Consequences of Nuclear War



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Acknowledge Profs Al Saperstein (Wayne State) and Alan Robock (Rutgers) for their work and help with this presentation.

Why is a Climate and Space Prof giving a Talk on Nuclear War?

- Climate Impacts (aerosols, black carbon, ozone destruction, nuclear winter)
- Anthropogenic Space Weather (EMP and radiation impacts on satellites, electronics, communication and power grid)
- 2 minutes to midnight
- Scientist's ethical obligation to communicate our work and our moral responsibility to work for peace

F. Sherwood "Sherry" Rowland (1927–2012)

Frank Sherwood Rowland, known to his friends and colleagues as Sherry, died at his home in Corona del Mar, Calif., on 10 March 2012. He was 84. A Nobel Prize-winning atmo-

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?"

and after 11 months in service he emerged as a noncommissioned officer with a rating of Specialist (Athletics) 3rd Class.

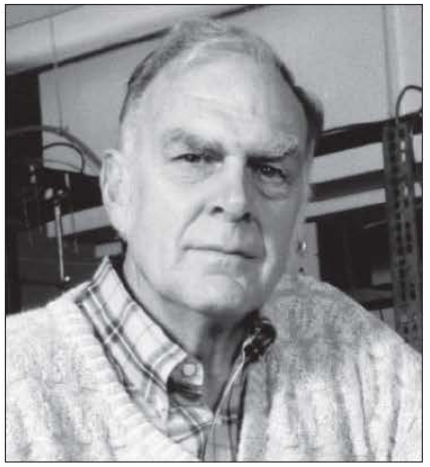
Sherry's research was driven by curiosity, meticulous work, and a keen ability to perceive. As a graduate student at the University of Chicago, Sherry was randomly assigned to be mentored by Willard "Bill" Libby, a future Nobel laureate who had just finished developing the carbon-14 dating technique. As Sherry later wrote in his Nobel Prize autobiography (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1995/rowland.html), "Almost everything I learned about how to be a research scien-

subfield of—not atom—chemistry, it expanded to atmospheric chemistry in 1972 when James Lovelock discovered that a human-generated compound, CFC-11, was now present in trace quantities in both hemispheres. Although the compound was initially lauded for its chemical inertness, Sherry knew that it could not remain inert in the atmosphere forever, and he sought to learn the fate of CFCs.

Together with postdoctoral researcher Mario Molina, he discovered an astonishing 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 question, challenging and interesting to us, but a potentially grave environmental problem

Sherry's subsequent research focused on air quality in the world's megacities and on global climate change. Together with other members of the research group led by himself and Donald Blake, he showed that liquefied petroleum gas contributed to poor air quality in Mexico City and that global concentrations of atmospheric methane, a leading greenhouse gas, were increasing.

Throughout his career, Sherry received numerous awards, distinctions, and honorary degrees, including the Tyler Prize for Environmental Achievement (1983) and the Japan Prize (1989). He published more than 400 research articles, served as president of the American Association for the Advancement of Science (1993–1994), and was foreign secretary for the U.S. National Academy of Sciences (1994–2002).

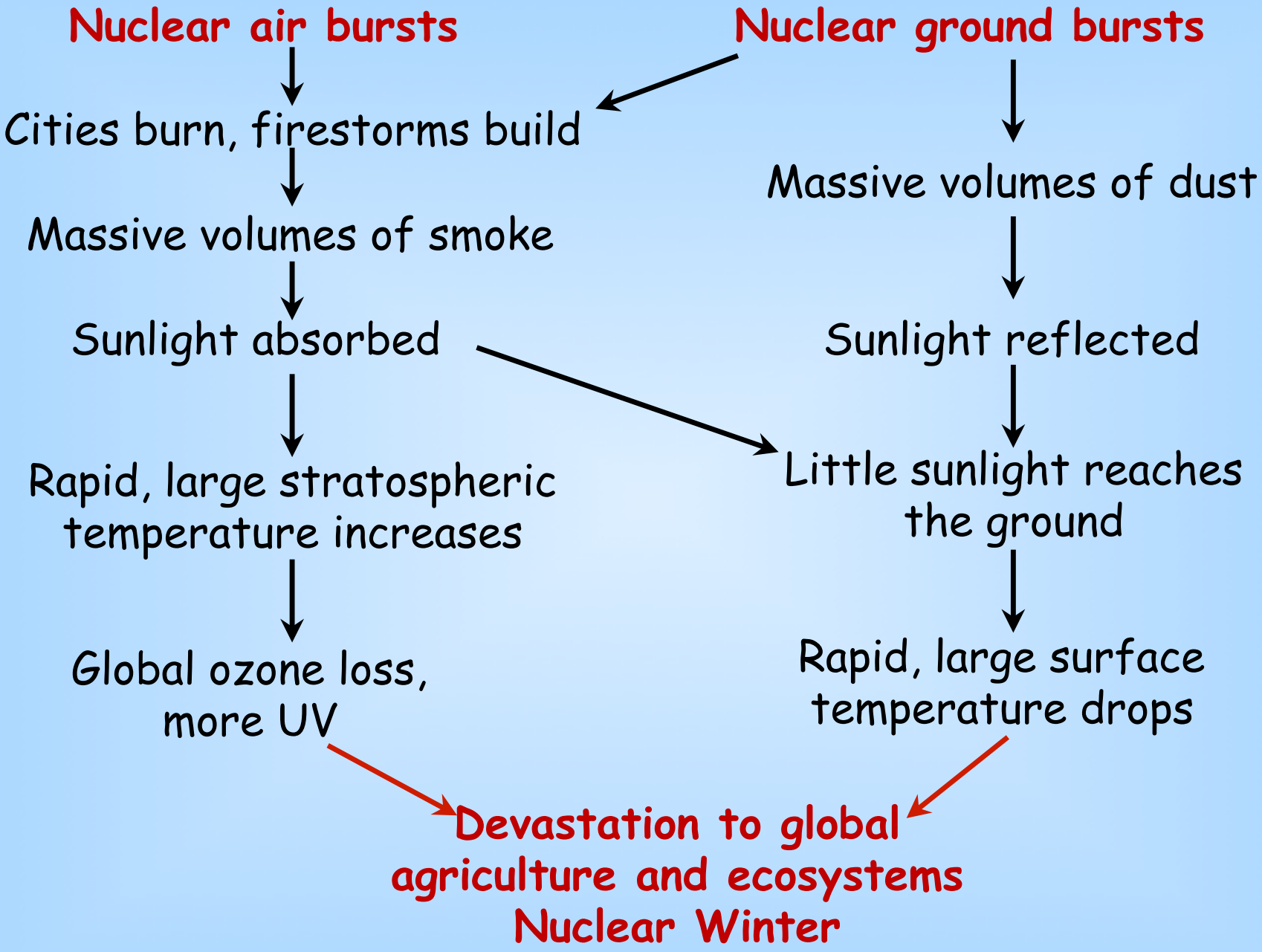


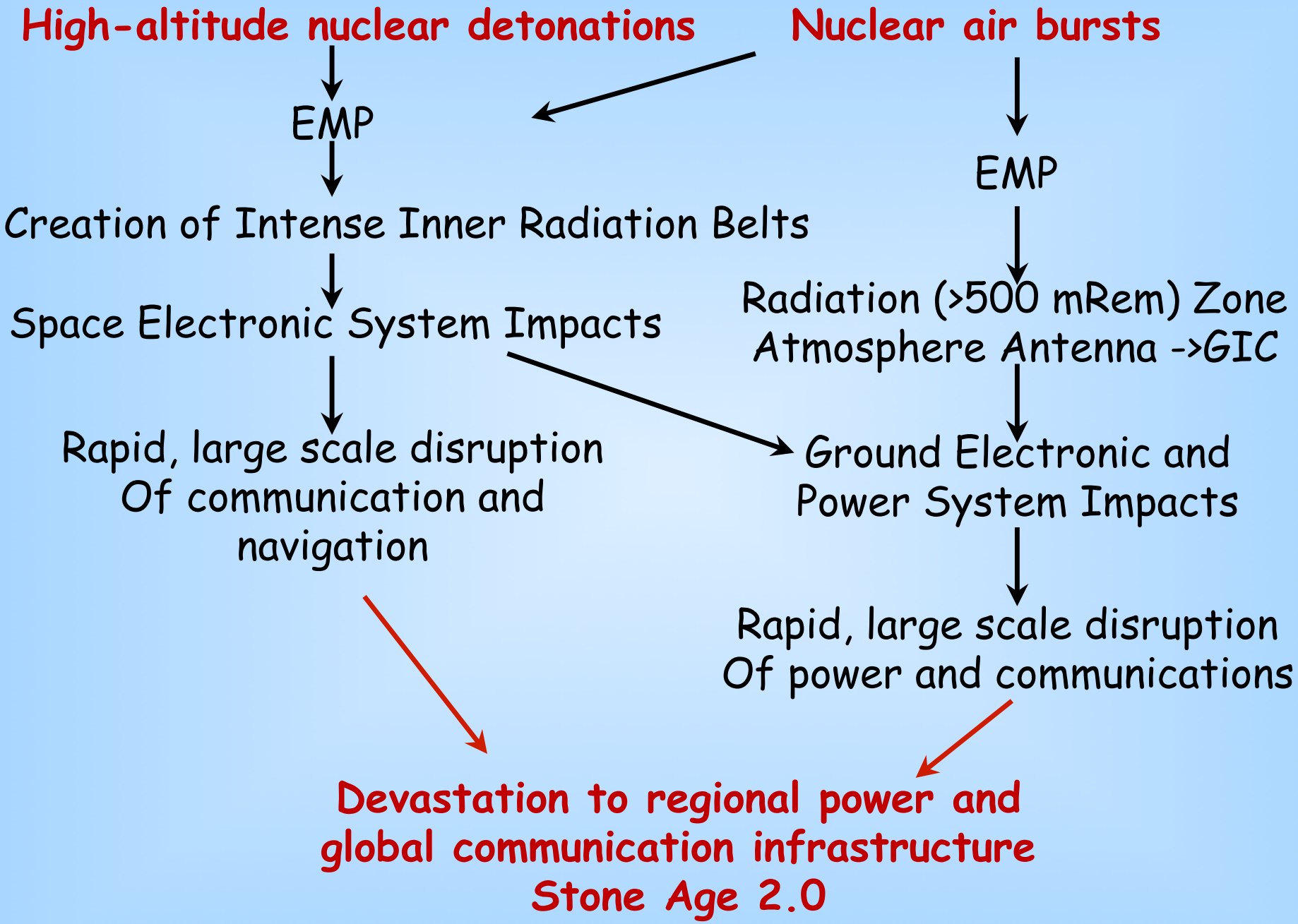
F. Sherwood "Sherry" Rowland

In addition to his remarkable and diverse scientific accomplishments, Sherry was a natural and gracious mentor who invariably brought out the best potential in each of his students and colleagues. Considered an icon of the atmospheric sciences, Sherry touched countless lives and personally inspired hundreds of students, technicians, and faculty around the world.

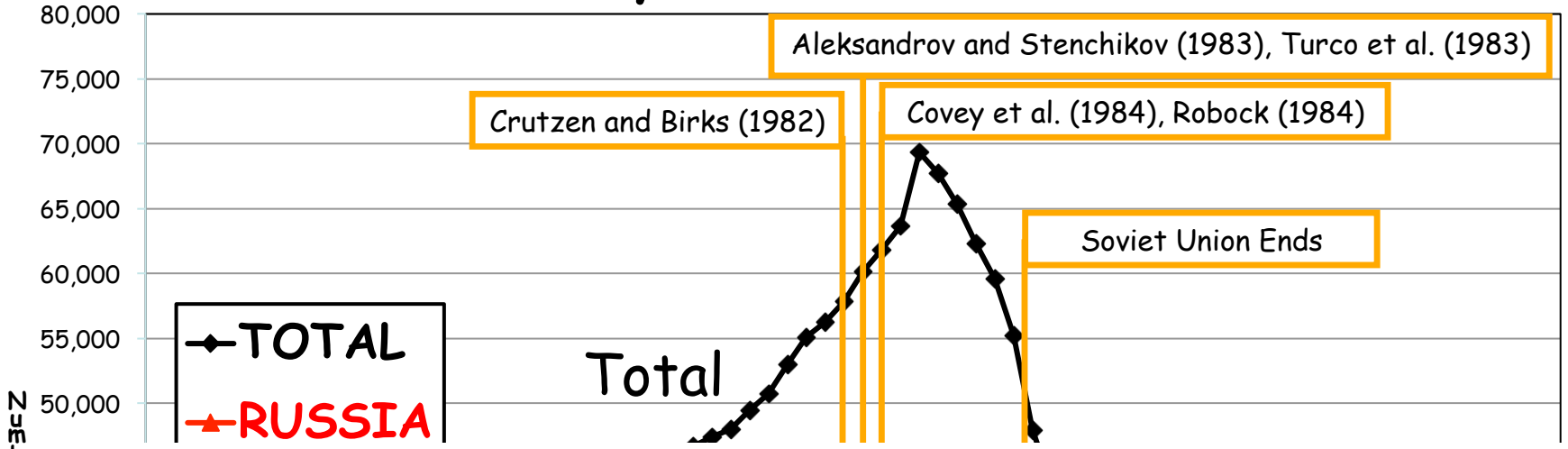
Sherry was a rare scholar-athlete who displayed extraordinary integrity, perseverance, and clarity of thought. He was tremendously respected by his peers, and his legacy continues today at the University of California, Irvine, as classes are taught and research is performed in the building that bears his name: Rowland Hall. His exceptional career merged atmospheric science and chemistry and masterfully bridged science and policy for the enduring protection of our planet.

—Donald R. Blake and Isobel J. Simpson, University of California, Irvine; E-mail: drblake@uci.edu.

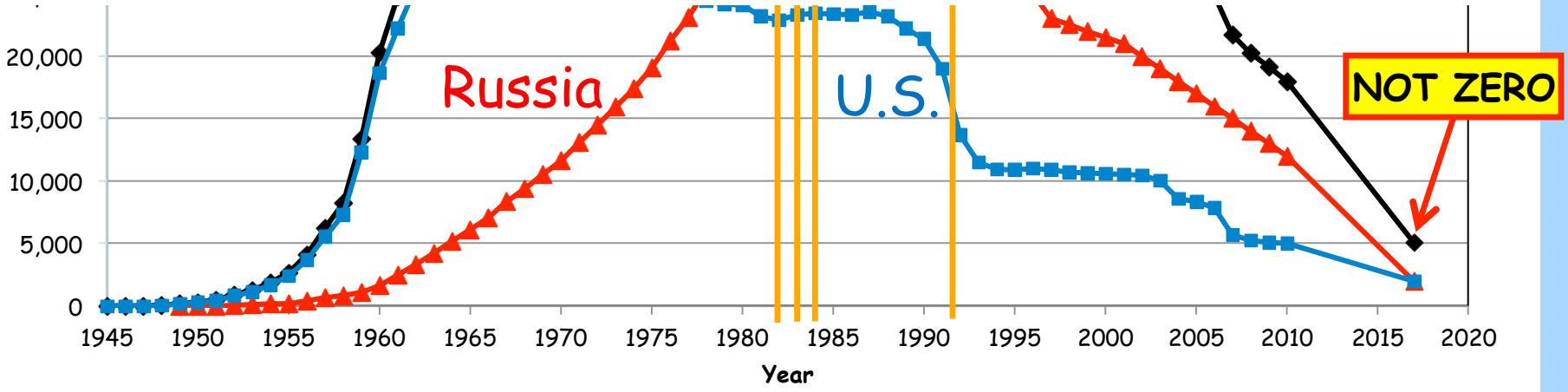

Nuclear air bursts
Nuclear ground bursts
Cities burn, firestorms build
Massive volumes of dust
Massive volumes of smoke
Sunlight absorbed
Sunlight reflected
Rapid, large stratospheric temperature increases
Little sunlight reaches the ground
Global ozone loss, more UV
Rapid, large surface temperature drops
Devastation to global agriculture and ecosystems
Nuclear Winter


High-altitude nuclear detonations
Nuclear air bursts
EMP
EMP
Creation of Intense Inner Radiation Belts
Space Electronic System Impacts
Radiation (>500 mRem) Zone
Atmosphere Antenna ->GIC
Rapid, large scale disruption
Of communication and
navigation
Ground Electronic and
Power System Impacts
Rapid, large scale disruption
Of power and communications
Devastation to regional power and
global communication infrastructure
Stone Age 2.0

History of Nuclear Warheads



2017 latest CBO estimates that existing plans for U.S. nuclear forces would cost $400 billion over the 2017–2026 and $1.2 trillion through 2046 (6% of Defense spending)



R. S. Norris, H. M. Kristensen, *Bull. Atom. Scientists*, **66**, 77 (2010).

Ronald Reagan:

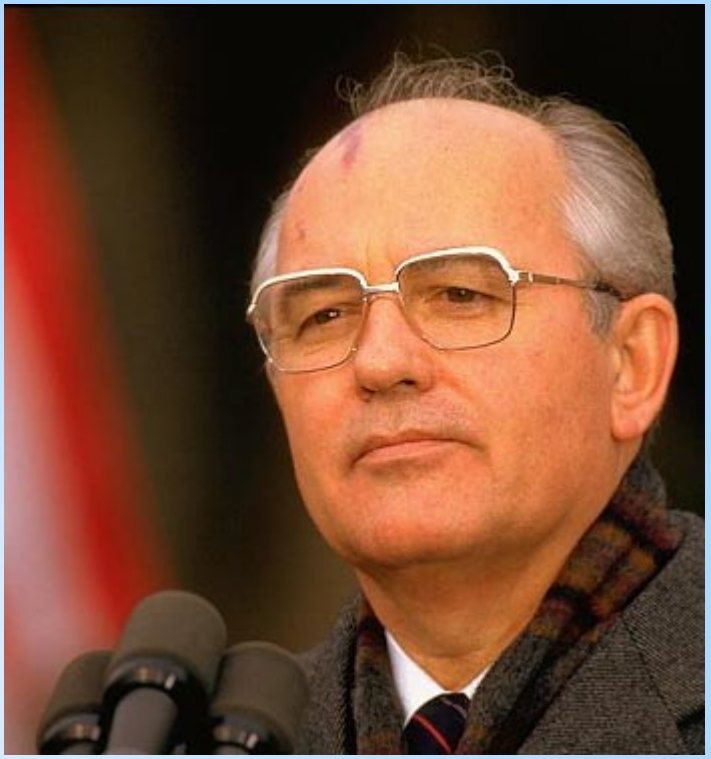
When asked about the effects of nuclear war in a February 12, 1985 interview in the *New York Times* said,



"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 ..."

http://www.nytimes.com/1985/02/12/world/transcript-of-interview-with-president-on-a-range-of-issues.html?pagewanted=all

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/

The New York Times

Opinion

Mikhail Gorbachev: A New Nuclear Arms Race Has Begun

President Trump says he plans to withdraw from a nonproliferation treaty that I signed with Ronald Reagan. It's just the latest victim in the militarization of world affairs.

By Mikhail Gorbachev
Mr. Gorbachev is the former president of the Soviet Union.

Oct. 25, 2018

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Today's arsenal (2019) is about 1/3 of the 1985 arsenal. It is the equivalent of the explosive power of about

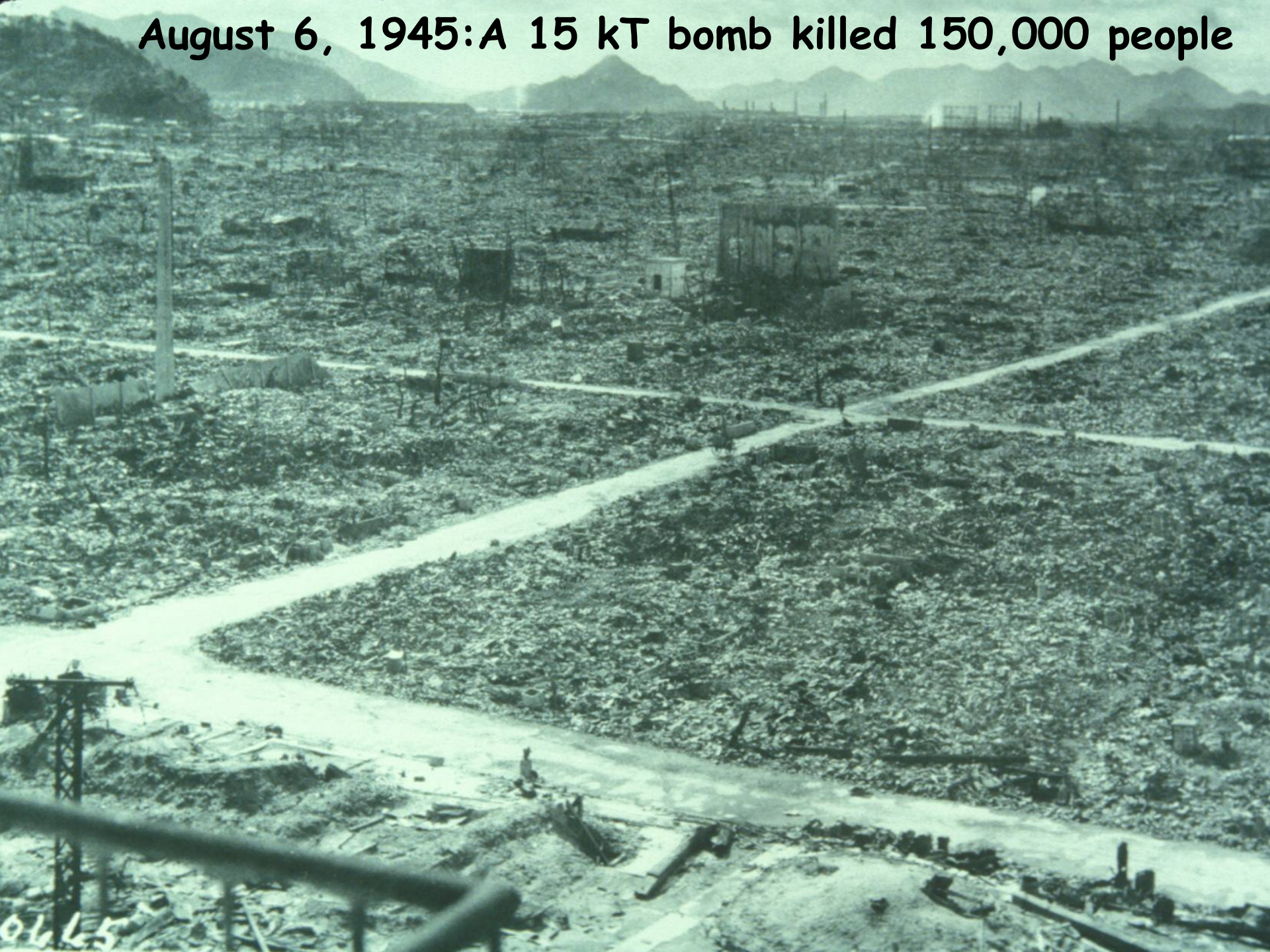
5,000,000,000,000 kg
(11,000,000,000,000 lbs) of TNT.

5,000 MT yield

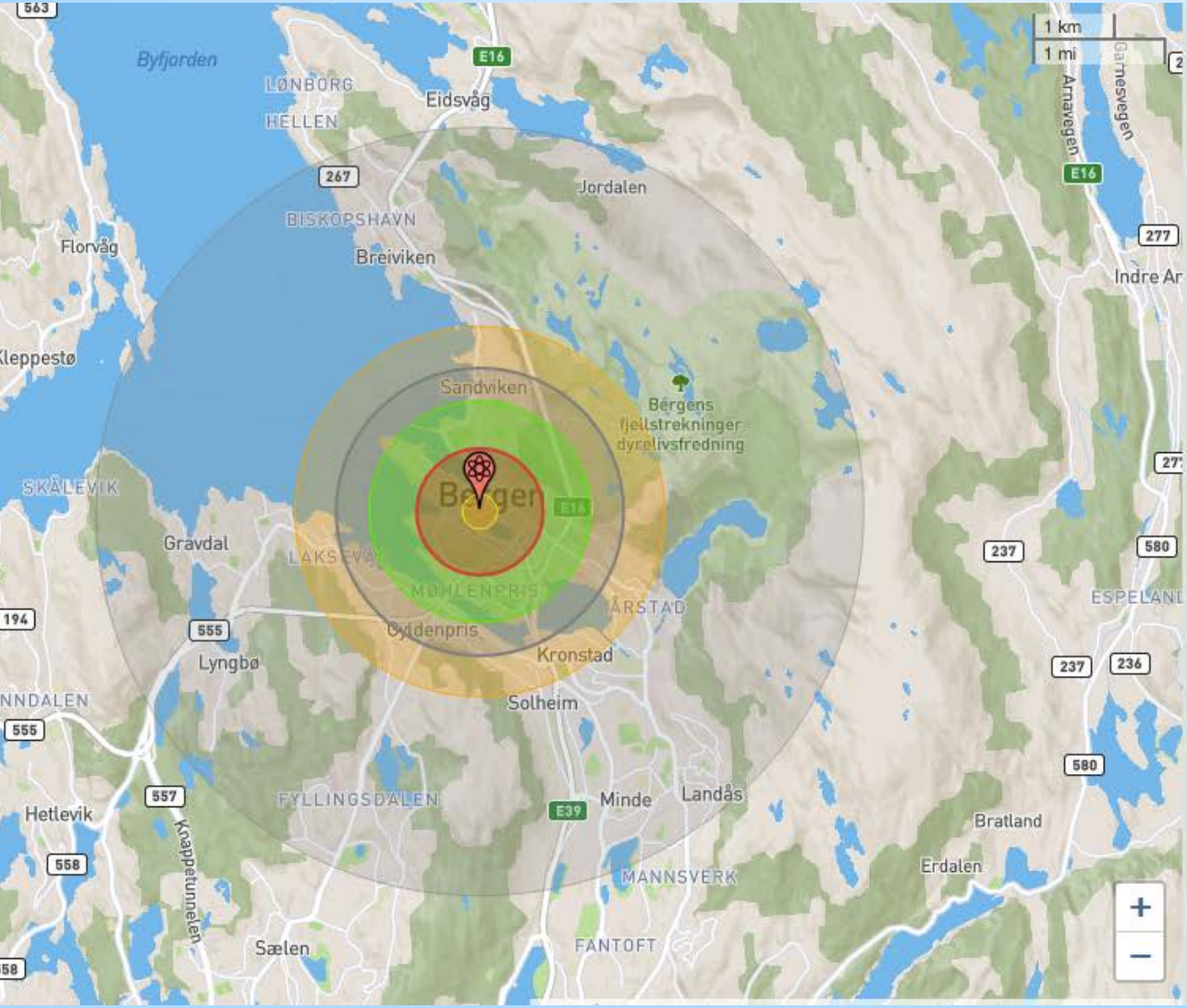
If we divided this up and gave everyone on the planet his or her share, each person would have the equivalent of just under a kT of TNT.

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!


August 6, 1945: A 15 kT bomb killed 150,000 people

What if Fat Man dropped on Bergen?



NUKEMAP 2.65 : FAQ

You might als MISSILE

Estimated fatalities:

23,370

Estimated injuries:

22,170

In any given 24-hour period, there are on average 81,636 people in light (1 psi) blast range of the simulated detonation.

Modeling casualties from a nuclear attack is difficult. These numbe should be seen as evocative, not definitive. Fallout effects are deliberately ignored, because they can depend on what actions pe take after the detonation. For more information about the model, cl here.

Effects radii for 20 kiloton airburst* (smallest to largest):

Fireball radius: 200 m (0.13 km²)

Maximum size of the nuclear fireball; relevance to lived effects depends on of detonation. If it touches the ground, the amount of radioactive fallout is significantly increased. Minimum burst height for negligible fallout: 180 m.

Air blast radius (20 psi): 0.76 km (1.82 km²)

At 20 psi overpressure, heavily built concrete buildings are severely damag demolished; fatalities approach 100%. Often used as a standard benchmar **heavy** damage in cities. Optimal height of burst to maximize this effect is 4

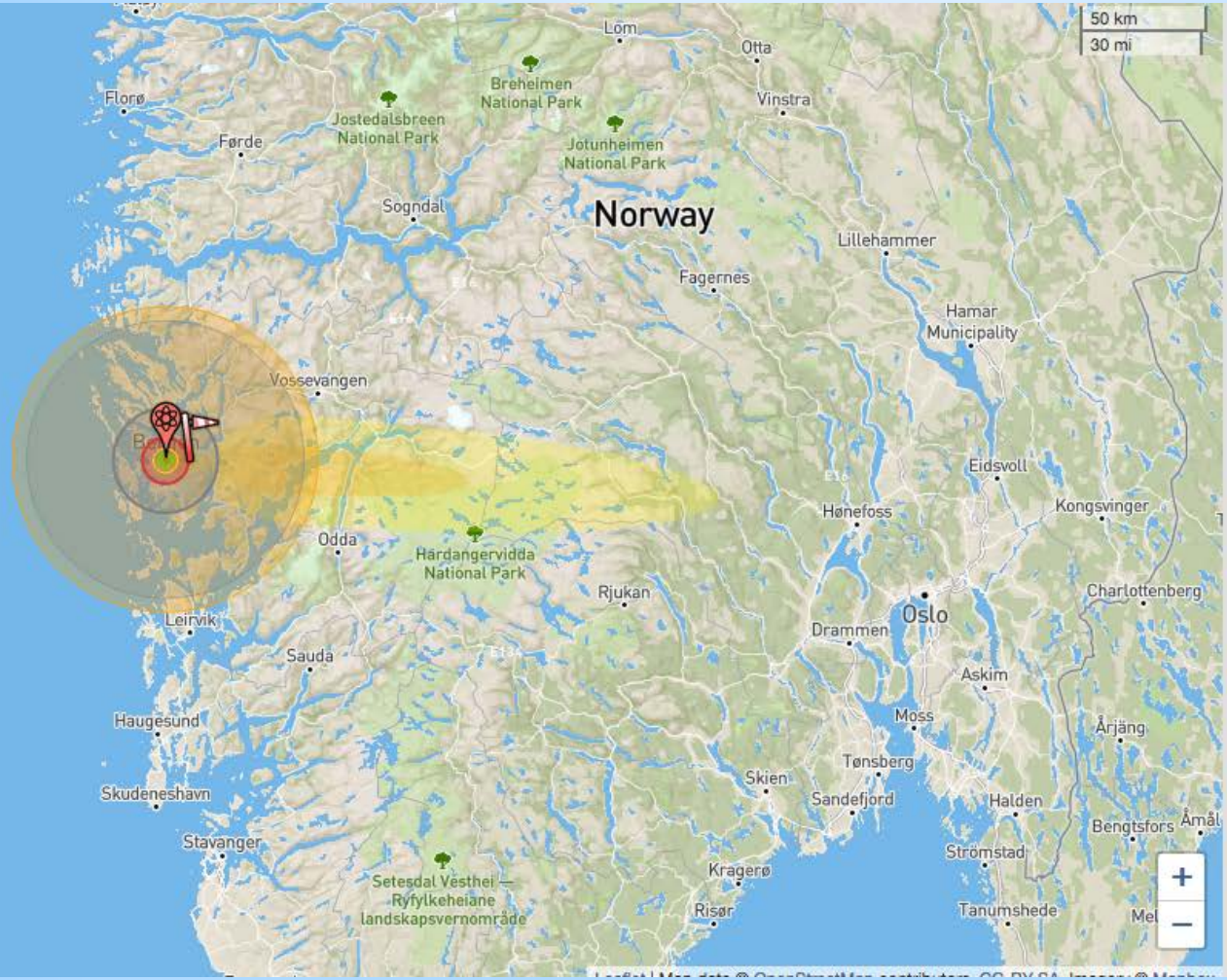
Radiation radius (500 rem): 1.31 km (5.42 km²)

500 rem radiation dose; without medical treatment, there can be expected between 50% and 90% mortality from acute effects alone. Dying takes bet several hours and several weeks.

Air blast radius (5 psi): 1.72 km (9.26 km²)

At 5 psi overpressure, most residential buildings collapse, injuries are unive fatalities are widespread. Often used as a standard benchmark for **medium** damage in cities. Optimal height of burst to maximize this effect is 0.85 km

Russian Tsar (50 MT) on Bergen



NUKEMAP 2.65 : FAQ

You might also try: MISSILEMAP

Estimated fatalities:

275,120

Estimated injuries:

50,260

In any given 24-hour period, there are on average 372,549 people in the light (1 psi) blast range of the simulated detonation.

Modeling casualties from a nuclear attack is difficult. These numbers should be seen as evocative, not definitive. Fallout effects are deliberately ignored, because they can depend on what actions people take after the detonation. For more information about the model, click here.

Effects radii for 50 megaton airburst* (smallest to largest): ▼

Radiation radius (500 rem): 3.14 km (30.9 km²)

500 rem radiation dose; without medical treatment, there can be expected between 50% and 90% mortality from acute effects alone. Dying takes between several hours and several weeks.

Fireball radius: 4.62 km (67.1 km²)

Maximum size of the nuclear fireball; relevance to lived effects depends on height of detonation. If it touches the ground, the amount of radioactive fallout is significantly increased. Minimum burst height for negligible fallout: 4.16 km.

Air blast radius (20 psi): 8.91 km (249 km²)

At 20 psi overpressure, heavily built concrete buildings are severely damaged or demolished; fatalities approach 100%. Often used as a standard benchmark for **heavy** damage in cities. Optimal height of burst to maximize this effect is 6.7 km.

Air blast radius (5 psi): 20.7 km (1,350 km²)

At 5 psi overpressure, most residential buildings collapse, injuries are universal, fatalities are widespread. Often used as a standard benchmark for **medium** damage in cities. Optimal height of burst to maximize this effect is 11.5 km.

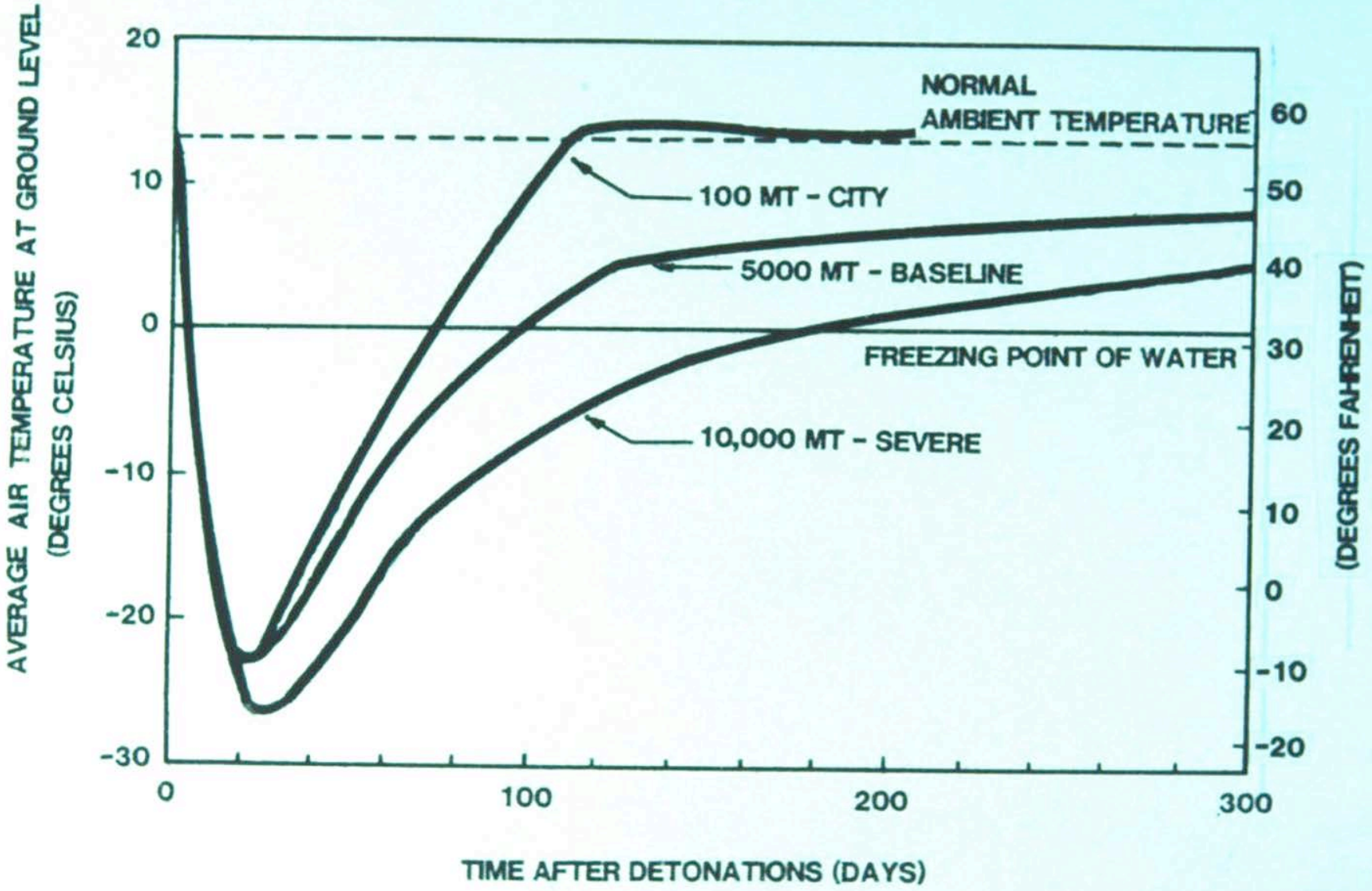
TTAPS

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.


AVERAGE AIR TEMPERATURE AT GROUND LEVEL
(DEGREES CELSIUS)
20
10
0
-10
-20
-30
NORMAL
AMBIENT TEMPERATURE
100 MT - CITY
5000 MT - BASELINE
FREEZING POINT OF WATER
10,000 MT - SEVERE
0
100
200
300
TIME AFTER DETONATIONS (DAYS)
60
50
40
30
20
10
0
-10
-20
(DEGREES FAHRENHEIT)

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.

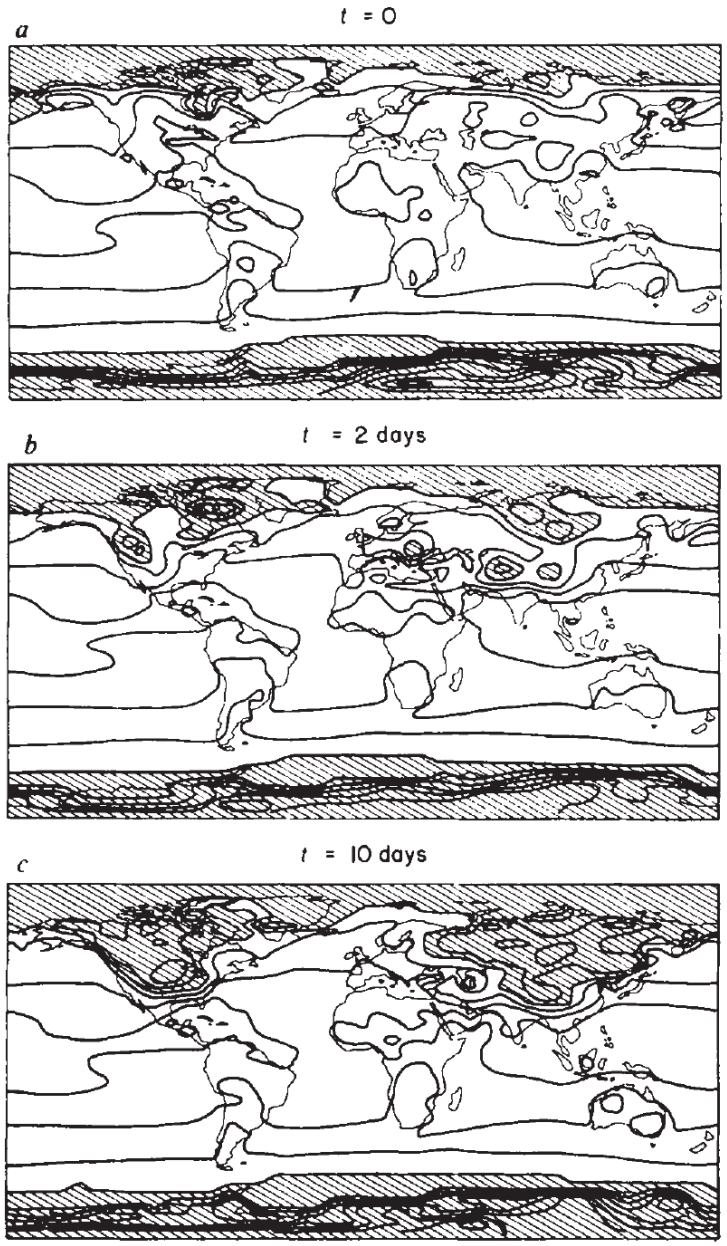


Fig. 3 Surface temperature (T) at three selected instants of time: $t = 0$ is the time at which smoke was added to the atmosphere in the summer case. Temperature contours are drawn for every 10 K. Areas with $T < 270$ K (that is, well below freezing) are shaded. The warmest contour value in the tropics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

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

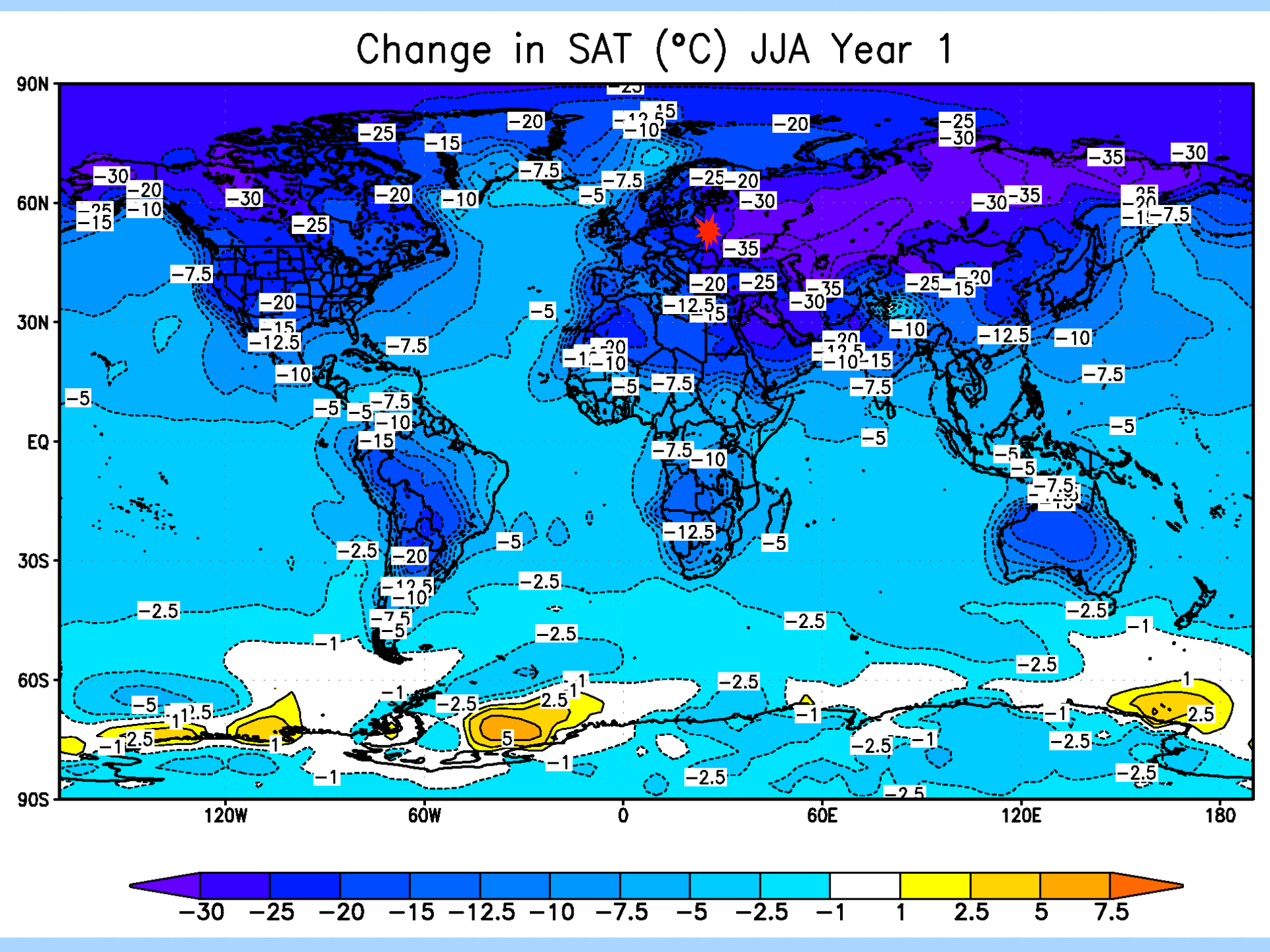
We use the NASA GISS ModelE atmosphere-ocean general circulation model.

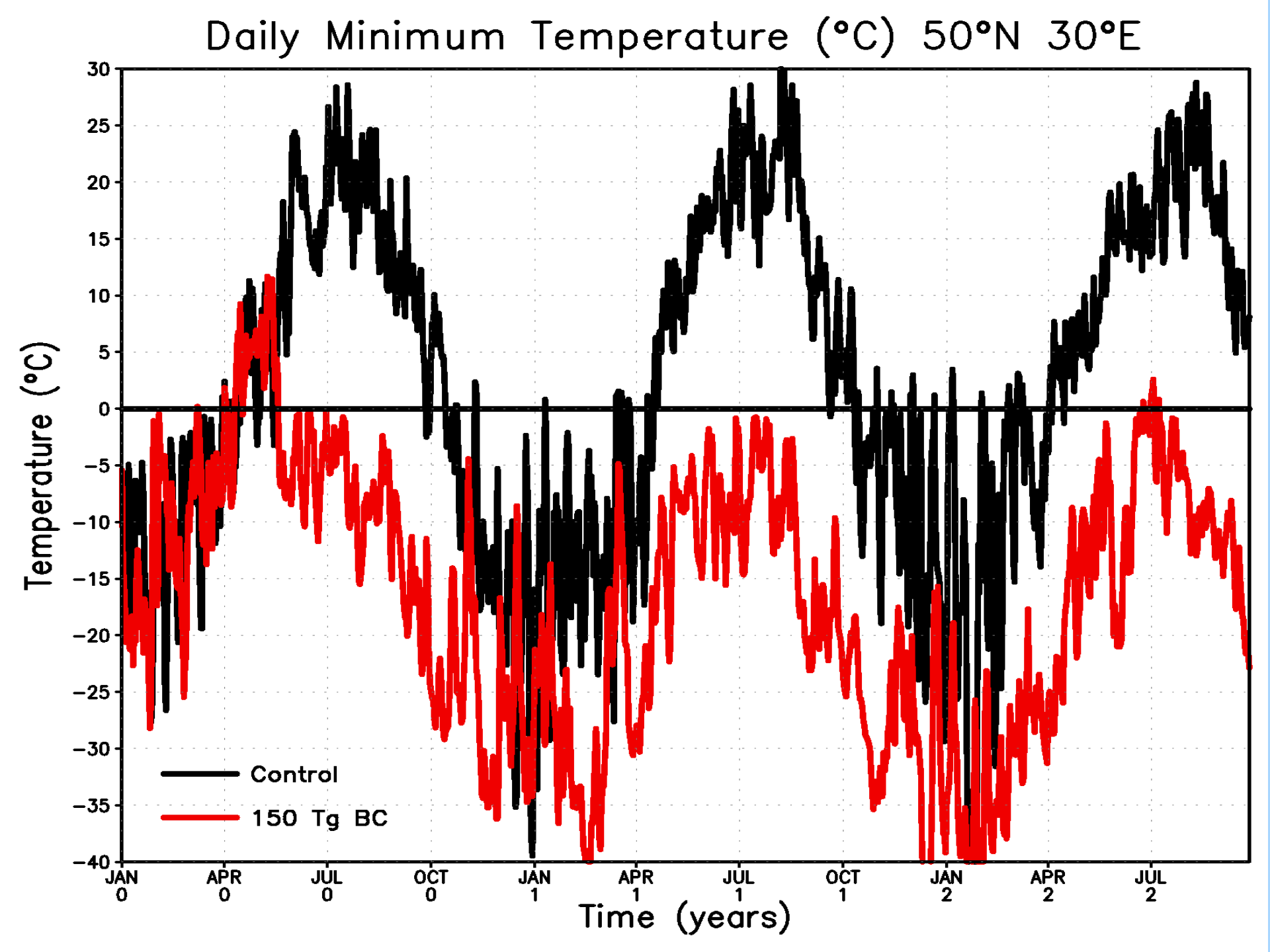
- 50 Tg or 150 Tg of smoke into the 300-150 mb layer (upper troposphere) over the US and Russia on May 15
- 30-yr control run, two 10-yr runs (50 Tg or 150 Tg)

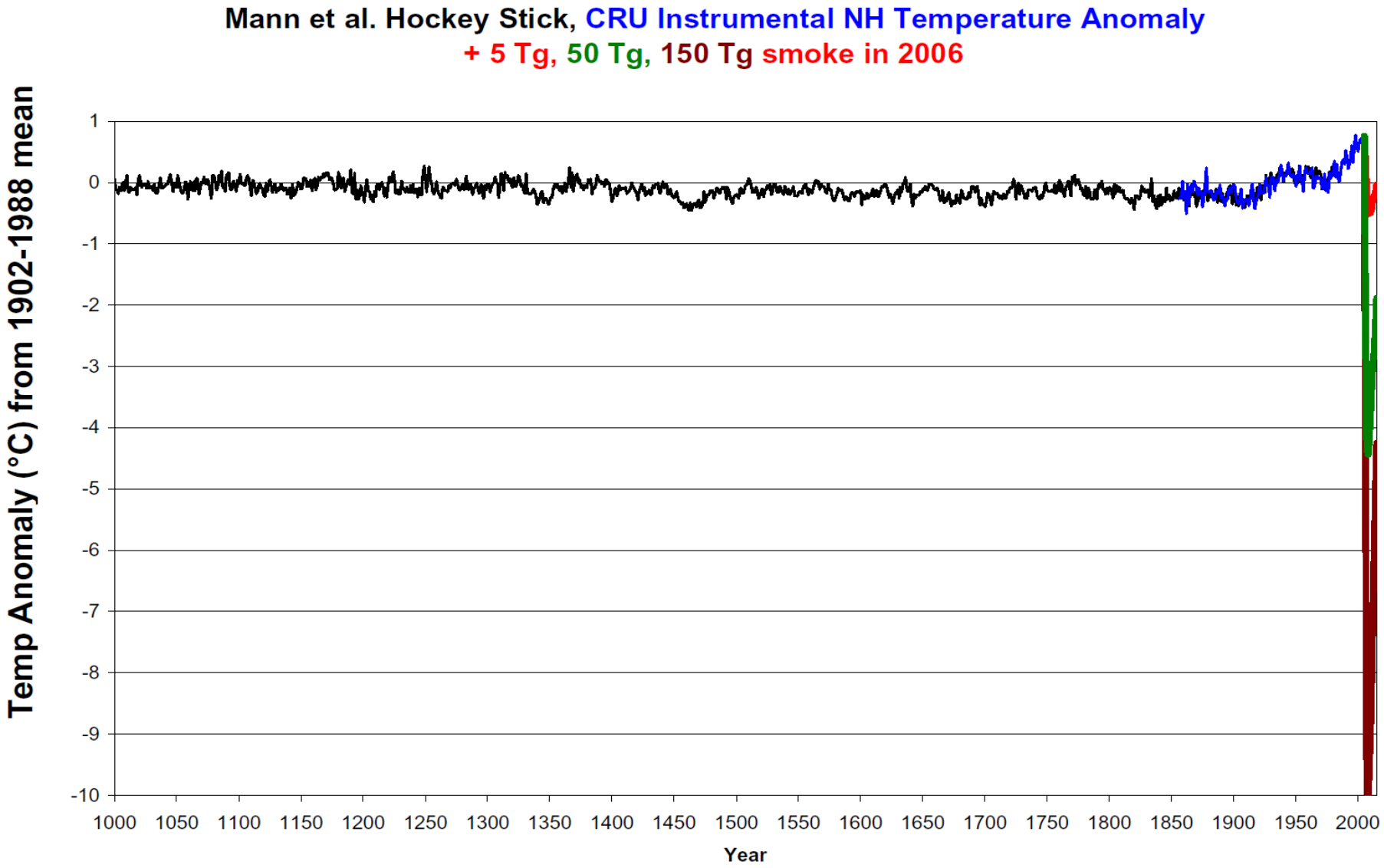
What could produce 150 Tg of smoke?

- 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 et al., 2007b


Change in SAT (°C) JJA Year 1
90N
60N
30N
EQ
30S
60S
90S
120W
60W
0
60E
120E
180
−30 −25 −20 −15 −12.5 −10 −7.5 −5 −2.5 −1 1 2.5 5 7.5


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)

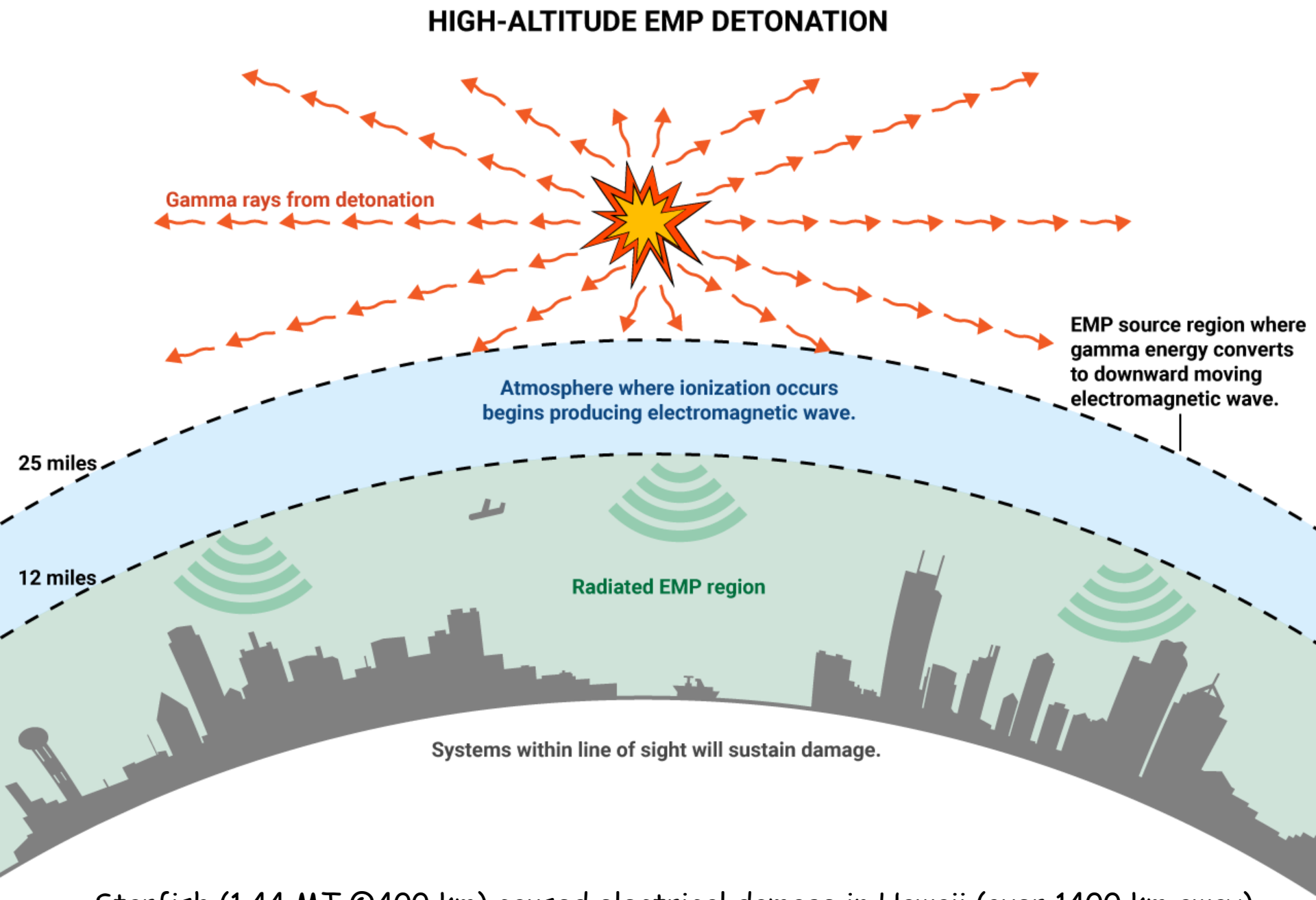

Mann et al. Hockey Stick, CRU Instrumental NH Temperature Anomaly
+ 5 Tg, 50 Tg, 150 Tg smoke in 2006
Temp Anomaly (°C) from 1902-1988 mean
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000
Year

EMP – Can damage electronics and power distribution systems

- E1 – very large electric field due to gamma radiation directly impacts space and ground electronic systems

- E2 –blast wave E-field and particle acceleration and (for HAND) coherent gyration of Compton scattered electrons can make whole atmosphere a big antenna inducing EMP that can damage electrical systems (similar frequency to lightning impacts)

- E3 – large geomagnetic perturbations can give rise to ground-induced currents also damaging electric grid (similar frequency to CME driven geomagnetic storms)

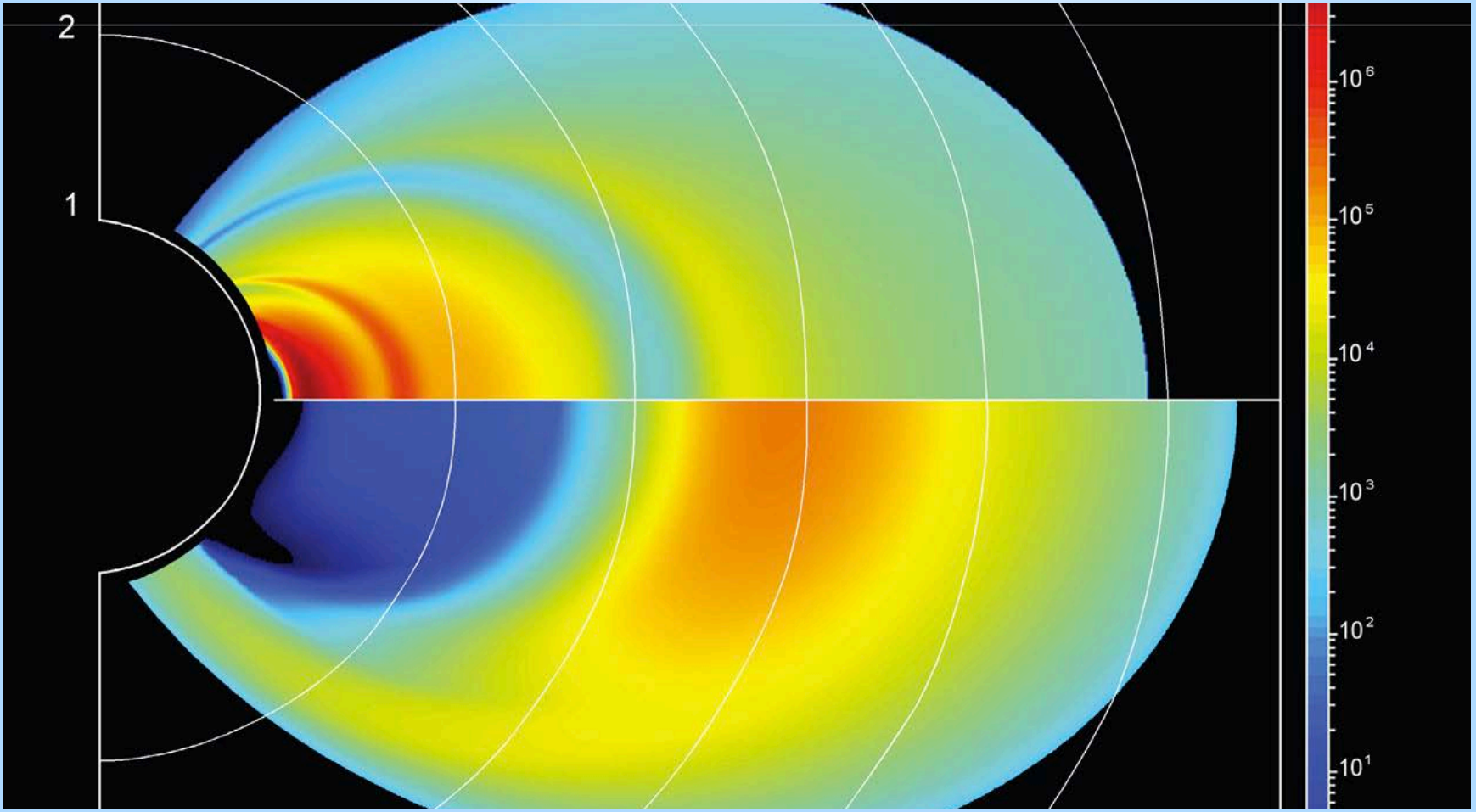


Starfish (1.44 MT @400 km) caused electrical damage in Hawaii (over 1400 km away).

Source: Congressional Commission to Assess the Threat of Electromagnetic Pulse to the United States of America

Graphic redesign by Geopolitical Futures

1962 Starfish Test (Explorer XV) vs 2015 from RBSP: Inner Belt >10 million times



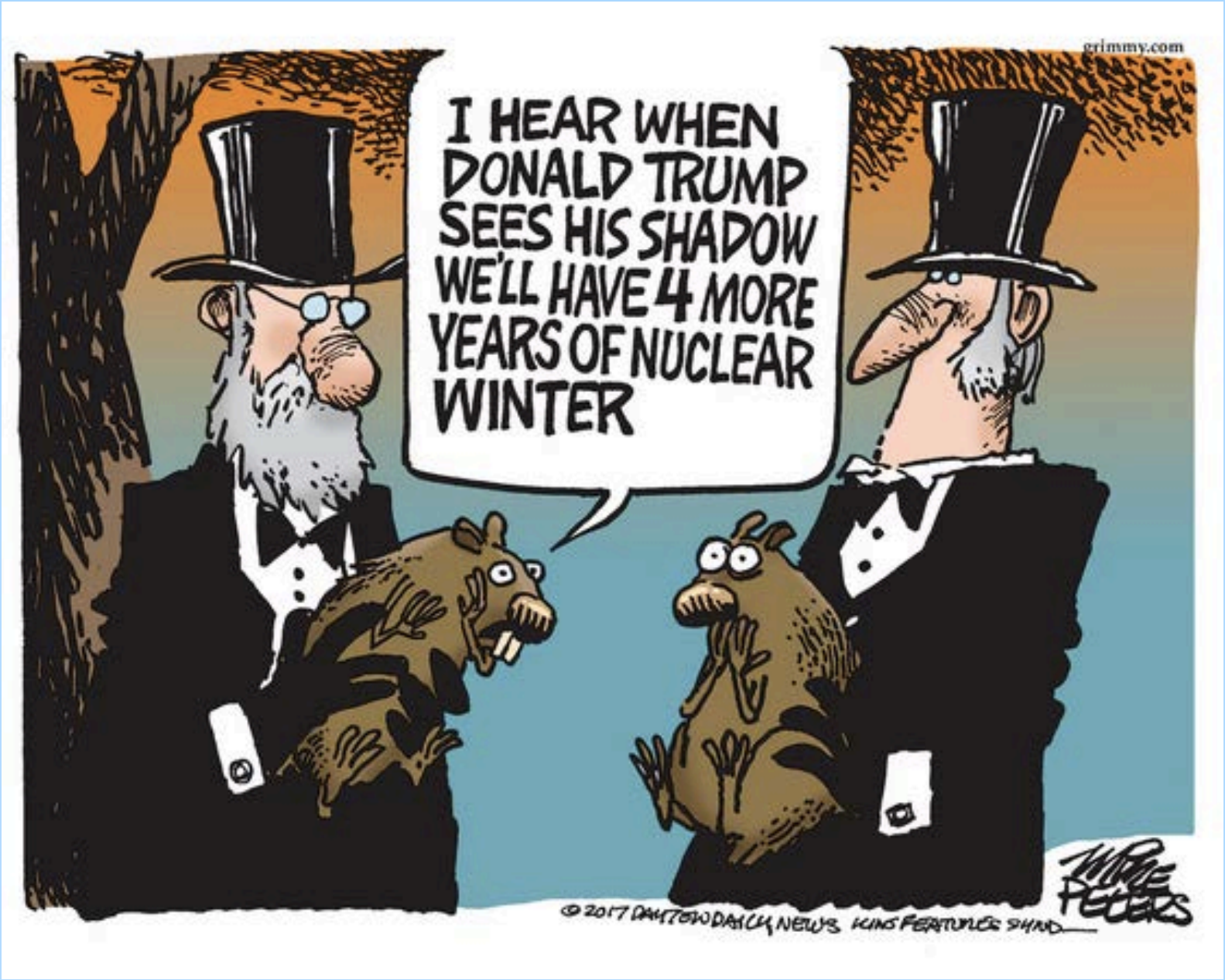
From Gombosi et al., 2017

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



Union of
Concerned Scientists
Science for a Healthy Planet and Safer World

Go to https://www.ucsusa.org/ to learn more about Nuclear weapons



http://comicskingdom.com/mike-peters/2017-02-02



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

Dr. Seuss, *The Lorax* (1971)

Climate and Space papers:

C. Covey, S.H. Schneider, S.L. Thompson **Global atmospheric effects of massive smoke injections from a nuclear war: results from general circulation model simulations**, Nature, 308 (1984), pp. 21-25

Gombosi, T. I., D. N. Baker, A. Balogh, P. J. Erickson, J. D. Huba, L. J. Lanzerotti. **Anthropogenic Space Weather**. *Space Science Reviews*, 2017; DOI: 10.1007/s11214-017-0357-5

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. National Acad. Sci.*, **105**, 5307–5312.

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.

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.

Robock, Alan, 2011: Nuclear winter is a real and present danger. *Nature*, **473**, 275-276.

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

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.

Robock, Alan, Owen B. Toon, Richard P. Turco, Luke Oman, Georgiy L. Stenchikov, and Charles Bardeen, 2007c: The continuing environmental threat of nuclear weapons: Integrated policy responses needed. *EOS*, **88**, 228, 231, doi: 10.1029/2007ES001816.

Robock, Alan, and Owen Brian Toon, 2010: Local nuclear war, global suffering. *Scientific American*, **302**, 74-81.

Robock, Alan, and Owen B. Toon, 2012: Self-assured destruction: The climate impacts of nuclear war, *Bull. Atomic Scientists*, **68**(5), 66-74, doi:10.1177/0096340212459127.

Toon, Owen B., Richard P. Turco, Alan Robock, Charles Bardeen, Luke Oman, and Georgiy 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.

Toon, Owen B., Alan Robock, Richard P. Turco, Charles Bardeen, Luke Oman, and Georgiy L. Stenchikov, 2007: Consequences of regional-scale nuclear conflicts. *Science*, **315**, 1224-1225.

Toon, Owen B., Alan Robock, and Richard P. Turco, 2008: Environmental consequences of regional and global nuclear war in the 21st century. *Physics Today*, **61**, No. 12, 37-42.

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.

U.S. Nuclear Weapon Program Costs

- Spurred by memo of UK refugee German physicists, U.S./UJ create "Manhattan Project"- 1942-1045
- Cost: $2 billion ($26B in current U.S.$)
- $4.5B/year over 10 years for SSP (stockpile stewardship program)
- 2014- $23.3B for nukes; $20.5B associate costs

- 2017 latest CBO estimates that existing plans for U.S. nuclear forces would cost $400 billion over the 2017–2026 period

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



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

September 23, 2015



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

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 mili
gun battle with Indian security forces, in Kashi

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.

Three Pakistani soldiers were killed and one was injured Monday evening,
oked" cease-fire
ch District.

oldiers were killed after
over by fire from Indian
for the ministry said

rs, including an army
fire in the Rajouri

he two militaries has
resque Himalayan
oth declared
claim Kashmir in its

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Be Prepared for an India-Pakistan Limited War

Why is there an assumption that nuclear weapons would preclude a limited conflict between India and Pakistan?

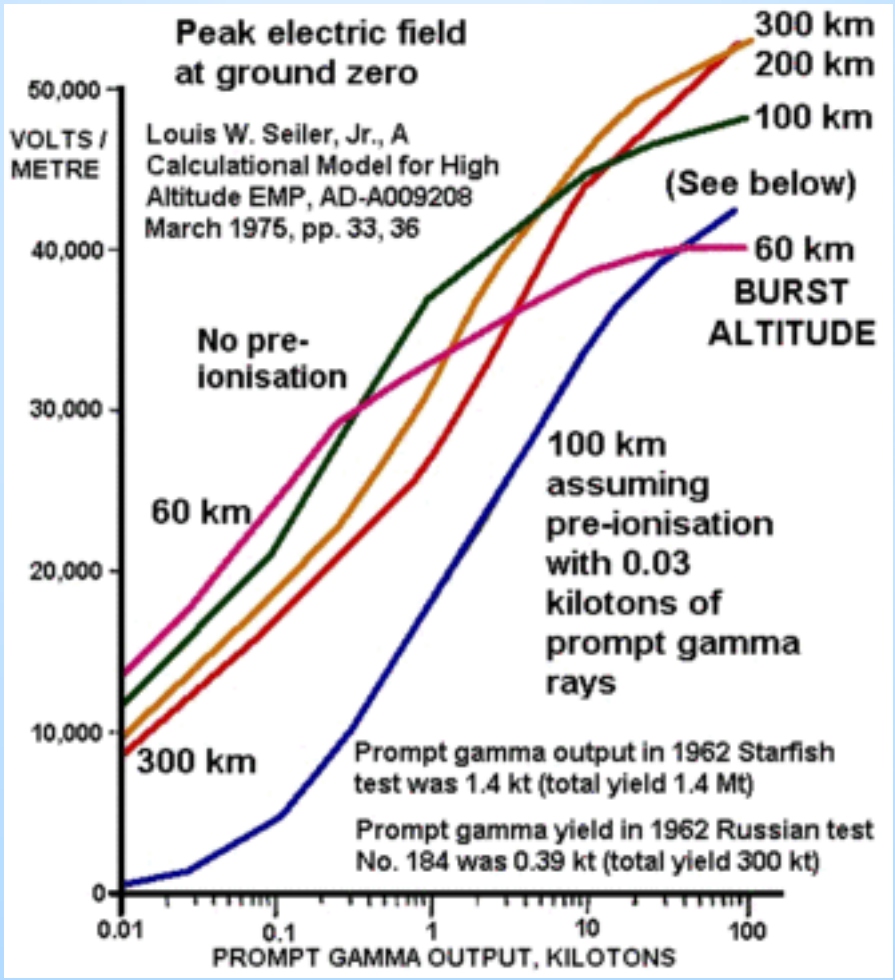
By Nishank Motwani
October 05, 2018



Indian army soldiers shout slogans in support of India and against Pakistan as they leave the site of a gunbattle in Dialgham, about 60 kilometers south of Srinagar, Indian-controlled Kashmir (July 1, 2017).

Nuclear strategy and deterrence in South Asia will play by its own rules. As obvious as this statement is, the problem is that most of the literature on the nuclear strategies and postures of regional nuclear

Altitude (and yield) determine impacts



"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

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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.