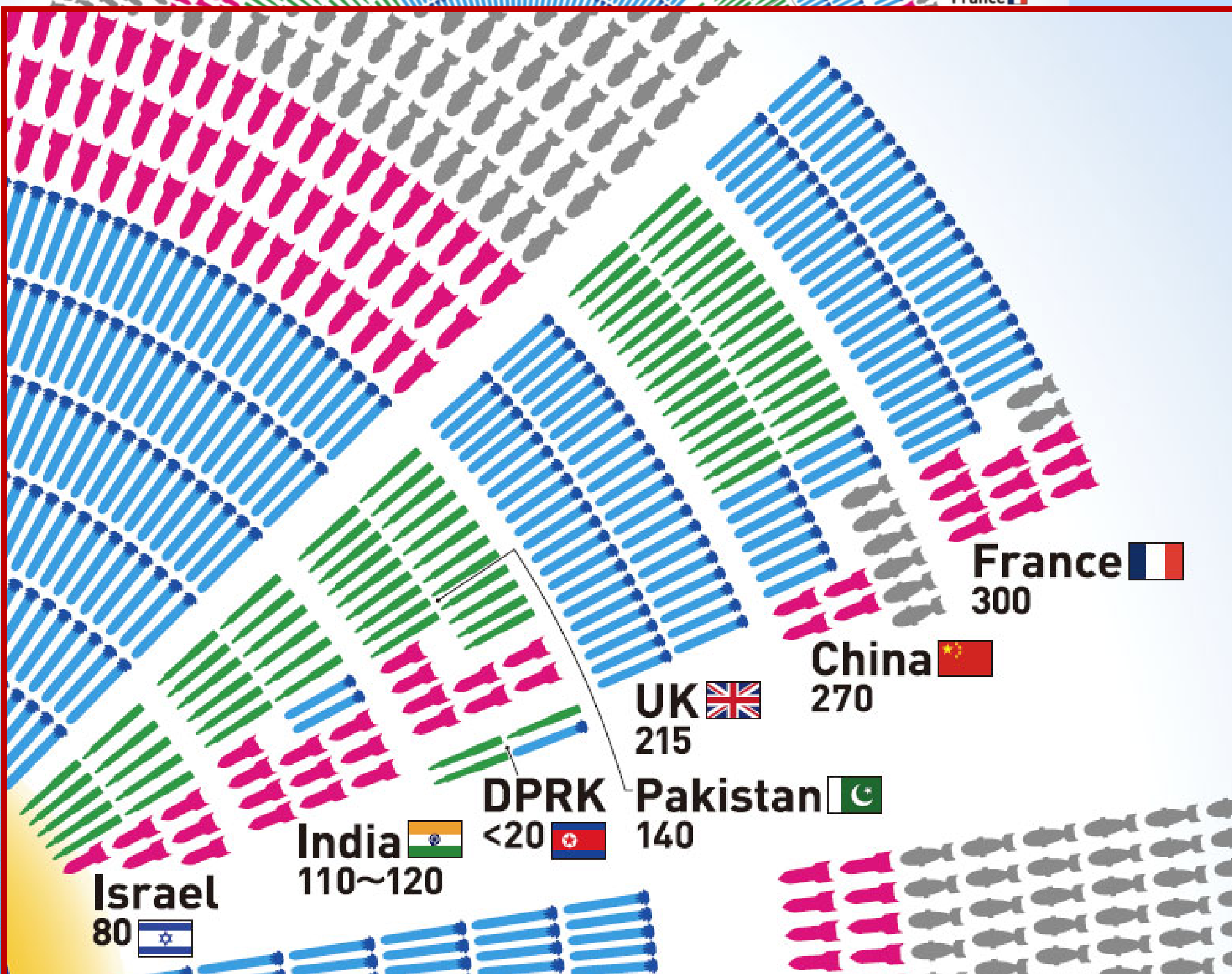
Russia 7,000

Ballistic missiles including ICBM······1,606
Deployed at sea including SLBM······1,528
Carried by aircraft······1,170
Retired or to be dismantled, etc.······2,700

US 6,800

Ballistic missiles including ICBM······800
Deployed at sea including SLBM······1,660
Carried by aircraft······1,540
Retired or to be dismantled, etc.······2,800





France 300

Deployed at sea including SLBM······240
Carried by aircraft······50
Retired or to be dismantled, etc.······10

China 270

Ballistic missiles including ICBM······173
Deployed at sea including SLBM······48
Carried by aircraft······20
Retired or to be dismantled, etc.······30

UK 215

Deployed at sea including SLBM······215

Israel 80

Ballistic missiles including ICBM······50
Carried by aircraft······30

Pakistan 140

Ballistic missiles including ICBM······104
Carried by aircraft······36

India 110~120

Ballistic missiles including ICBM······56
Deployed at sea including SLBM······2~16
Carried by aircraft······48

DPRK <20

Ballistic missiles including ICBM······?
Deployed at sea including SLBM······?

epartr

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

Our team:

Principal Investigators: Alan Robock (Rutgers University) and Brian Toon (University of Colorado)

Co-Investigators: Yunping Xi, Julie Lundquist, Nicole Lovenduski, and Cheryl Harrison (University of Colorado), Charles Bardeen (University of Colorado and NCAR), Michael Mills (NCAR), Eric Jensen (NASA), Joshua Elliott and Ian Foster (University of Chicago), Lili Xia and Gal Hochman (Rutgers University), 1 postdoc, 8 graduate students

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Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

1. What are the likeliest scenarios of nuclear war? How many weapons, of what size, would be used on what targets?

Attack scenario	Story	Total weapons	Number, size, target, timing for each bomb
Previous India vs. Pakistan[1]	50 each on targets with most fuel (highest population density)	100	50x15 kt on the largest targets in India + 50x15 kt on the largest targets in Pakistan; each burned an area of 13 km^2, based on Hiroshima for 15 kt, resulting in 6.5 Tg soot in total. Only 5 Tg soot was used in climate model simulations.
Previous Global Conflict[2]	Global war after START II	4400	1000 on US, 200 each on France, Germany, India, Japan, Pakistan, U.K., 1100 each on Russia, China; 100 kt; 86.6 km^2 based on linear yield scaling to 100 kt, priority by population

All three categories: counterforce, command and control, countervalue (war-supporting industry and cities)

Major Attack Option (MAO) 1 = counterforce
MAO2 = MAO1 + command and control
MAO3 = MAO2 + countervalue

[1] *Toon et al.* [2007b]
[2] *Toon et al.* [2008]

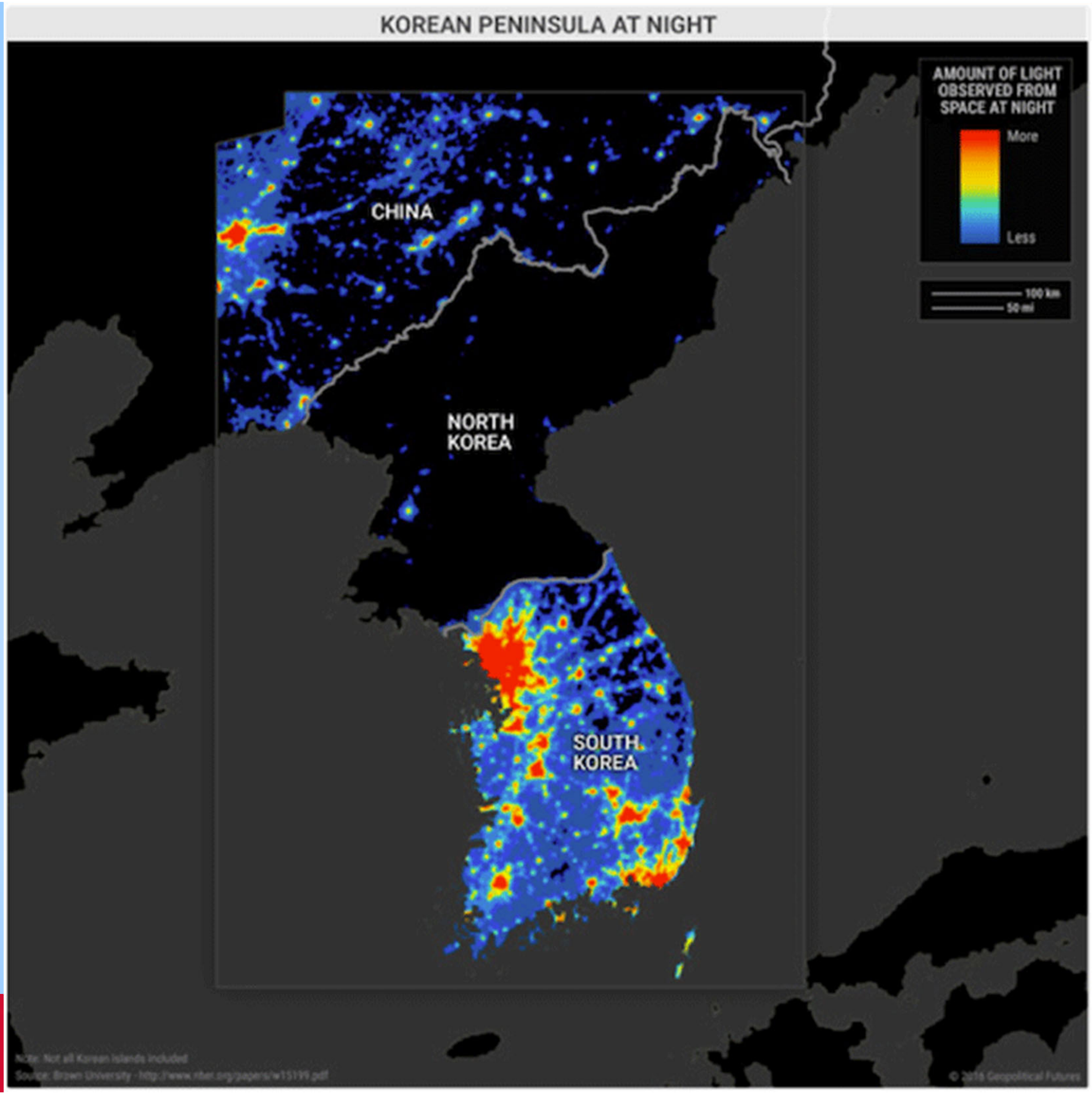
Attack scenario	Story	Total weapons	Number, size, target, timing for each bomb
India Pakistan	Border conflict grows to all-out war	360: Each country: 170-180 weapons, 25% 50 kt, 50% 15 kt, 25% 5 kt Failure rate: 15%	Day 1: 5 kt, low air burst against Indian tanks Day 2: 2x15 kt low air burst against Pakistani garrison in Bhawalpur, plus 14x5 kt Day 3: 8 ballistic missiles, 2 cruise missiles on garrisons in 5 Indian cities (10x15 kt, low air burst) , plus 15x5 kt Day 4: 25x15 kt, air burst against 5 major Pakistani cities , plus 15x5 kt Day 5-7: Complete arsenals targeted at cities (90x50 kt, 145x15 kt), plus 15x5 kt each day
US North Korea	North Korean missile shot down by US and South Korea	20x10-15 kt, 80x100-475 kt	20x10-15 kt against US and South Korean bases 50x100-475 kt against NK counterforce 20x100-475 kt against NK war-supporting industries 10x100-475 kt against NK command and control

How much smoke would be produced in a nuclear war between the U.S. and North Korea?

It depends!

It depends on the targets and the size of the weapons.

North Korea can't power its lights at night



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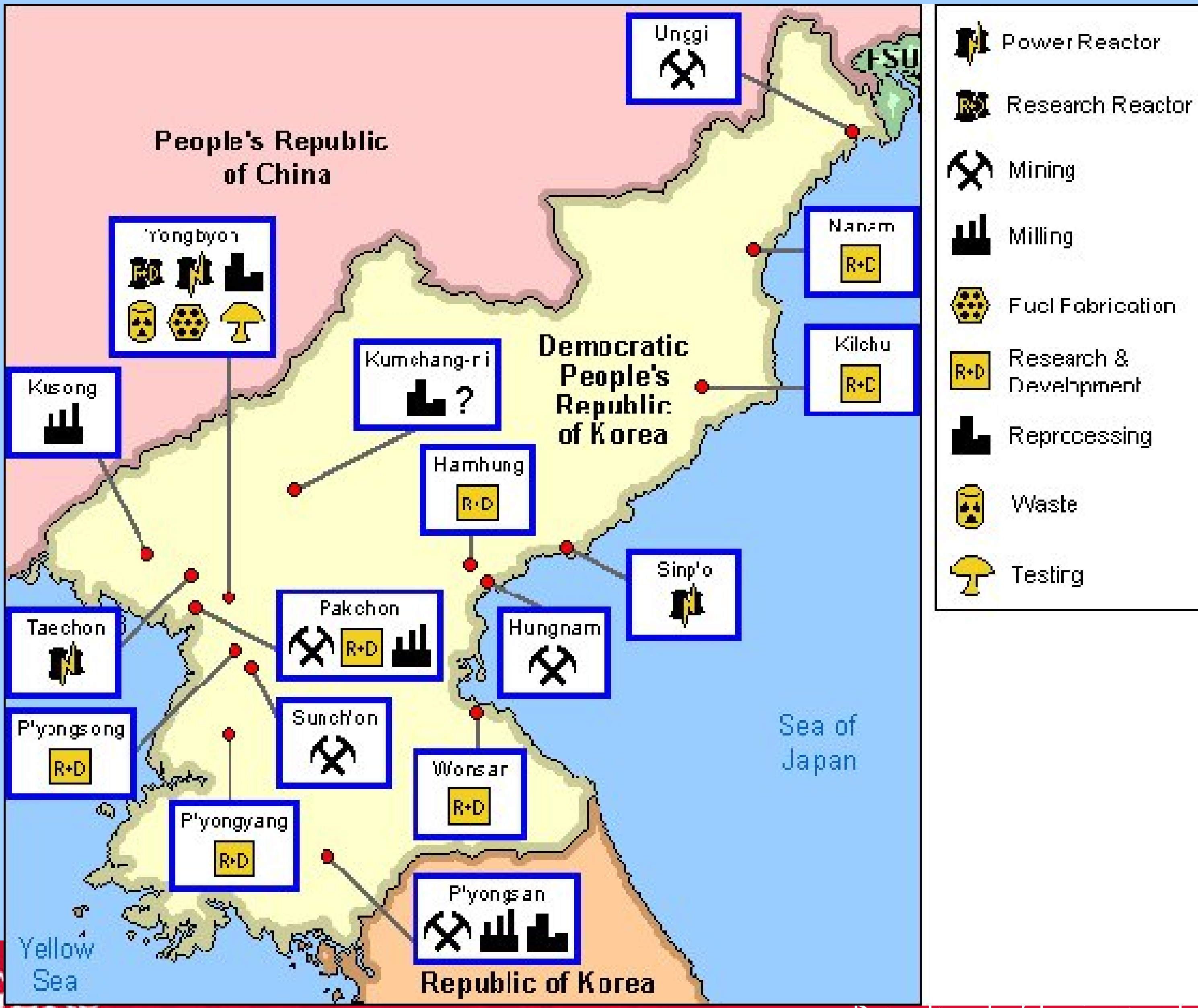
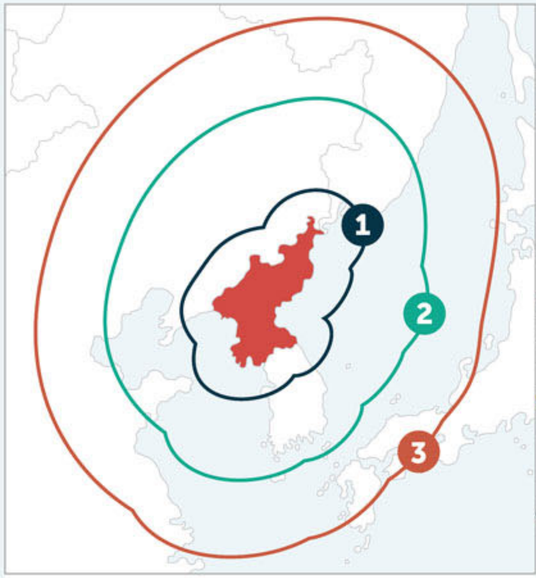
Military facilities in North Korea.

25 million people
15 cities with 100,000 people
Army~1 million (4th largest)
Reserve~ 5.5 million
Submarines ~70 similar to US
Tanks~4000
Artillery ~6500
Rocket launchers ~2500
Aircraft ~1000
Chemical Weapons

North Korean Nuclear Facilities

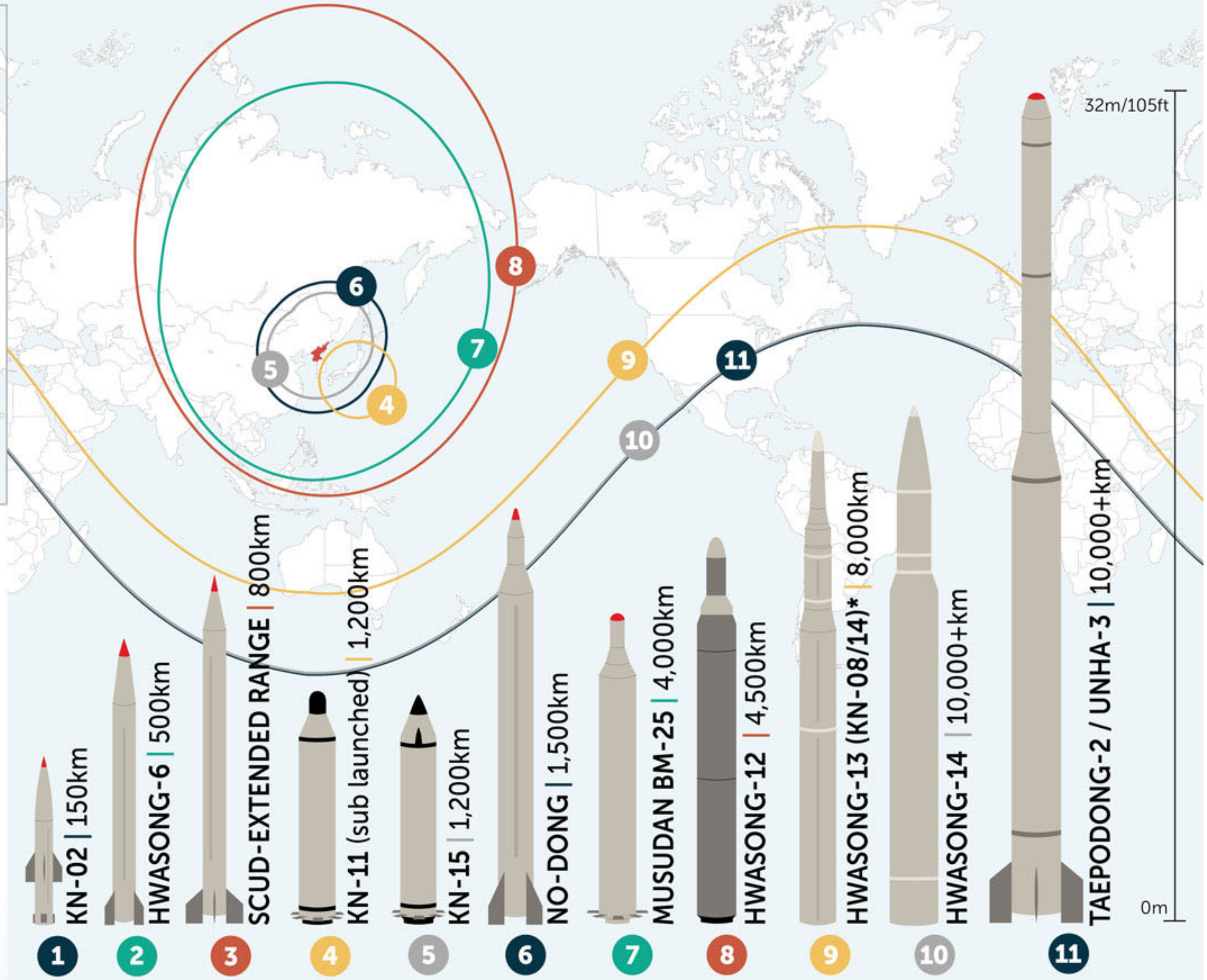


NORTH KOREA'S BALLISTIC MISSILES



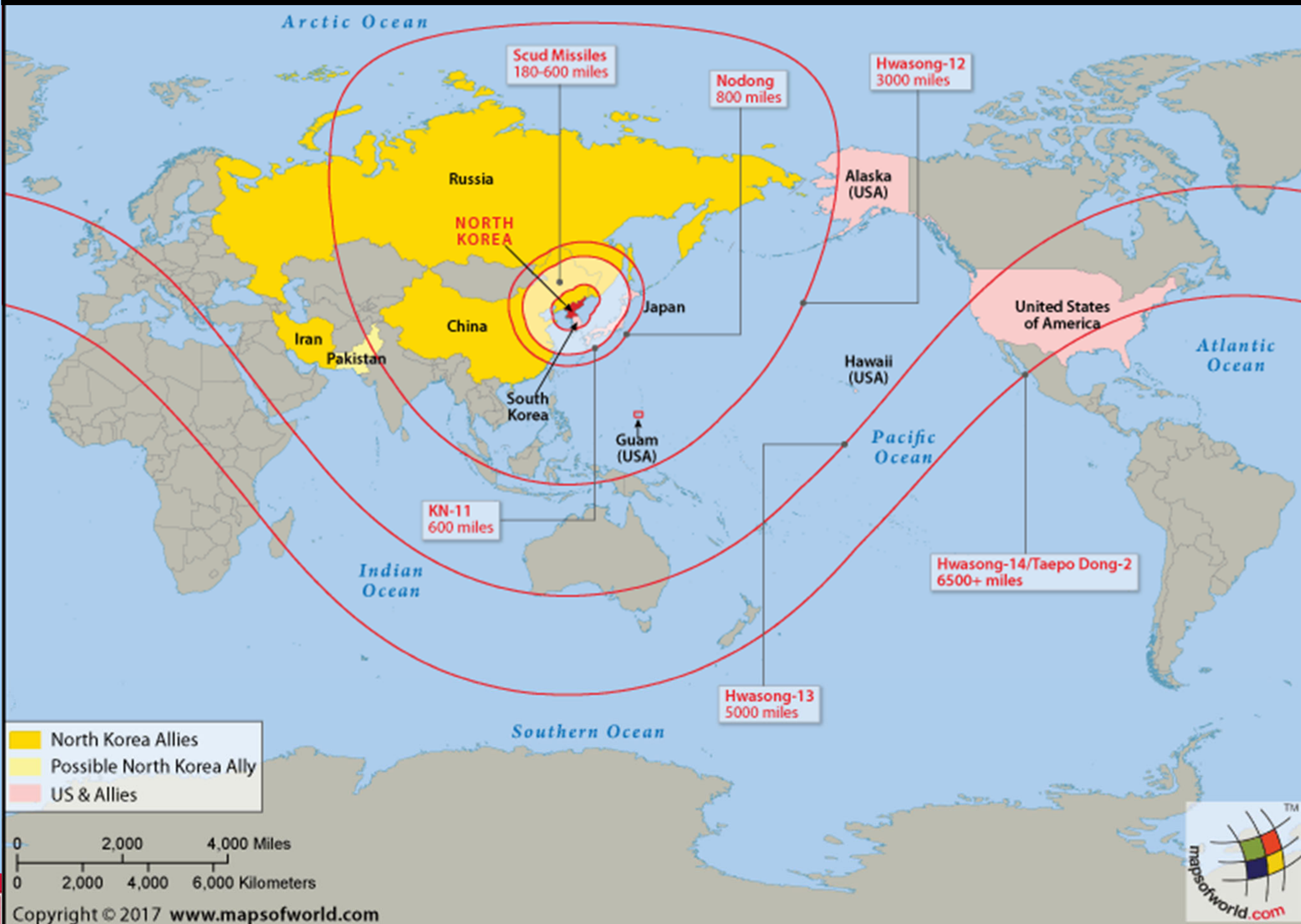
North Korea's ballistic missile program is one of the most rapidly developing threats to global security. In recent years, an unprecedented pace of missile testing has included new and longer range missiles, sea-launches, and the orbiting of satellites. The most notable of these advances is North Korea's development of a new intercontinental ballistic missile, the Hwasong-14, which can likely reach the continental United States.

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES | MISSILE DEFENSE PROJECT



*Not yet flight tested.

North Korean missile range



One possible scenario:

North Korea sinking a South Korean ship or shelling of an island triggers a reciprocal response. For example, North Korea tests a long range missile and the US and South Korea shoot the missile down. North Korea responds by launching another missile at the THAAD missile base in South Korea. The US launches Tomahawk cruise missiles at North Korean nuclear missile bases and general conventional war breaks out. North Korea barrages Seoul with conventional artillery, and the US and South Korean forces invade North Korea and threaten the defeat of the regime within weeks.

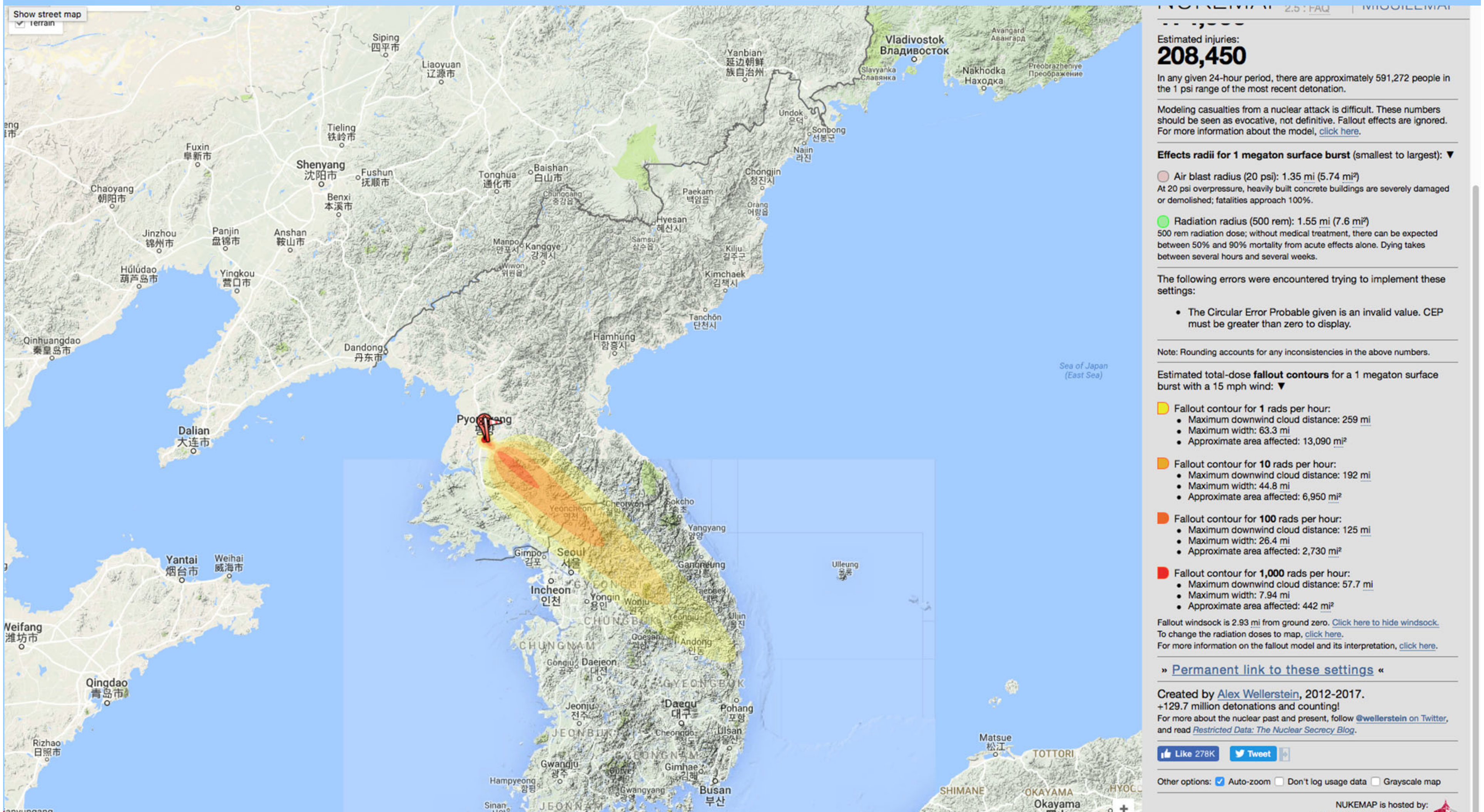
One possible scenario:

The North Koreans reply with their complete nuclear arsenal, 20 weapons with yields of 10-15-kt against US bases in South Korea and Japan, and against South Korean bases, some of which are in cities. The US replies with 80 weapons of 100- or 475-kt against North Korea. Of these 80 weapons, 50 are used against counterforce targets (North Korean military), 20 are used against war-supporting industries, and 10 are used against command and control.

One possible scenario:

North Korean missile shot down by US and South Korea	20 x 10-15 kt 80 x 100-475 kt	20 x 10-15 kt against US and South Korean bases 50 x 100-475 kt against NK counterforce 20 x 100-475 kt against NK war-supporting industries 10 x 100-475 kt against NK command and control

Radiation dose from 1 Mt ground burst



But what if…

- North Korea has developed hydrogen bombs?

- North Korea can bomb Tokyo and other Japanese cities?

- North Korea can bomb U.S. cities?

- China or Russia get involved, due to an errant missile or fear that a missile going over is a ruse to attack them?

Attack scenario	Story	Total weapons	Number, size, target, timing for each bomb
US, China	Taiwan misunder-standing escalates to all-out war	450 x100-475 kt, 10x3000 kt, 10x4000-5000 kt, 163x200-300 kt	DF21 (200-300 kt each) at 20 regional military bases, (South Korea and Japan). 100 or 475 kt per warhead, with 5% failure rate, against 175 Chinese counterforce aim points. China launches all remaining strategic forces at US cities. US responds by 100 or 475 kt per warhead, with 5% failure rate, against 450 Chinese aim points in all three categories
US, UK, France, Russia	Baltic distur-bance leads to all-out war	4400	MAO1 leading to MAO3, details need to be worked out
Hacking	Multiple scenarios	50-400	50 or 400x300-335 kt US ICBMs or 150x100-800 kt Russian missiles
Deter-rence	Maximum for each country producing no climate problems	10 each	Start with 10 weapons, of the size each country is expected to have, from each of US, UK, France, Russia, China, Israel, India, Pakistan and North Korea, targeted on cities

Attack scenario	Story	Total weapons	Number, size, target, timing for each bomb
US First strike			
Russian First strike			
US Trident	1 fully loaded, attacking cities	96	96x475 kt targeted on cities in Russia, or in China
UK Trident	1 fully loaded, attacking cities	40	40x100 kt targeted on cities in Russia
Port destruct-tion	100 Mt robot submarine	5	100 Mt on robot Russian submarine exploded at surface in harbors of New York, Washington, Los Angeles, San Francisco, Miami

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

2. What is the inventory of flammable material in potential target zones? How much soot would be produced from fires and firestorms after nuclear attack? Would multiple discrete fires in a large megacity coalesce into a larger firestorm, which would produce more soot than assumed by the recent studies? What fraction of the soot would be placed in the upper atmosphere where it can produce global climate change?

Alan Robock
Department of Environmental Sciences

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

3. How do soot particles get transported and modified by the atmosphere? What can we learn from the observed behavior of soot from forest fires? How would chemical and physical processes alter the particles in the stratosphere, and how would this affect their lifetimes and effects on radiation and climate? How sensitive are the amount and properties of the smoke to prevailing winds, season of the conflict, and duration of the conflict?

Alan Robock
Department of Environmental Sciences

Our new grant from the Open Philanthropy Project

Environmental and Human Impacts of Nuclear War

The scientific questions we proposed to answer are:

4. What would be the climate response to a variety of nuclear conflict scenarios? How does the effect vary with different combatant groups and different attack scenarios? How would temperature, precipitation, sunlight, and ultraviolet radiation change? Are the preliminary results described above robust when tested with different climate models?
5. How would agricultural production, water resources, and the ocean food chain change in response to the resulting climatic disruption and enhanced ultraviolet radiation?
6. How would the availability of food and water in each nation, including the United States, change as global markets and distribution systems react?

THE TIMES

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MATT RIDLEY

FEBRUARY 19 2018, 12:01AM, THE TIMES

Russian spies' role in the great green hoax

MATT RIDLEY

A new book argues that nuclear winter, one of the great environmental scares of the 1980s, was fabricated by Moscow

JOURNAL OF GEOPHYSICAL RESEARCH
Atmospheres
AN AGU JOURNAL

JGR

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Research Article

Climate impact of a regional nuclear weapons exchange: An improved assessment based on detailed source calculations

Jon Reisner, Gennaro D'Angelo, Eunmo Koo, Wesley Even, Matthew Hecht, Elizabeth Hunke, Darin Comeau, Randall Bos, James Cooley

Accepted manuscript online: 13 February 2018 Full publication history

Abstract

We present a multi-scale study examining the impact of a regional exchange of nuclear weapons on global climate. Our models investigate multiple phases of the effects of nuclear weapons usage, including growth and rise of the nuclear fireball, ignition and spread of the induced firestorm, and comprehensive Earth system modeling of the oceans, land, ice, and atmosphere. This study follows from the scenario originally envisioned by Robock et al. (2007a), based on the analysis of Toon et al. (2007), which assumes a regional exchange between India and Pakistan of fifty 15-kiloton weapons detonated by each side. We expand this scenario by modeling the processes that lead to production of black carbon, in order to refine the black carbon forcing estimates of these previous studies. When the Earth system model is initiated with 5×10^9 kg of black carbon in the upper troposphere (approximately 9 to 13 km), the impact on climate variables such as global temperature and precipitation in our simulations is similar to that predicted by previously published work. However, while our thorough simulations of the firestorm produce about 3.7×10^9 kg of black carbon, we find that the vast majority of the black carbon never reaches an altitude above weather systems (approximately 12 km). Therefore, our Earth system model simulations conducted with model-informed atmospheric distributions of black carbon produce significantly lower global climatic impacts than assessed in prior studies, as the carbon at lower altitudes is more quickly removed from the atmosphere. In addition, our model ensembles indicate that statistically significant effects on global surface temperatures are limited to the first 5 years and are much smaller in magnitude than those shown in earlier works. None of the simulations produced a nuclear winter effect. We find that the effects on global surface temperatures are not uniform and are concentrated primarily around the highest arctic latitudes, dramatically reducing the global impact on human health and agriculture compared with that reported by earlier studies. Our analysis demonstrates that the probability of significant global cooling from a limited exchange scenario as envisioned in the previous studies is highly unlikely, a conclusion supported by examination of natural analogs, such as large forest fires and volcanic eruptions.

BUT:

1. "the impact of secondary ignitions, such as gas line breaks, are not considered ... For example, evidence of secondary ignitions in the Hiroshima conflagration ensuing the nuclear bombing ... led to unique conditions that resulted in significantly enhanced fire behavior." Since we used the fire in Hiroshima as a model for the area burned in our previous work, already they are preventing their simulation from producing as big fires.

2. In contrast to the Hiroshima fire, Reisner et al. simulated a line fire, similar to most forest fires that start at a single point. Hiroshima mass fires started from many ignition points distributed over the zone of the thermal pulse and pressure wave. Such mass fires are much more intense than line fires.

BUT:

3. They used “a section of suburban Atlanta, GA were chosen for use as a ‘generic suburb’ for the study.” This is clearly not representative of dense cities in India and Pakistan, and therefore would not have the correct fuel loading. They did this because they do not have data for India and Pakistan cities. They claim, without support, that buildings there are primarily concrete and not wood. However, even for concrete buildings, it is the contents that burn and provide the fuel load. We are actually doing inventories of actual buildings to get this right.

BUT:

4. "A dry atmosphere was utilized, and pyro-cumulus impacts or precipitation from pyro-cumulonimbus were not considered. While latent heat released by condensation could lead to enhanced vertical motions of the air, increased scavenging of soot particles by precipitation is also possible .... These processes will be examined in future studies using HIGRAD-FIRETEC." Thus they eliminate a major source of buoyancy that would loft the soot, latent heat of condensation.

In fact, the "mother of all pyroCb" lofted soot into the lower stratosphere in August 2017 over British Columbia, Canada, and over the succeeding weeks the soot was lofted many more kilometers because it was heated by the Sun, as observed by satellites. This August fire is direct evidence of the process we modeled before, from a much smaller heat source than a burning city.

Yu, Pengfei, Owen B. Toon, Charles G. Bardeen, Yunqian Zhu, Karen H. Rosenlof, Robert W. Portmann, Troy D. Thornberry, Ru-Shan Gao, Sean M. Davis, Eric T. Wolf, Joost de Gouw, David A. Peterson, Michael D. Fromm, and Alan Robock, 2019: Black carbon lofts wildfire smoke high into the stratosphere to form a persistent plume. *Science*, **365**, 587-590, doi:10.1126/science.aax1748.

BUT:

5. Their simulations of fire were only run for 40 minutes, and they did not actually model firestorms.

6. **In summary, they modeled the wrong type of fire (they should have modeled a mass fire), in an area with lower fuel loading than we considered (a suburb not a city), they omitted factors known to be important to smoke lofting (latent heat release), and they didn't model the full duration of the event.**

Robock, Alan, Owen B. Toon, and Charles G. Bardeen, 2019: Comment on "Climate impact of a regional nuclear weapons exchange: An improved assessment based on detailed source calculations" by Reisner et al. *J. Geophys. Res. Atmos.*, **124**, 12,953-12,958, doi:10.1029/2019JD030777.

R-12 ROCKET (SS-4)

Middle range ballistic rocket belonging to the Strategic Rocket Troops

Length: 22.1 m

Diameter: 1.65 m

Weight: 27 200 Kg

Range: 700 to 2100 Km

Power of nuclear load: 1 megaton (77 times more powerful than the bomb which devastated Hiroshima).

Three regiments arrived in Cuba with a total of 36 operational rockets with 36 nuclear heads. These were positioned at three ports: Bahia Honda, Mariel and Casilda at the Pinar del Rio province.

The exhibit is a replica donated by the Soviet Government during the early years of the Revolution.


Scenes from the
1992 Gulf War


LA VICTORIA ESTRATÉGICA
Fidel Castro Ruz

Fidel Castro Ruz

Reflexiones
Sept. 23, 2010

"While the United States and Russia each committed to reducing their operative nuclear arsenals down to some 2,000 weapons in April 2010 in Prague, the only way to prevent a global climate catastrophe from taking place would be by eliminating nuclear weapons."

A lecture by a professor, or a feature film?

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≡ SECTIONS HOME SEARCH The New York Times

The Opinion Pages | OP-ED CONTRIBUTORS

Let's End the Peril of a Nuclear Winter

By ALAN ROBOCK and OWEN BRIAN TOON FEB. 11, 2016

http://www.nytimes.com/2016/02/11/opinion/lets-end-the-peril-of-a-nuclear-winter.html


WARNINGS
FINDING CASSANDRAS TO STOP CATASTROPHES
RICHARD A. CLARKE AND R.P. EDDY
NEW YORK TIMES BESTSELLING AUTHOR OF CYBER WAR
CASSANDRA AWARD
MMXVIII
The Cassandra Award Foundation
presents the 2018
Cassandra Award
to
Dr. Alan Robock
for his warnings on
the climatic consequences
of nuclear conflict
WARNINGS
FINDING CASSANDRAS TO STOP CATASTROPHES
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Tweet from R. P. Eddy on January 31, 2018: "It was a profound honor to present Dr. Alan Robock with the 2018 Cassandra Foundation Award. His work on nuclear winter demands a global audience. Robock beat all 52 nominees across our four factors: Legitimacy, Criticality, Persuasion, and Solvability. Congrats @AlanRobock !!"

RUTGERS

Global Flashpoints Forum, New York, New York, January 17, 2018
(On "Nuclear War with North Korea: The Cold Science")

Alan Robock
al Sciences

NUCLEAR ARMS CONTROL IN REVERSE

After end of the Cold War US activists moved on to other issues. But the anti-nuclear-arms-control people did not.

2002: ***G. W. Bush took US out of ABM Treaty*** and Russia began to develop new types of delivery vehicles. China began to build up.

2018: ***Trump Administration took US out of agreement that froze Iran's nuclear program.*** Seeks regime change instead. ***Biden working to put the US back in the treaty.***

2019: ***Took US out of 1987 Intermediate-Range Nuclear Forces Treaty*** under which US and Soviet Union had destroyed all ~2700 land-based missiles with ranges between 500 and 5500 km.

2020: ***Took US out of Open Skies Treaty***

Discussed conducting a rapid nuclear test. ***Stopped by House.***

Declined to extend New START Treaty, which limits US and Russian long-range missiles, bombers and associated deployed warheads. ***Biden extended it for 5 more years until 2026.***

Alan Robock
Department of Environmental Sciences

The U.S. President can take these immediate steps to make the world safer from nuclear war:

1. Take US land-based missiles off hair-trigger alert.
2. Give up sole presidential authority to launch nuclear weapons.
3. Extend the New START Treaty with Russia for another five years. No Congressional approval needed.
4. Change our nuclear policy to one of no first use of nuclear weapons. All options do not need to be on the table.
5. Stand down our land-based missiles and begin to dismantle them as part of a rapid reduction of our nuclear arsenal. No treaty with Russia is needed to do this.

In the longer term, there are additional steps to take.

Work with our allies, Russia, China, and Iran to re-establish our participation in the Iran agreement that prevents them from developing their own nuclear weapons, the Joint Comprehensive Plan of Action.

Halt the nuclear modernization program that is scheduled to cost more than $1 trillion over the next decade.

Sign the Treaty on the Prohibition of Nuclear Weapons, which will lead to the goal of a world free of nuclear weapons as clearly stated by former presidents Reagan and Obama, but toward which there has been little progress so far.

"Every gun that is made, every warship launched, every rocket fired signifies, in the final sense, a theft from those who hunger and are not fed, those who are cold and are not clothed. This world in arms is not spending money alone. It is spending the sweat of its laborers, the genius of its scientists, the hopes of its children."

President Dwight D. Eisenhower, April 16, 1953

The New York Times

Former World Leaders Urge Ratification of Nuclear Arms Ban Treaty

In an open letter, the onetime leaders implored their own governments to embrace an arms treaty negotiated at the U.N. three years ago. It is six ratifications short of the 50 needed to go into effect.

By Rick Gladstone

Sept. 20, 2020

Fifty-six former prime ministers, presidents, foreign ministers and defense ministers from 20 NATO countries, plus Japan and South Korea, released an open letter Sunday imploring their current leaders to join the Treaty on the Prohibition of Nuclear Weapons, the pact negotiated in 2017 that is now just six ratifications shy of the 50 needed to take effect.

RUTGERS

The New York Times

The open letter was coordinated by the International Campaign to Abolish Nuclear Weapons, which won a Nobel Peace Prize for its role in negotiations that led to the treaty. Fabrice Coffrini/Agence France-Presse — Getty Images

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Nobel Peace Prizes for Advocating Nuclear Disarmament (from https://www.nobelprize.org/prizes/lists/all-nobel-peace-prizes)

Year	Nobel Laureates
1959	**Philip Noel-Baker** "He engaged in intense efforts to prevent nuclear war between the United States and the Soviet Union."
1962	**Linus Pauling** "He spoke and wrote against the nuclear arms race, and he was a driving force in the Pugwash movement. ... He was one of the prime movers who urged the nuclear powers the USA, the Soviet Union and Great Britain to conclude a nuclear test ban treaty."
1982	**Alva Myrdal** "She worked actively to persuade the superpowers to disarm. The nuclear race was a major concern, and she fought for nuclear weapons-free zones in Europe." and **Alfonso García Robles** "played a key part in the laborious efforts to make Latin America a nuclear-free zone. ... He was lauded as 'Mr. Disarmament.'"
1985	**International Physicians for the Prevention of Nuclear War** "IPPNW held annual congresses to tell the world about the consequences of nuclear war. Extensive nuclear explosions could prevent sunlight from reaching the earth. The resulting drop in temperature would cause a 'nuclear winter.' The organization recommended a nuclear test ban and demanded that the great powers should refrain from first use in conflict situations."
1995	**Joseph Rotblat and Pugwash Conferences on Science and World Affairs** "for their efforts to diminish the part played by nuclear arms in international politics and, in the longer run, to eliminate such arms"
2005	**International Atomic Energy Agency (IAEA) and Mohamed ElBaradei** "for their efforts to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way"
2017	**International Campaign to Abolish Nuclear Weapons (ICAN)** "for its work to draw attention to the catastrophic humanitarian consequences of any use of nuclear weapons and for its ground-breaking efforts to achieve a treaty-based prohibition of such weapons"

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"For the greatest benefit to mankind"
Alfred Nobel

The Norwegian Nobel Committee has decided to award the

2017 NOBEL PEACE PRIZE

to:

International Campaign to Abolish Nuclear Weapons (ICAN)

"for its work to draw attention to the catastrophic humanitarian consequences of any use of nuclear weapons and for its ground-breaking efforts to achieve a treaty-based prohibition of such weapons."

Nobelprize.org

RUTGERS

Alan Robock
Department of Environmental Sciences

Beatrice Fihn
Executive Director of ICAN
Nobel Peace Prize Lecture
December 10, 2017

If only a small fraction of today's nuclear weapons were used, soot and smoke from the firestorms would loft high into the atmosphere - cooling, darkening and drying the Earth's surface for more than a decade.

It would obliterate food crops, putting billions at risk of starvation.

Yet we continue to live in denial of this existential threat.

Beatrice Fihn
Executive Director of ICAN
Nobel Peace Prize Lecture
December 10, 2017

The story of nuclear weapons will have an ending, and it is up to us what that ending will be.

Will it be the end of nuclear weapons, or will it be the end of us? One of these things will happen.

The only rational course of action is to cease living under the conditions where our mutual destruction is only one impulsive tantrum away.

Conclusions

The current arsenal can produce nuclear winter.

Nuclear winter could kill most of humanity. In a US-Russia nuclear war, more people could die in India or China than in the US or Russia, even if no bombs were dropped there.

A nuclear war between any nuclear states, using much less than 1% of the current nuclear arsenal, would produce climate change unprecedented in human history.

Such a "small" nuclear war could reduce food production by 10% to 40% for a decade, with massive increases in ultraviolet radiation, and kill billions by famine.

Conclusions

Nuclear weapons can be used if they exist.

A nuclear war could start tomorrow by accident, hackers, computer failure, bad sensors, or unstable leaders.

Nuclear arsenals do not deter attacks from non-nuclear states, terrorists, or pandemics.

The only way deterrence could work between nuclear states is if states believe other states are willing to kill themselves by using their nuclear weapons, and if there is a guarantee that there will no unintended use.

The only way to prevent a global catastrophe is to get rid of nuclear weapons.

Alan Robock
Department of Environmental Sciences

Policy Implications

1. **Immediate American and Russian reductions** to the same arsenal sizes of the other nuclear nations, about 200-300 weapons each, would be an excellent step, but **still might not prevent nuclear winter**.

2. **Nuclear abolition** will **prevent nuclear famine**.

Alan Robock
Department of Environmental Sciences

You can join the Physicists Coalition for Nuclear Threat Reduction at **http://physicistscoalition.org/**, a project to engage and activate the US physics community.

Sponsored by American Physical Society, partnered with the APS Office of Government Affairs, with support from the Carnegie Corporation

Steered through the Princeton Program on Science and Global Security

Team members:

- Angela di Fulvio, University of Illinois
- Steve Fetter, University of Maryland
- Alex Glaser, Princeton University
- Laura Grego, Union of Concerned Scientists
- Rob Goldston, Princeton University
- Raymond Jeanloz, Univ. of California, Berkeley
- Fred Lamb, University of Illinois
- Zia Mian, Princeton University
- Sebastien Philippe, Princeton University
- Stewart Prager, Princeton University
- Alan Robock, Rutgers University
- Frank von Hippel, Princeton University

The Physicists Coalition for Nuclear Threat Reduction
http://physicistscoalition.org/

PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

Advocacy

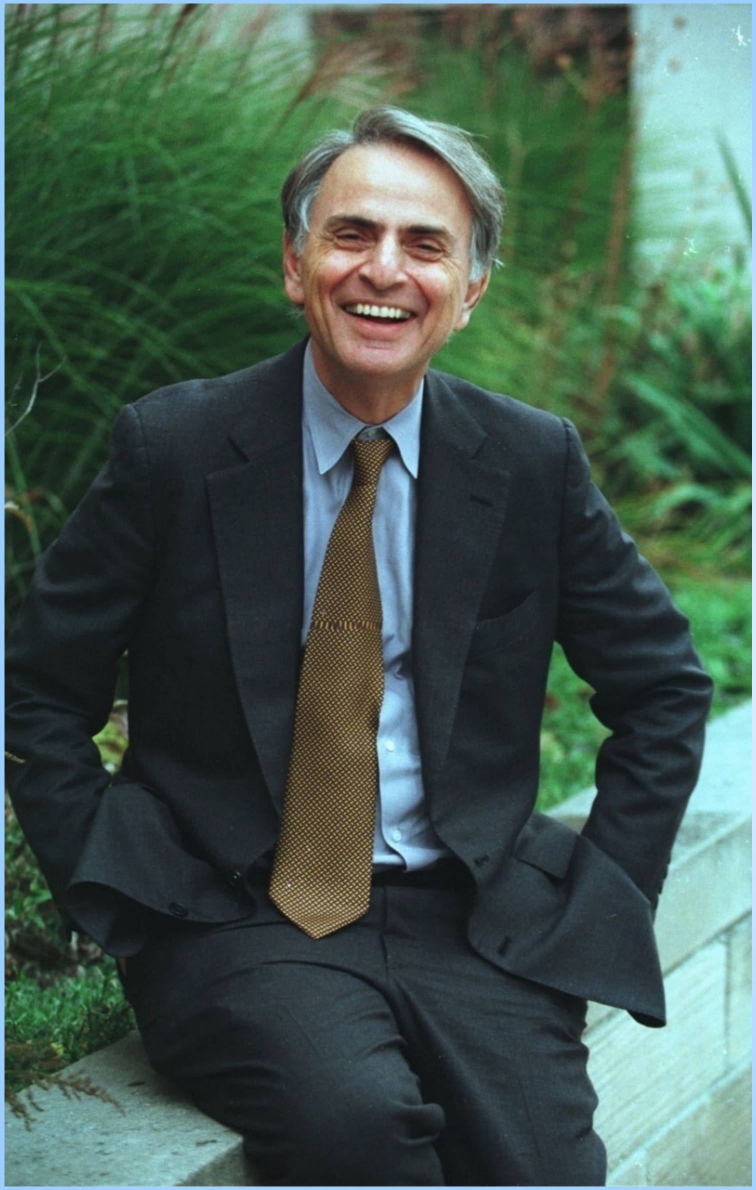
- By informed "citizen-scientists" (not experts)
- Centrally facilitated (to make easy and minimize time consumption)
- To Congress and other stake holders

2020 advocacy (already successful)

- No resumption of nuclear testing
- Extend the New START treaty for five more years

2021 advocacy (currently under discussion)

- Eliminate launch-on-warning
- Eliminate land-based ICBMs
- Eliminate Presidential sole-authority
- Adopt a no-first-use (or sole-purpose) policy

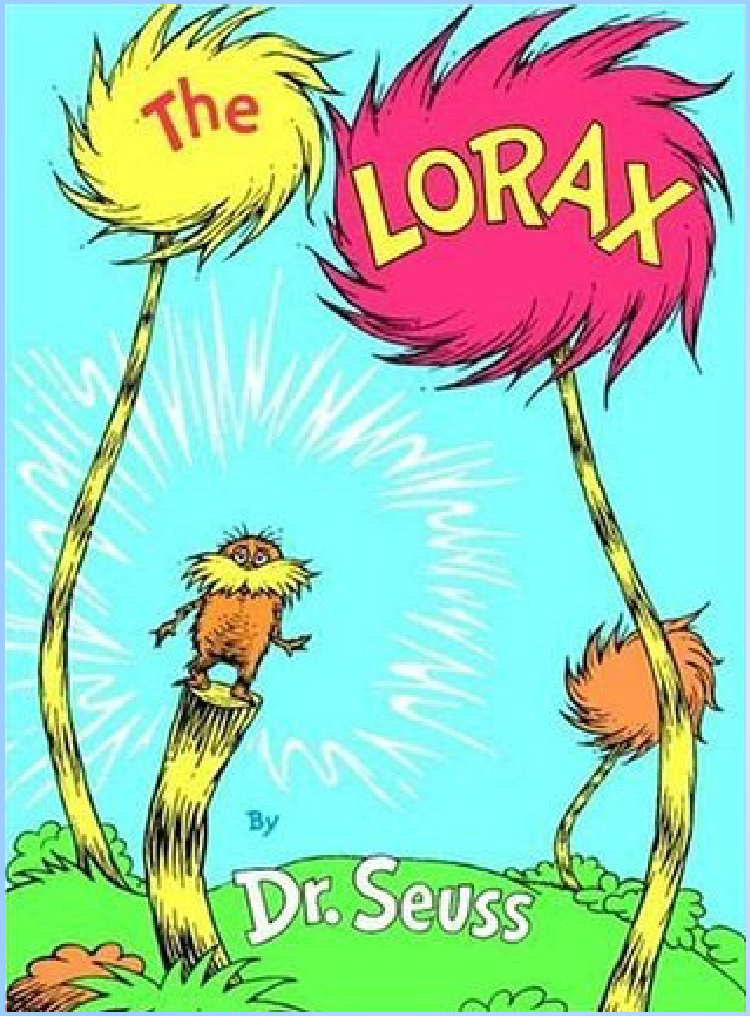


"For myself, I would far rather have a world in which the climatic catastrophe cannot happen, independent of the vicissitudes of leaders, institution, and machines. This seems to me elementary planetary hygiene, as well as elementary patriotism."

-Carl Sagan

"Elementary planetary hygiene" demands that we eliminate nuclear weapons faster than the current pace.

Alan Robock
Department of Environmental Sciences



"Unless someone like you cares a whole awful lot, nothing is going to get better. It's not."

Dr. Seuss, *The Lorax* (1971)

Alan Robock
Department of Environmental Sciences

For more about this work, go to

http://climate.envsci.rutgers.edu/nuclear/

The Physicists Coalition for Nuclear Threat Reduction
http://physicistscoalition.org/

PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

Goals

- Education: Inform and engage the physics community
- Advocacy: Build the Coalition for organized advocacy

The purpose of the first goal is to serve the second goal.

APS physics

Engaging and recruiting

- Through site visits, such as today (team of 12 experts available)
- Open to all physical scientists, including those in engineering science

Advocacy

- By informed "citizen-scientists" (not experts)
- Centrally facilitated (to make easy and minimize time consumption)
- To Congress and other stake holders

Alan Robock
Department of Environmental Sciences

You can join the Physicists Coalition for Nuclear Threat Reduction at
http://physicistscoalition.org/

PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

For more information, from APS we have

Callie Pruett
Senior Strategist for Grassroots Advocacy

Mark Elsesser
Associate Director of Government Affairs

Charlotte Selton
Special Projects Organizer

De: Comandante en Jefe
Fidel Castro Ruz

Para: Alan Robock

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