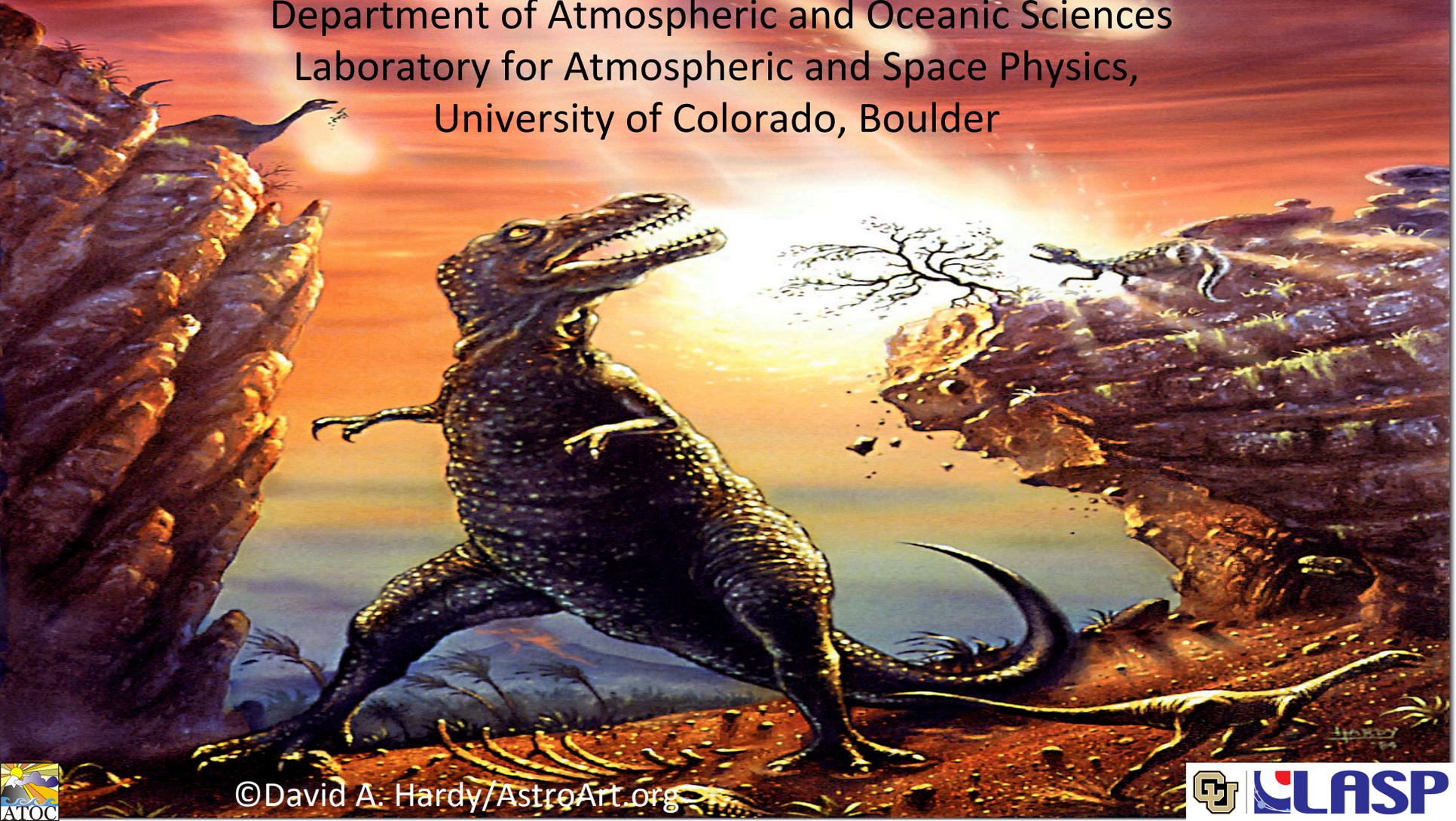


Dead Dinosaurs and Nuclear Wars

Brian Toon

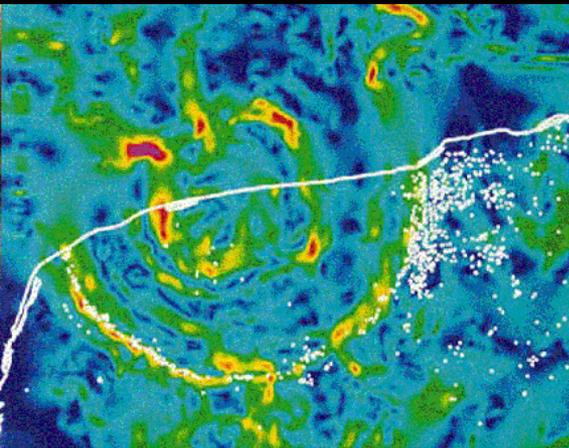
Department of Atmospheric and Oceanic Sciences
Laboratory for Atmospheric and Space Physics,
University of Colorado, Boulder



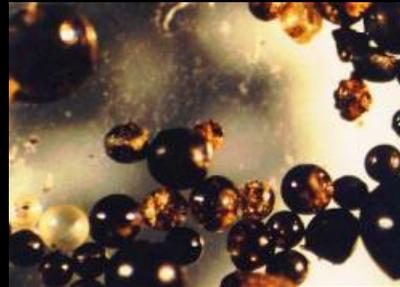


Moon forming impact, 4.5 Ga

Impacts have occurred since the dawn of time, and will occur again

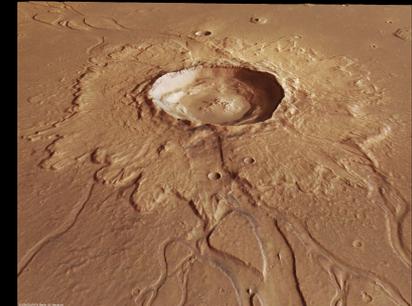


Chixulub crater, 65 Ma



Rooftop micrometeorites, ongoing

Martian impacts, ongoing



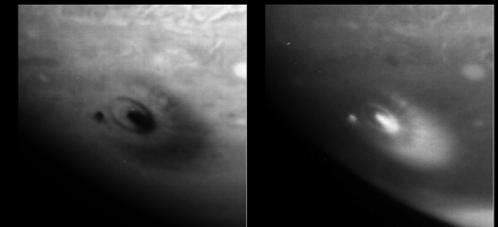
Forest blow down at Tunguska, 1908

SL-9 hits Jupiter, 1994

G Impact Site

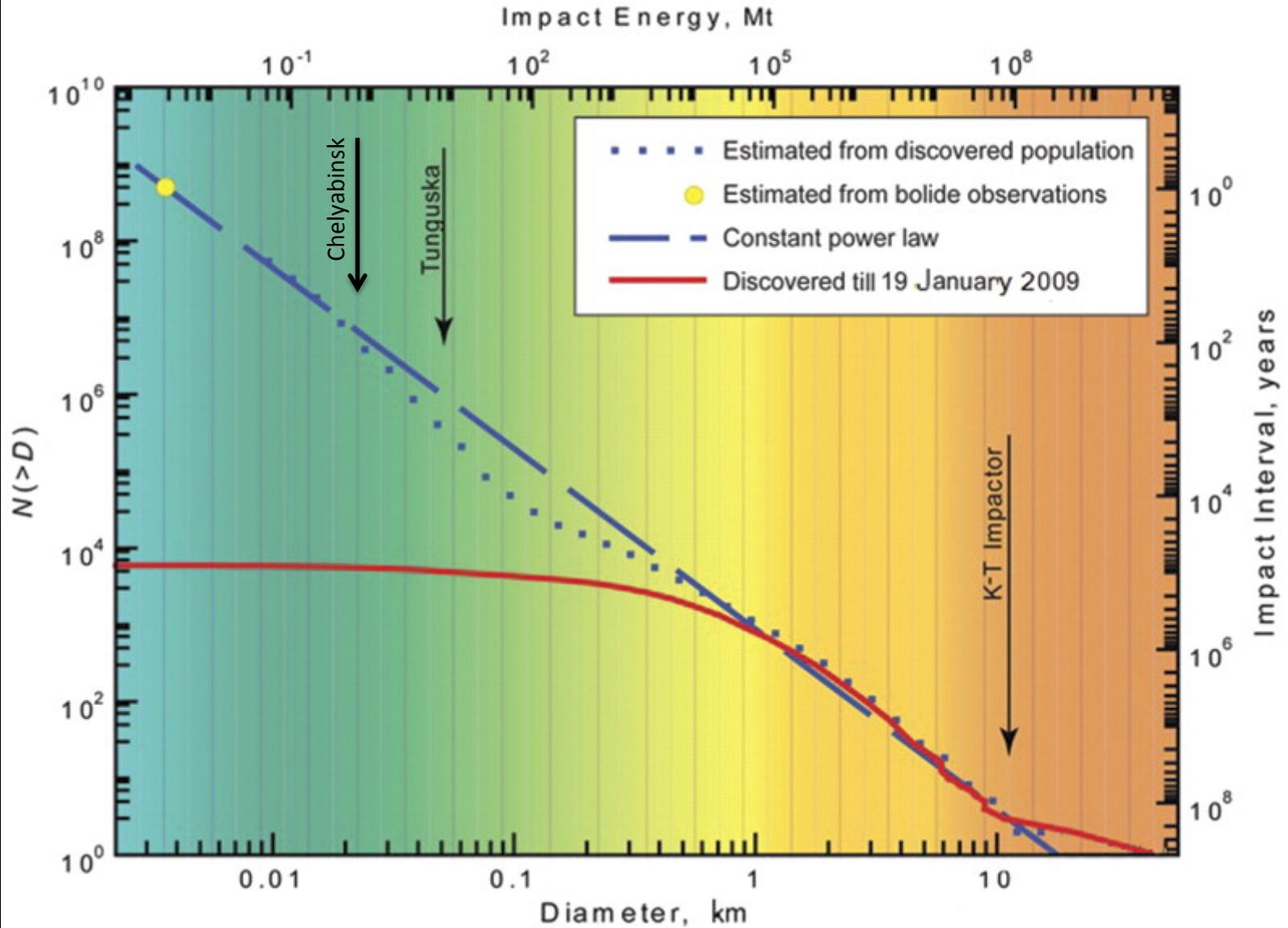
Green

Methane

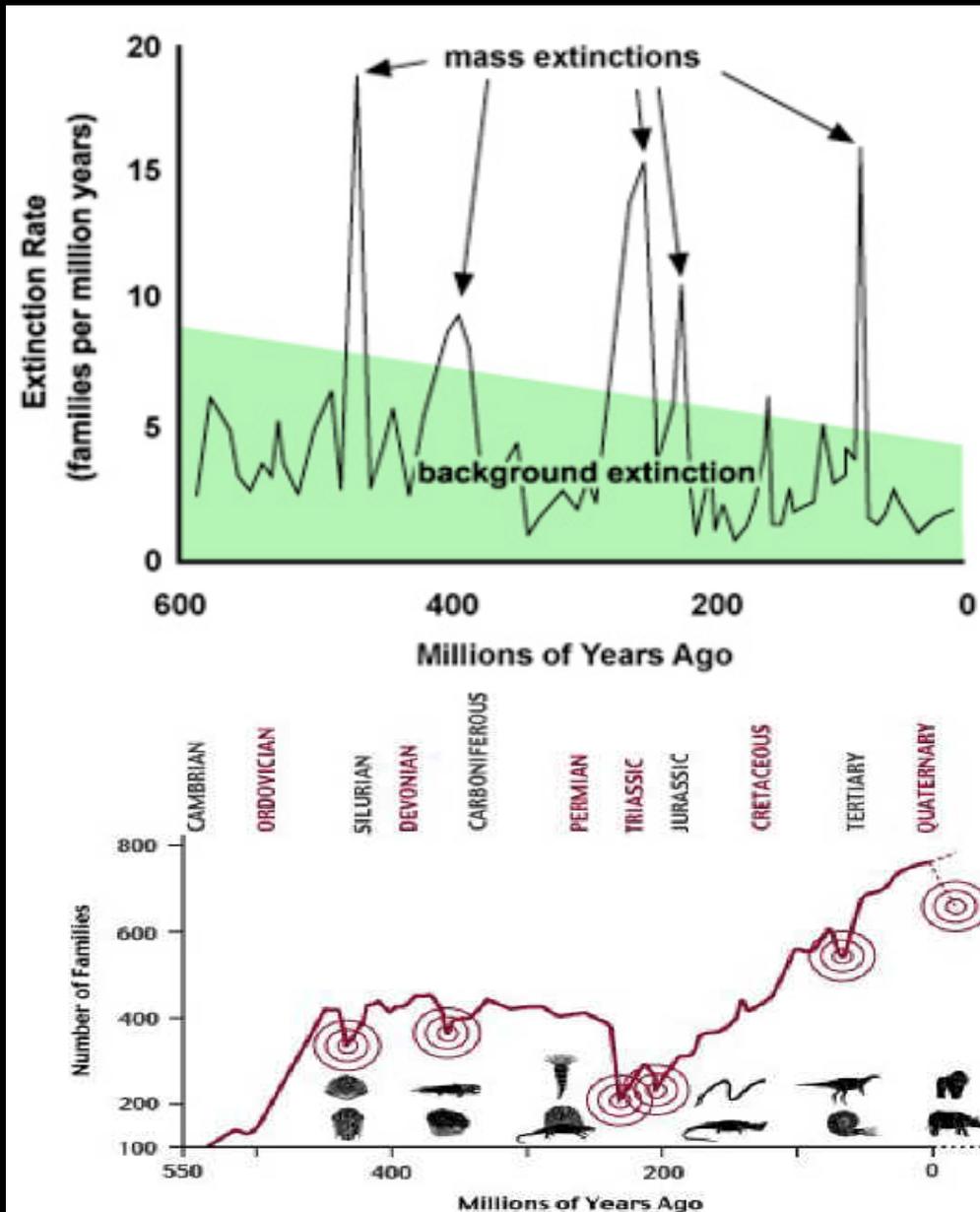
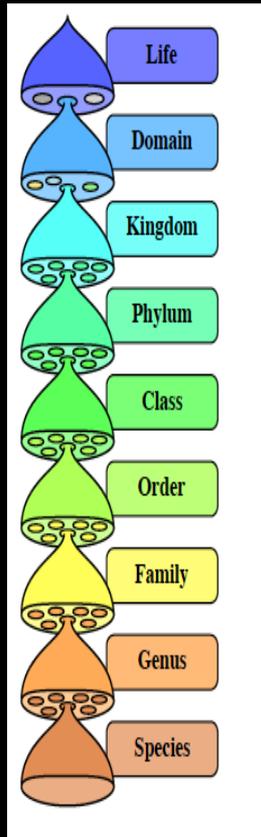


18 July 1994

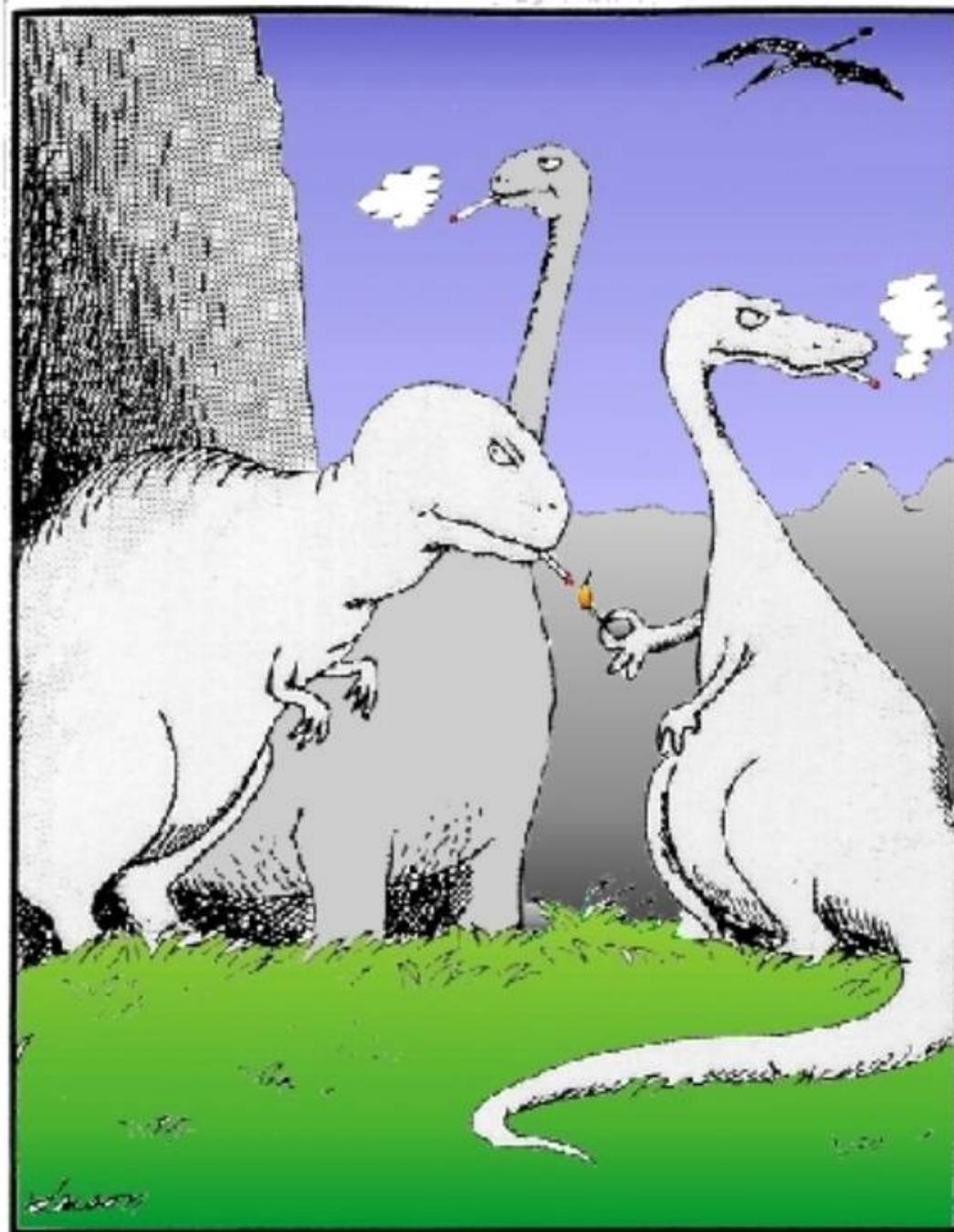
We know the chances of being hit



Geologic history shows 5-6 mass extinctions



Many mechanisms have been proposed for the extinction of the dinosaurs, but most have no data to support them



The real reason dinosaurs became extinct

Evidence was found in a worldwide “clay layer” of sediments in 1980s

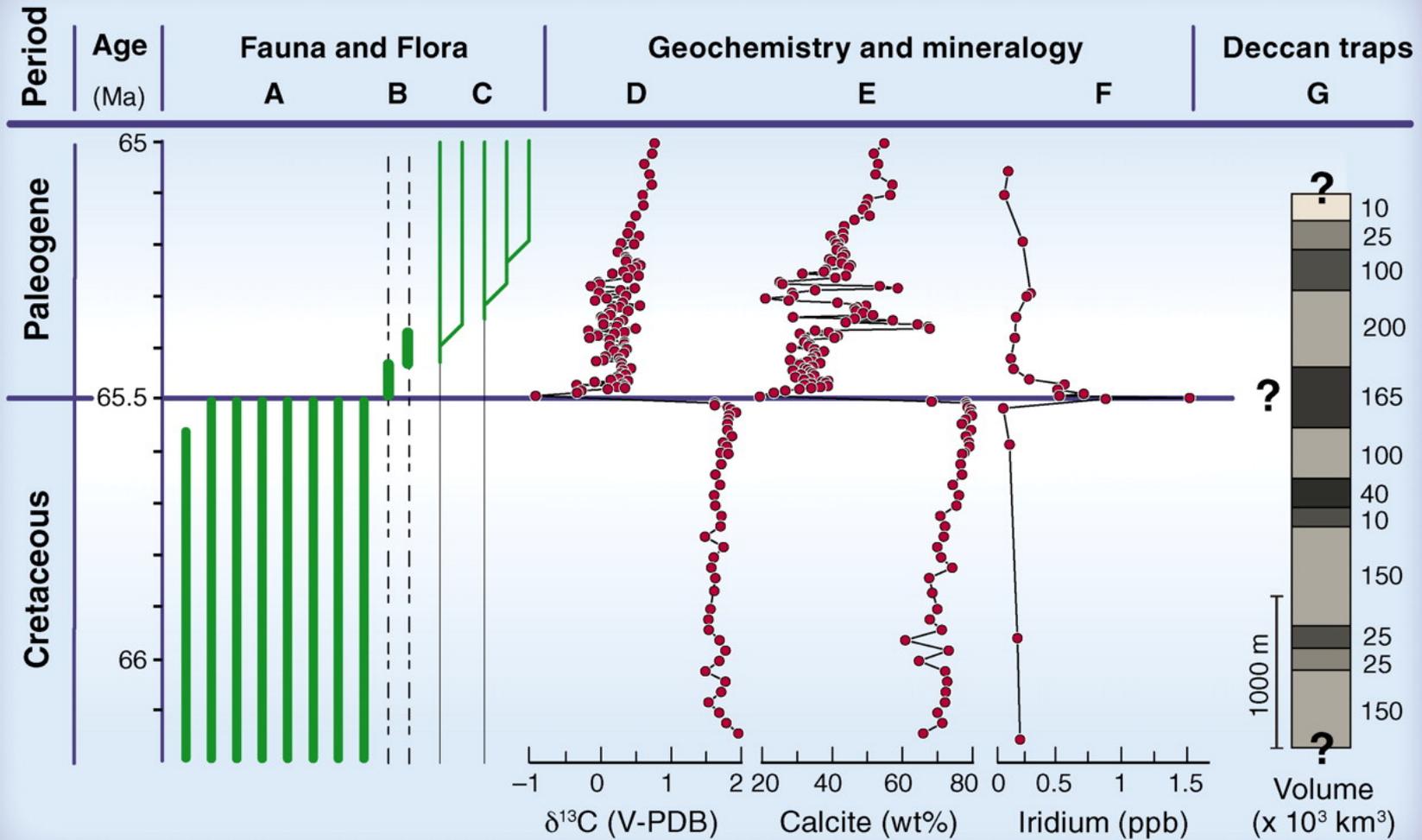


Clay Layer at Trinidad Lake State Park, Colorado

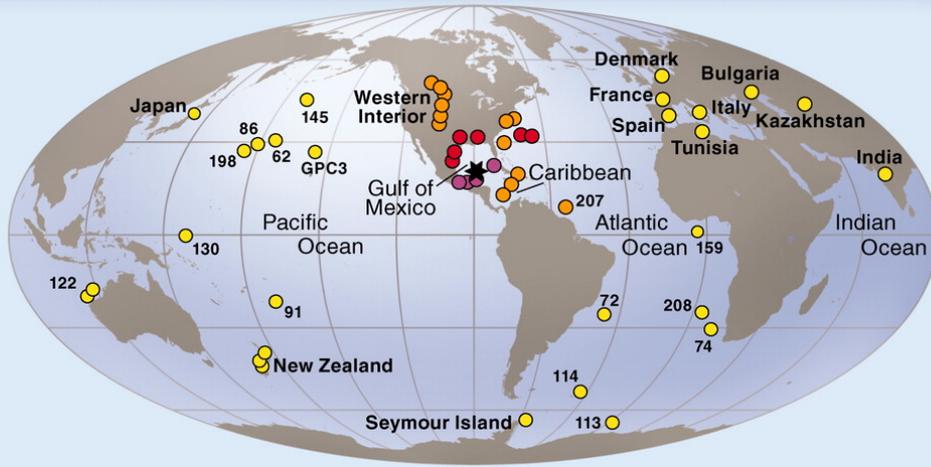


Louis and Walter Alvarez at Gubbio, Italy

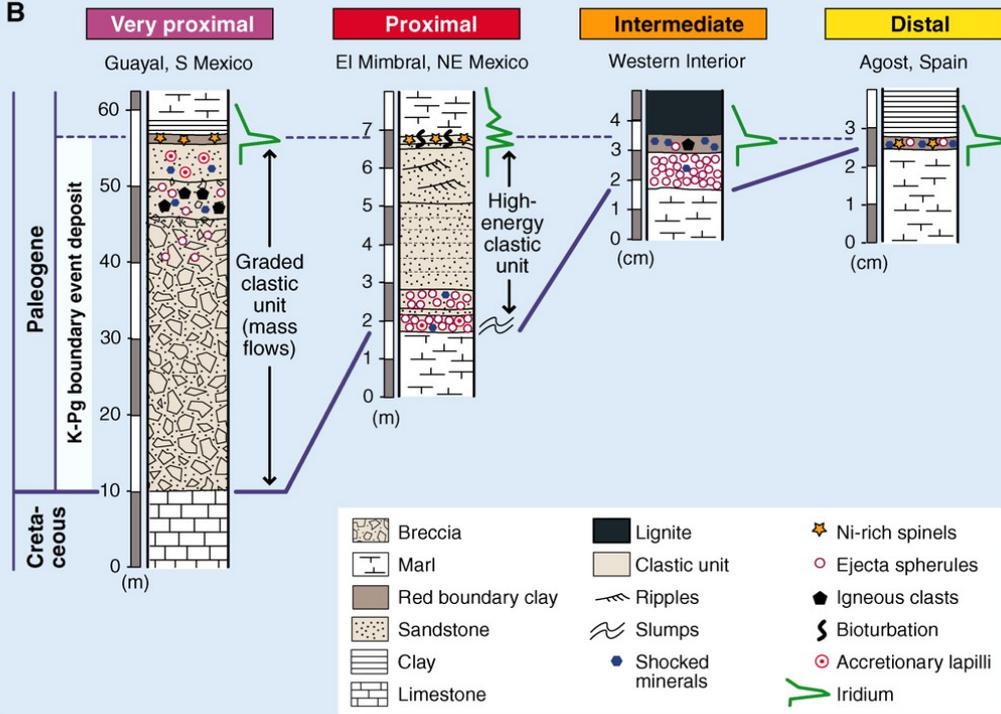
An iridium spike marks the K-Pg extinction



A



B

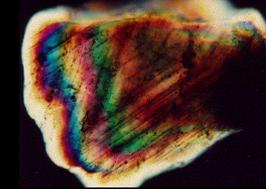


The debris layer is worldwide, and builds toward the crater

Schulte et al., Science, 2010

Particles killed the dinosaurs: the “clay layer” evidence

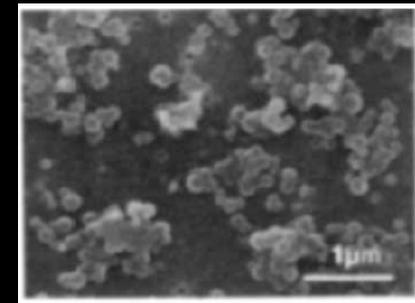
Pulverized target material



Melted target (maybe some from impactor)



Elemental carbon (from forest fires)



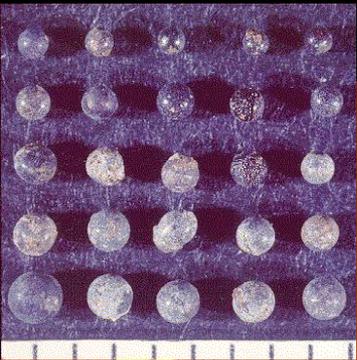
Vaporized impactor?

Sulfur?

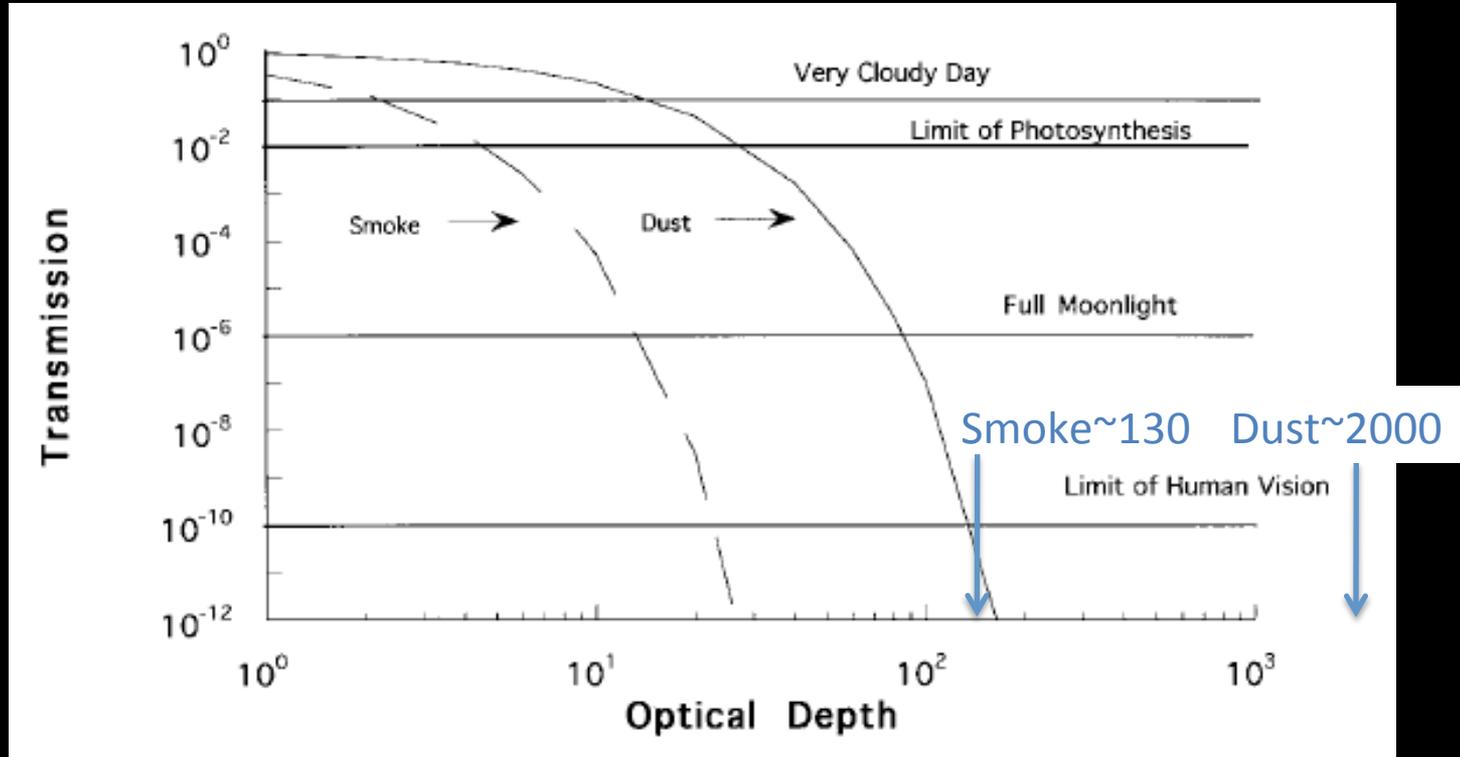


What likely happened ?

Very high radiant intensities from the shooting stars in the hours after the impact broiled the dinosaurs alive.



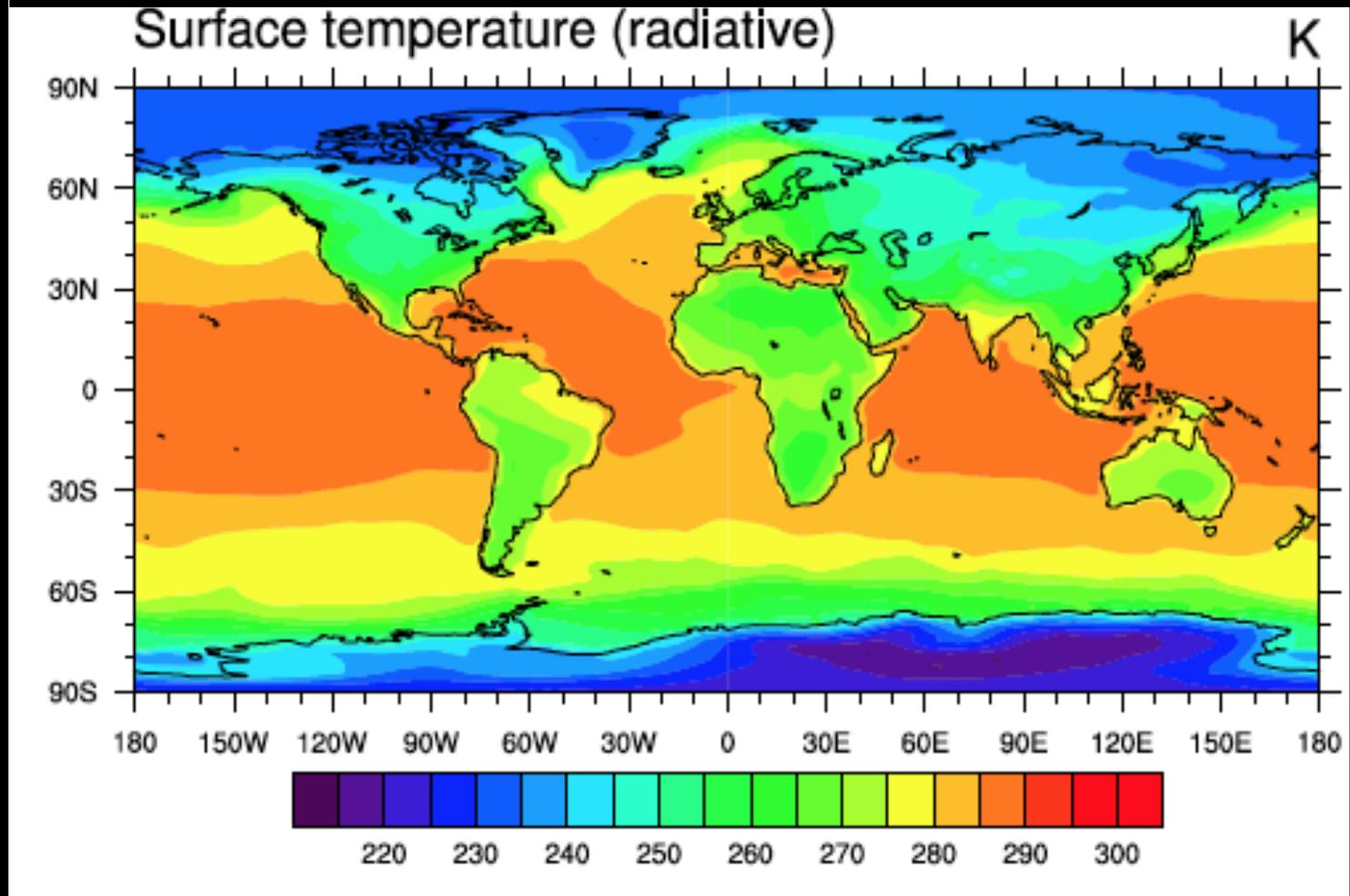
The airborne smoke and dust allowed little light to reach the surface



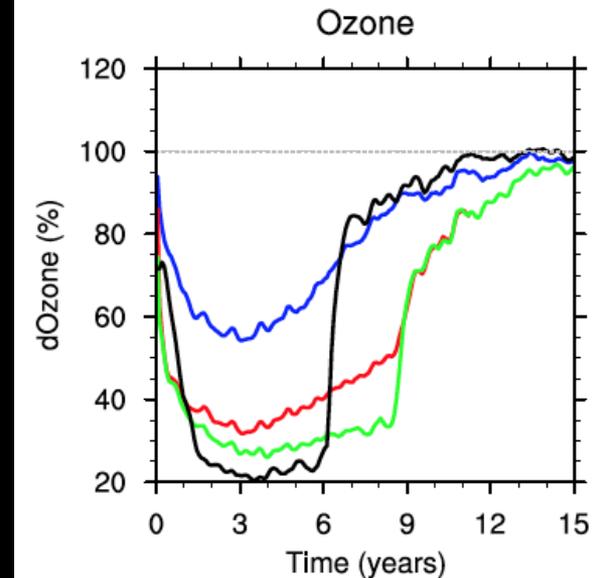
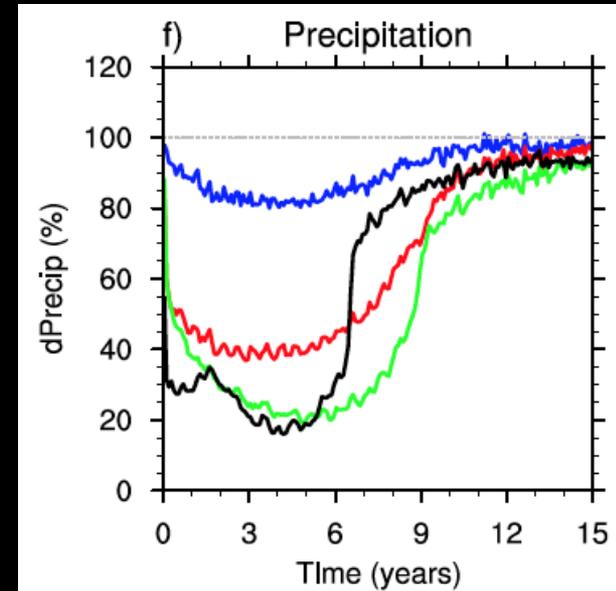
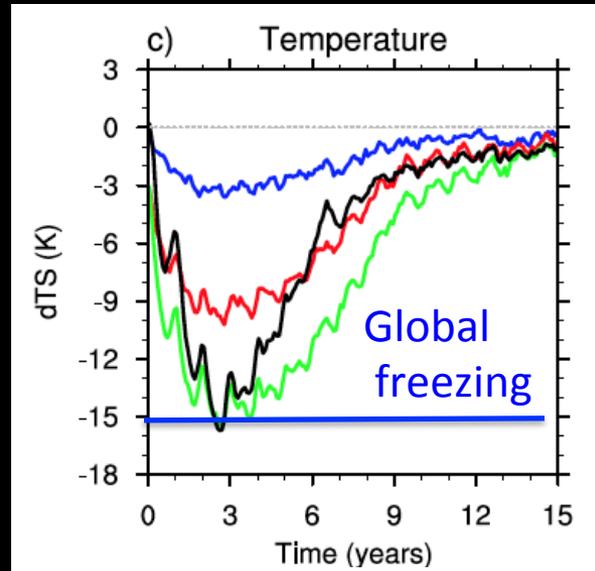
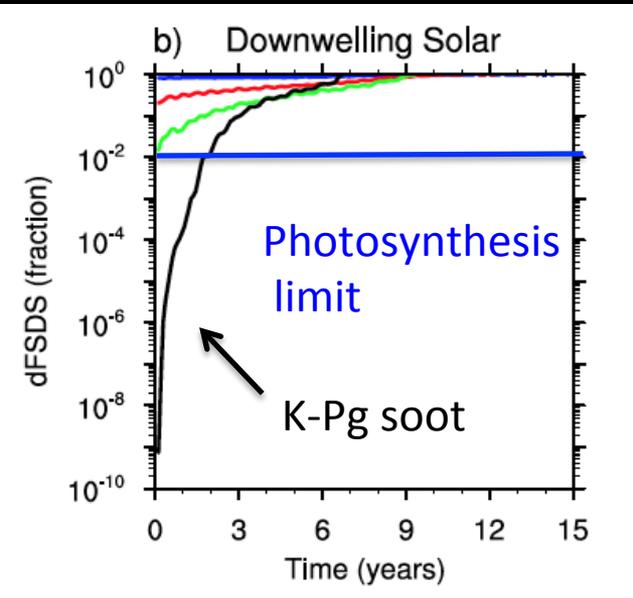
One layer of particles is about one optical depth

What likely happened due to soot?

On land and in the sea very cold temperatures

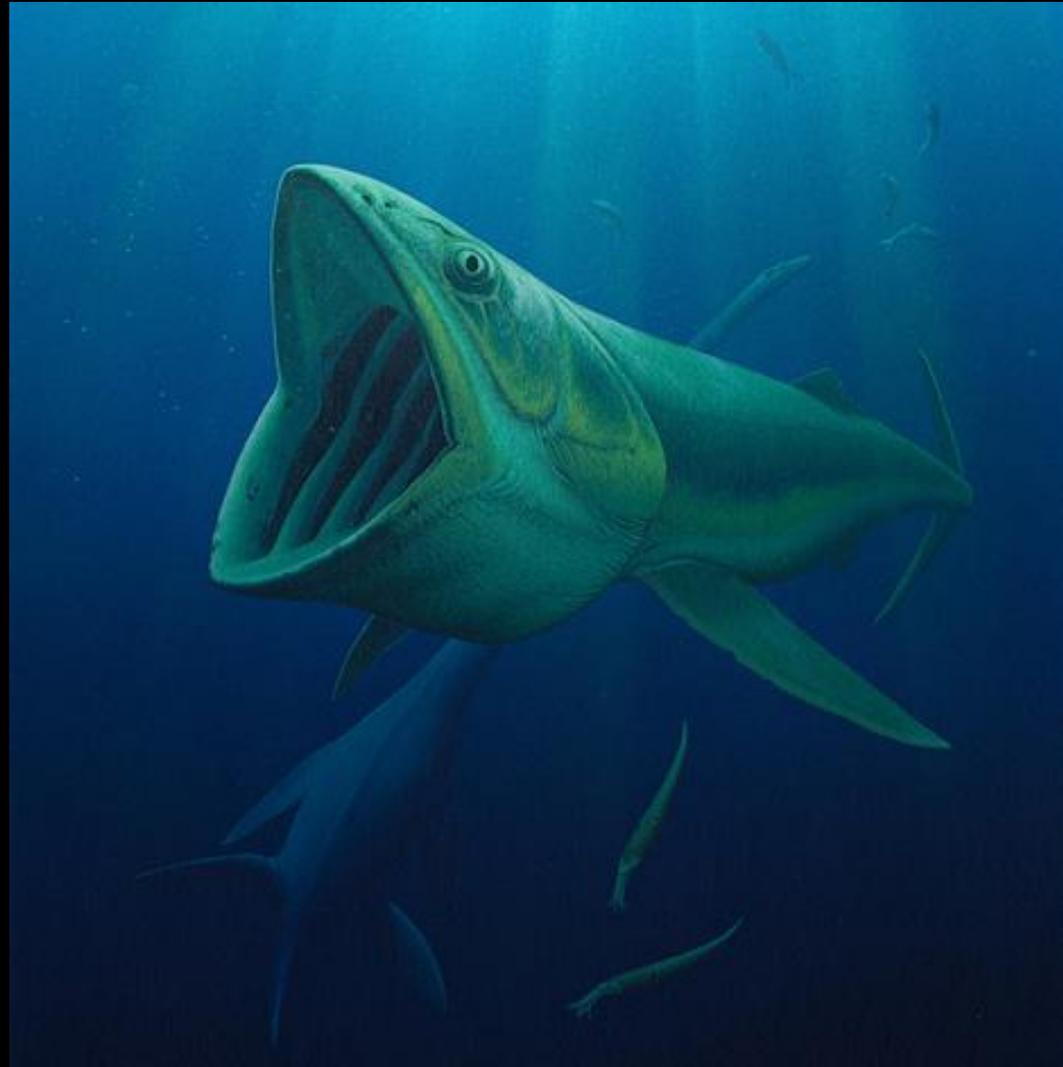


Light, temperature, rain, ozone fell due to soot



What likely caused extinctions in oceans?

In the oceans when sunlight was lost, plankton could not reproduce and the food chain collapsed.



Bonnericthys

How did our ancestors survive?

Sheltering was an important survival mechanism for land creatures.



Without the asteroid who would represent Earth-Troodon Sapiens?



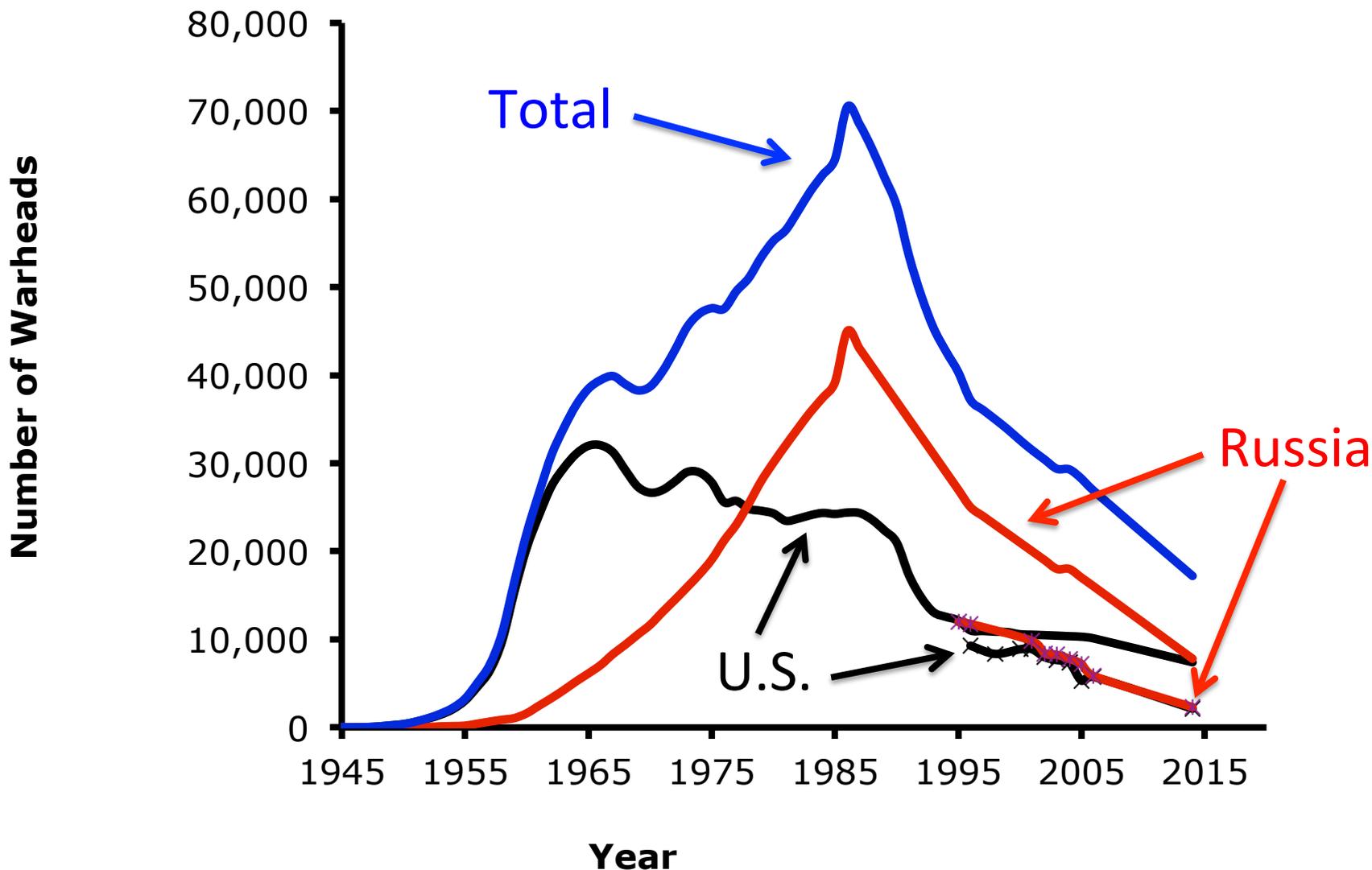
Credit : Canadian Museum of Nature, Ottawa, Canada

Dale Russell

Cloudless sky at noon after 100 atomic
bombs detonated in cities:
Local nuclear war, global starvation



Nuclear warheads peaked in 1986



Presidents Reagan and Gorbachev reduced weapons

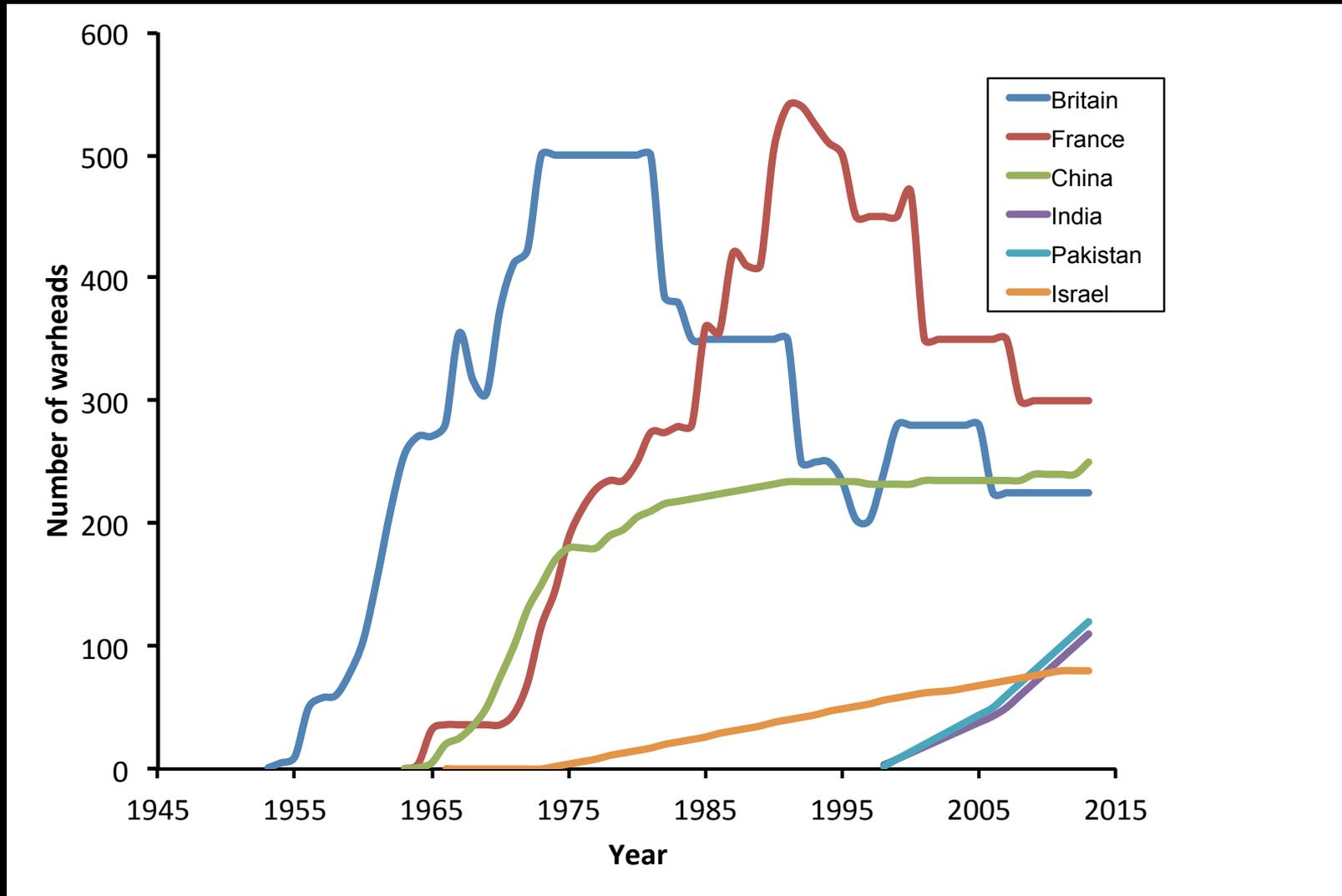
“Models made by Russian and American scientists showed that a nuclear war would result in a nuclear winter that would be extremely destructive to all life on Earth; the knowledge of that was a great stimulus to us, to people of honor and morality, to act in that situation.”

President Mikhail Gorbachev 2000 Salon.com interview

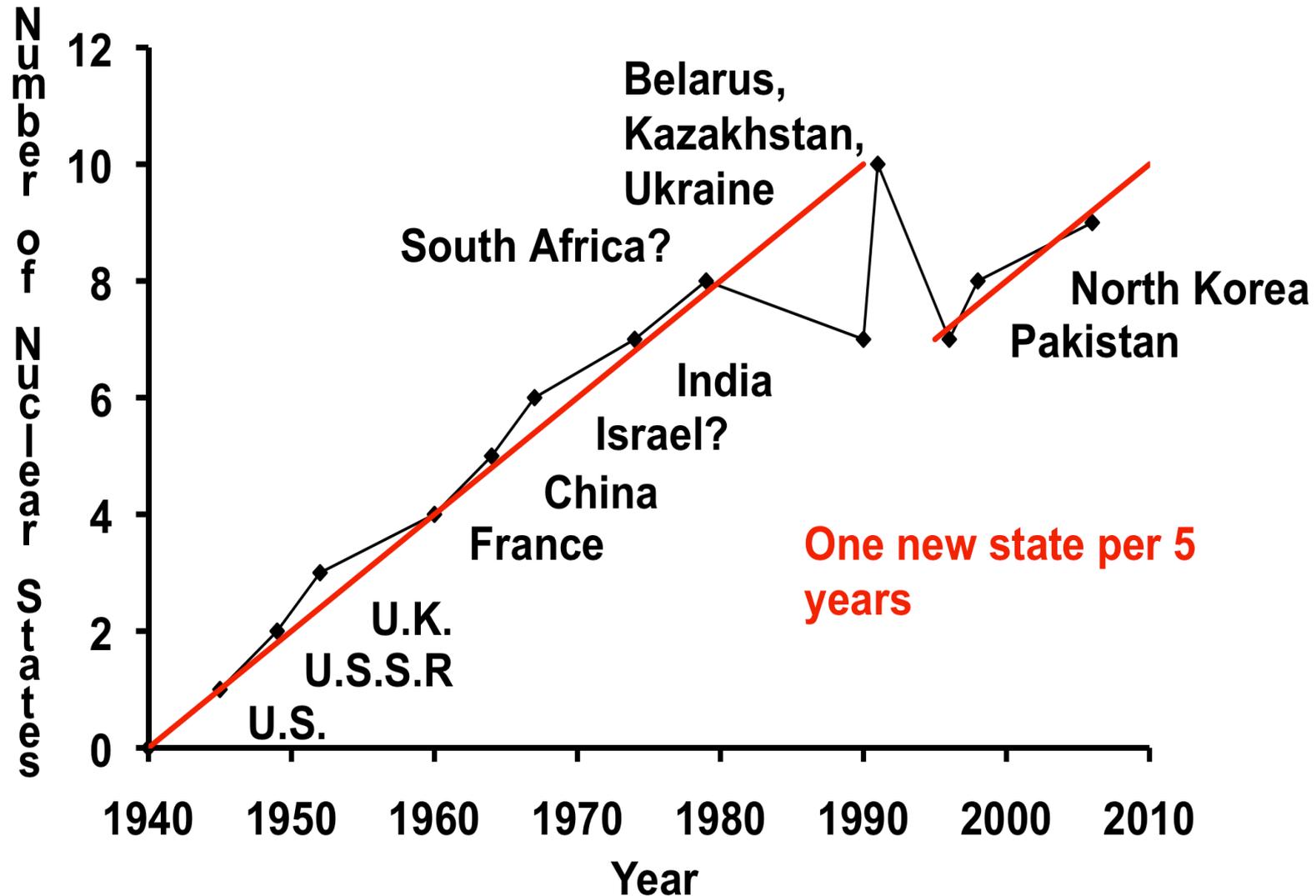
“ A great many reputable scientists are telling us that such a war could just end up in no victory for anyone because we would wipe out the earth as we know it. And if you think back to ... natural calamities - back in the last century, in the 1800's, ... volcanoes - we saw the weather so changed that 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 ...”

President Ronald Reagan in February 12, 1985 interview with the New York Times.

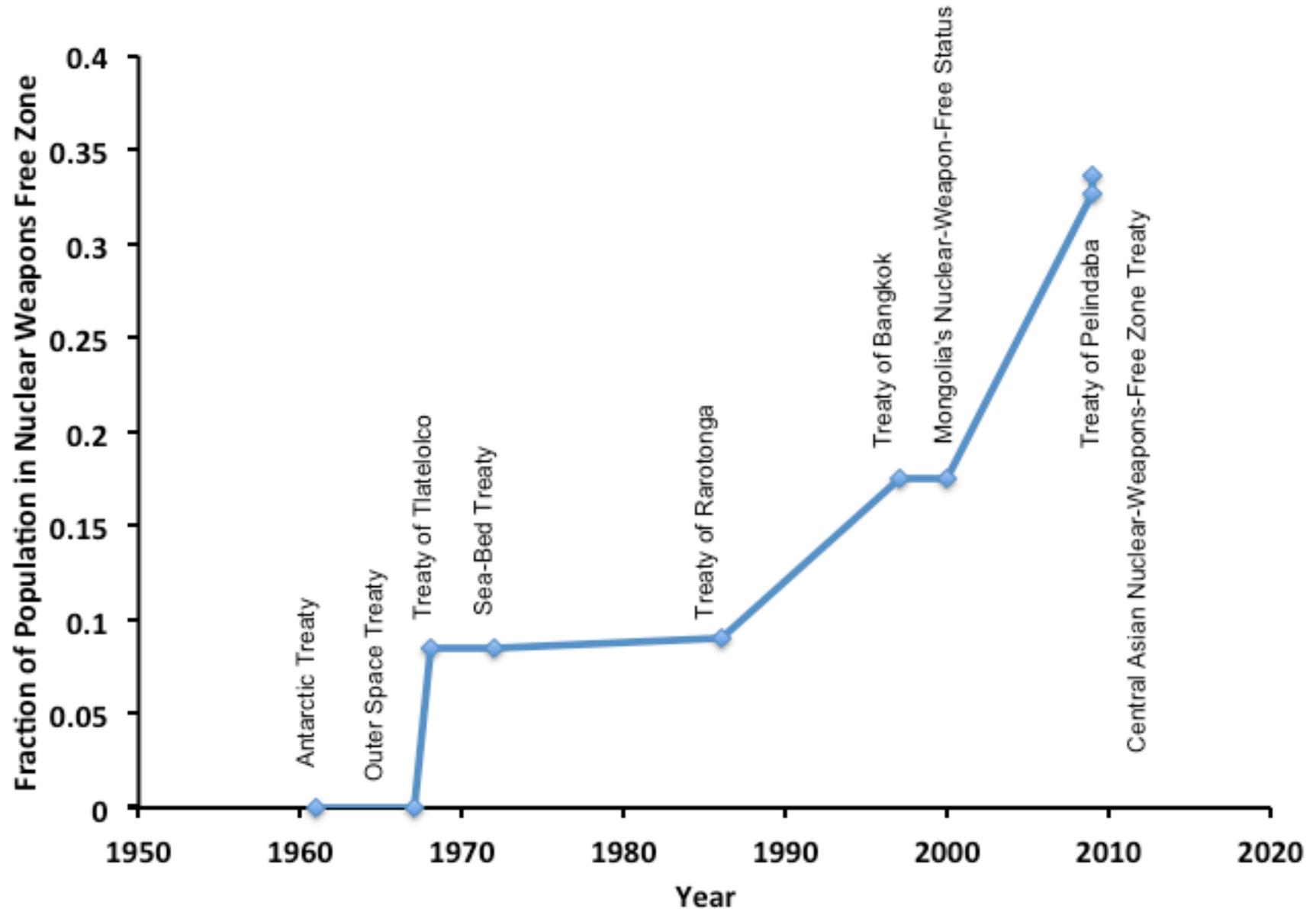
Unlike Britain, France, China and Israel India and Pakistan are increasing warheads



New nuclear states continue to appear



About 1/3 of the population is in nuclear free zones

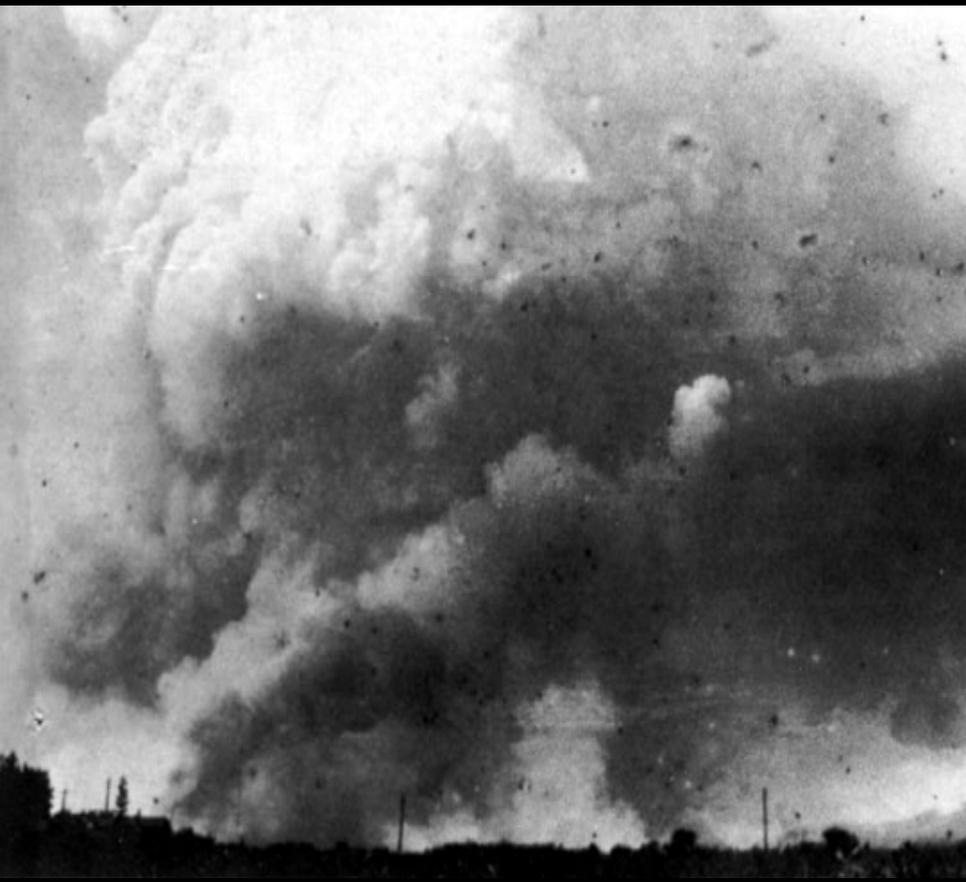


Destructive power of nuclear weapons: Hiroshima, ground zero



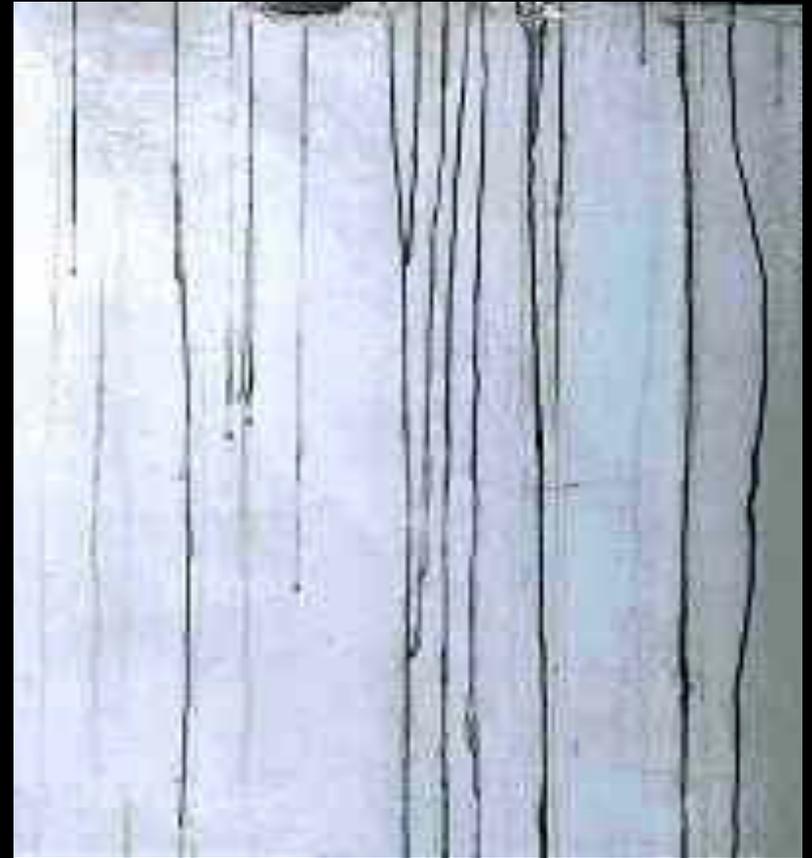
HIROSHIMA PEACE MEMORIAL MUSEUM

Fires in Hiroshima after the atomic blast



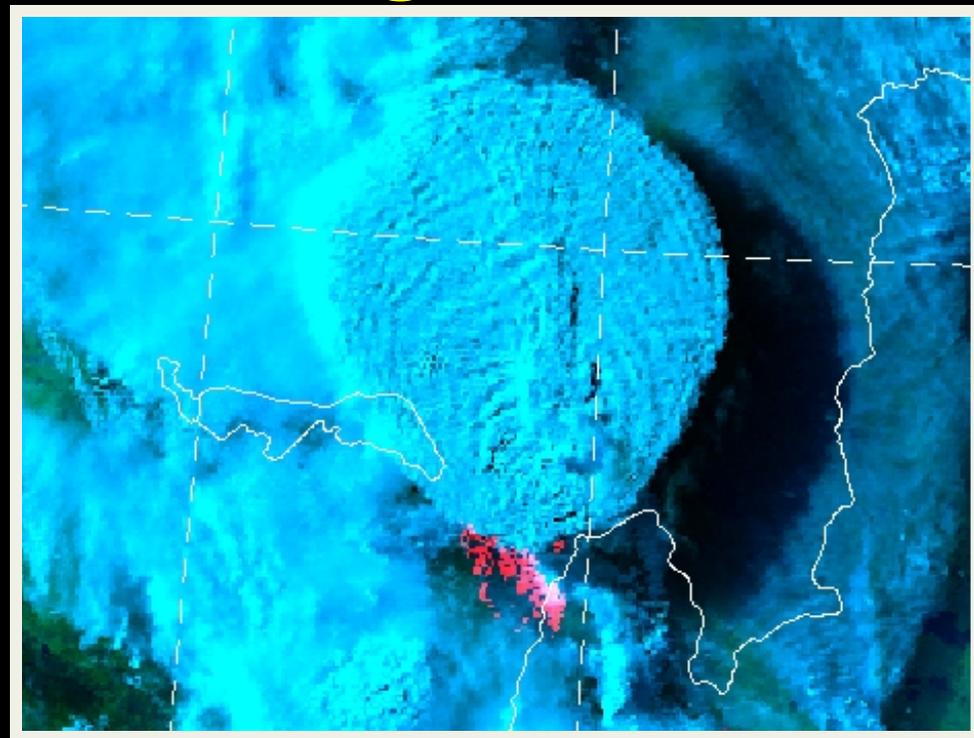
**Fire storm in Hiroshima
about three hours after
the explosion**

<http://www.atomicarchive.com>



**An oily, sooty,
radioactive “black rain”
fell on Hiroshima after
the explosion**

Smoke is observed to go into the upper troposphere after large fires

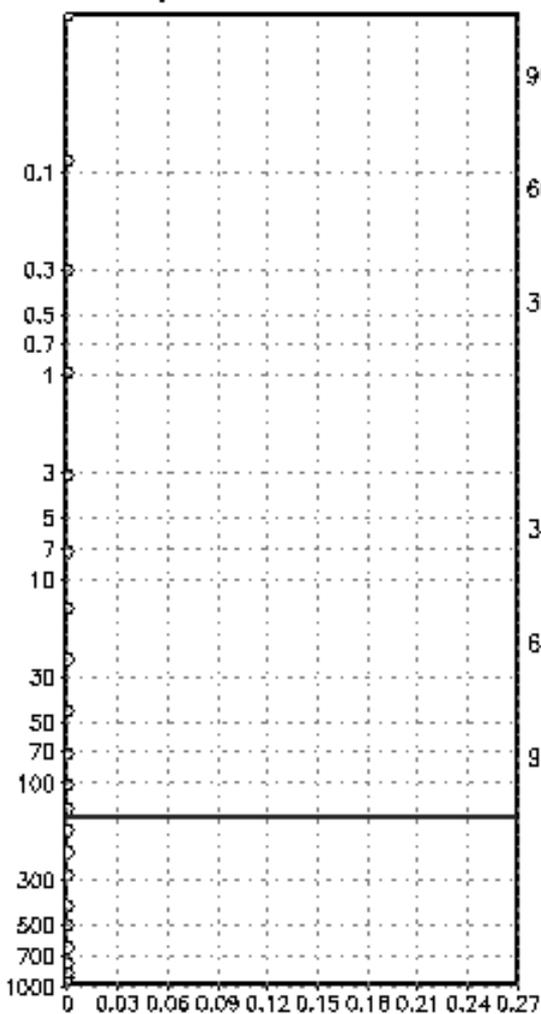


**The Chisholm (Alberta)
PyroCb
28 May 2001**

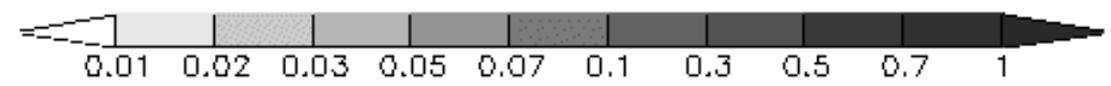
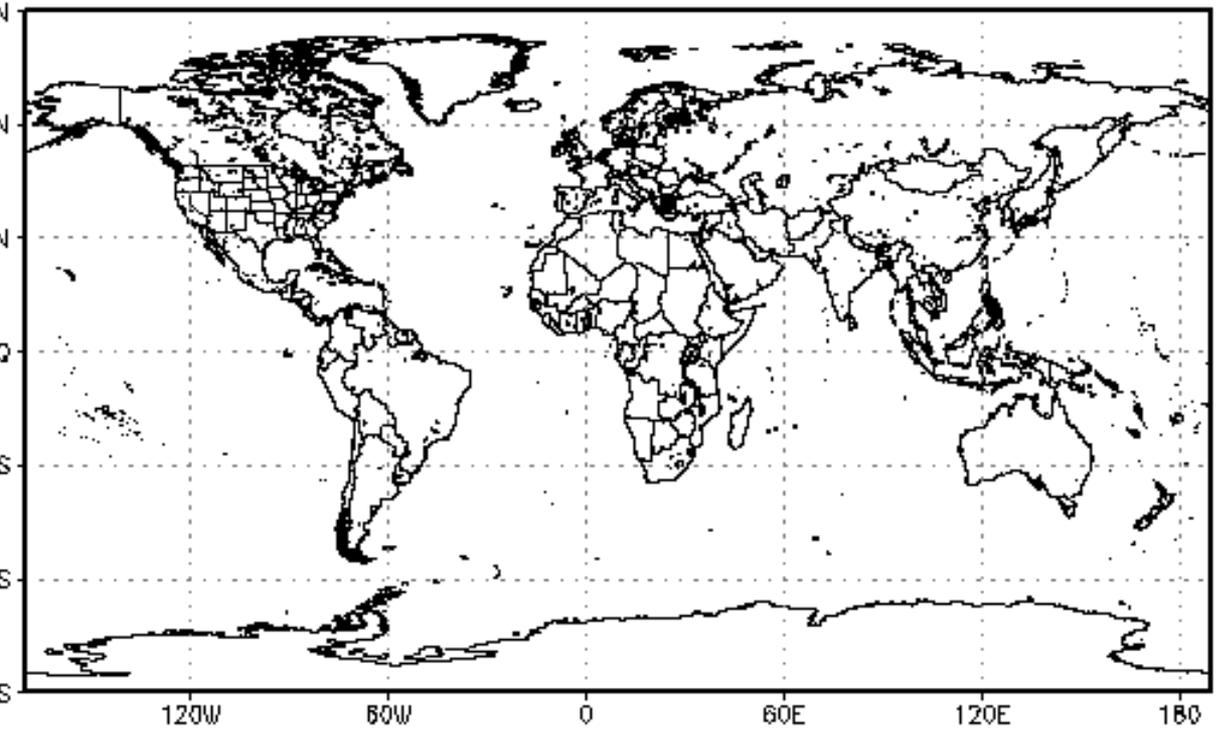
Fromm & Servranckx, (GRL, 2003)

Smoke injected into upper troposphere from regional conflict rapidly spreads

BC per model level

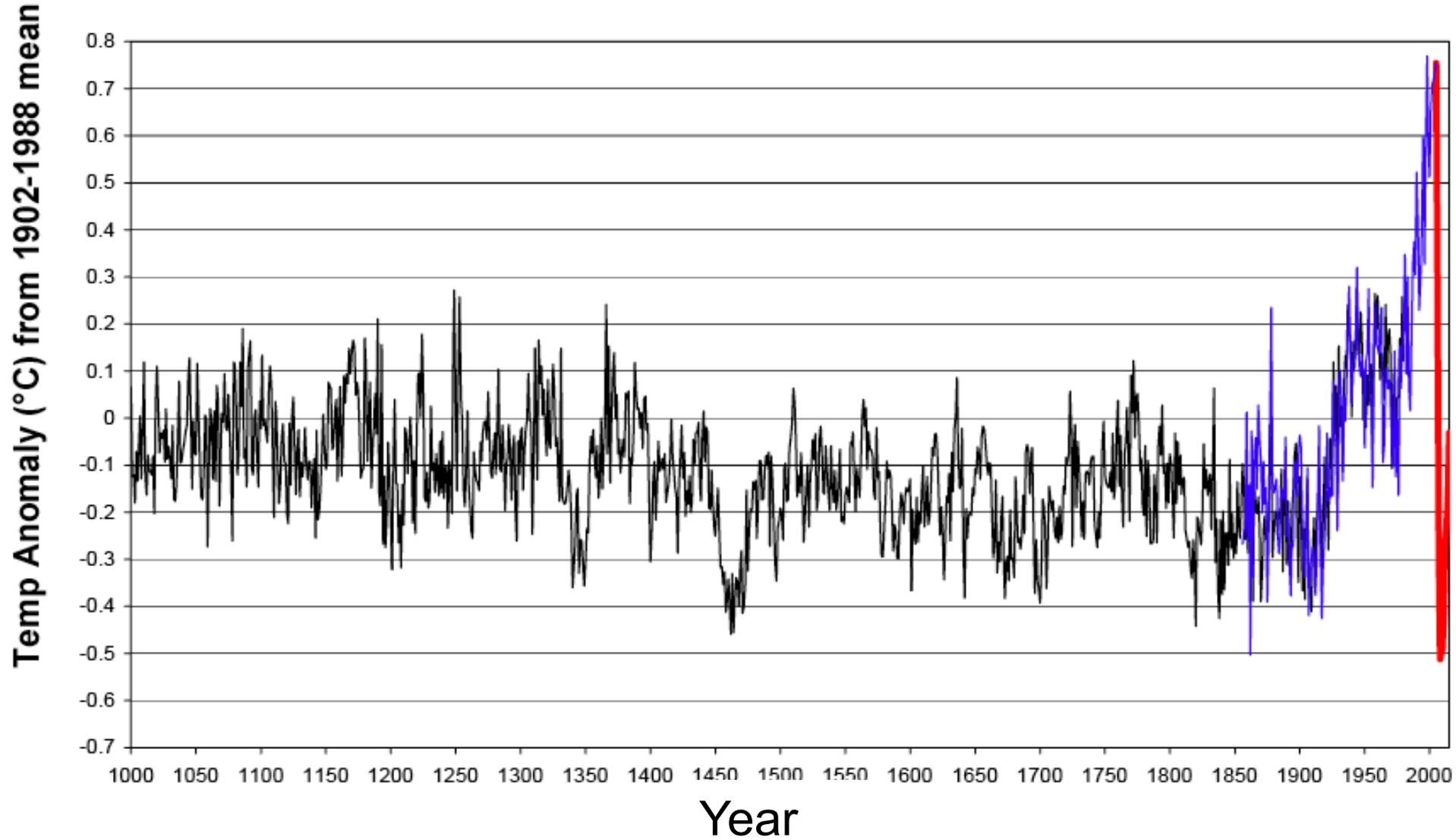


BC Absorption Optical Depth May 14

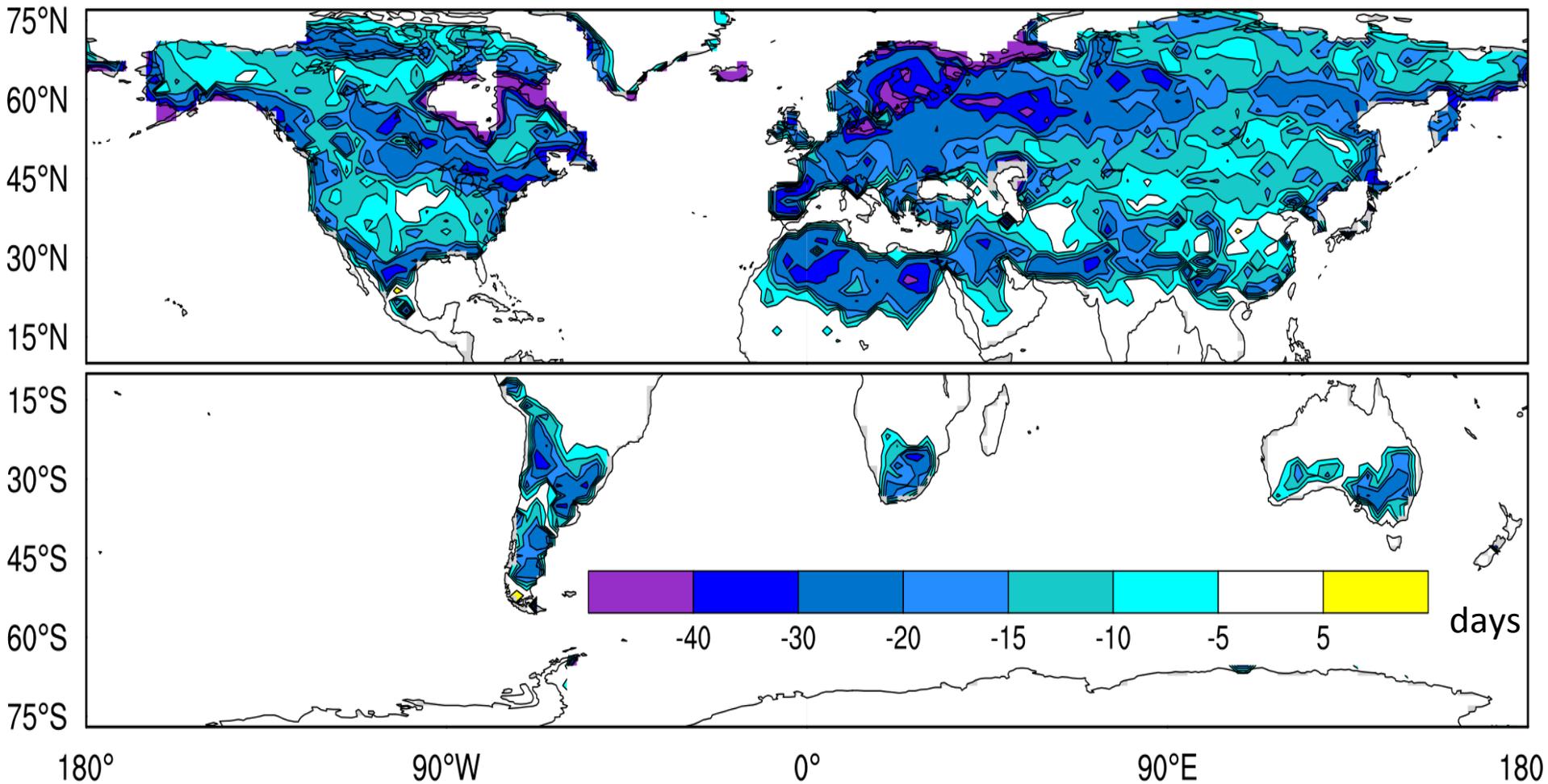


Fraction

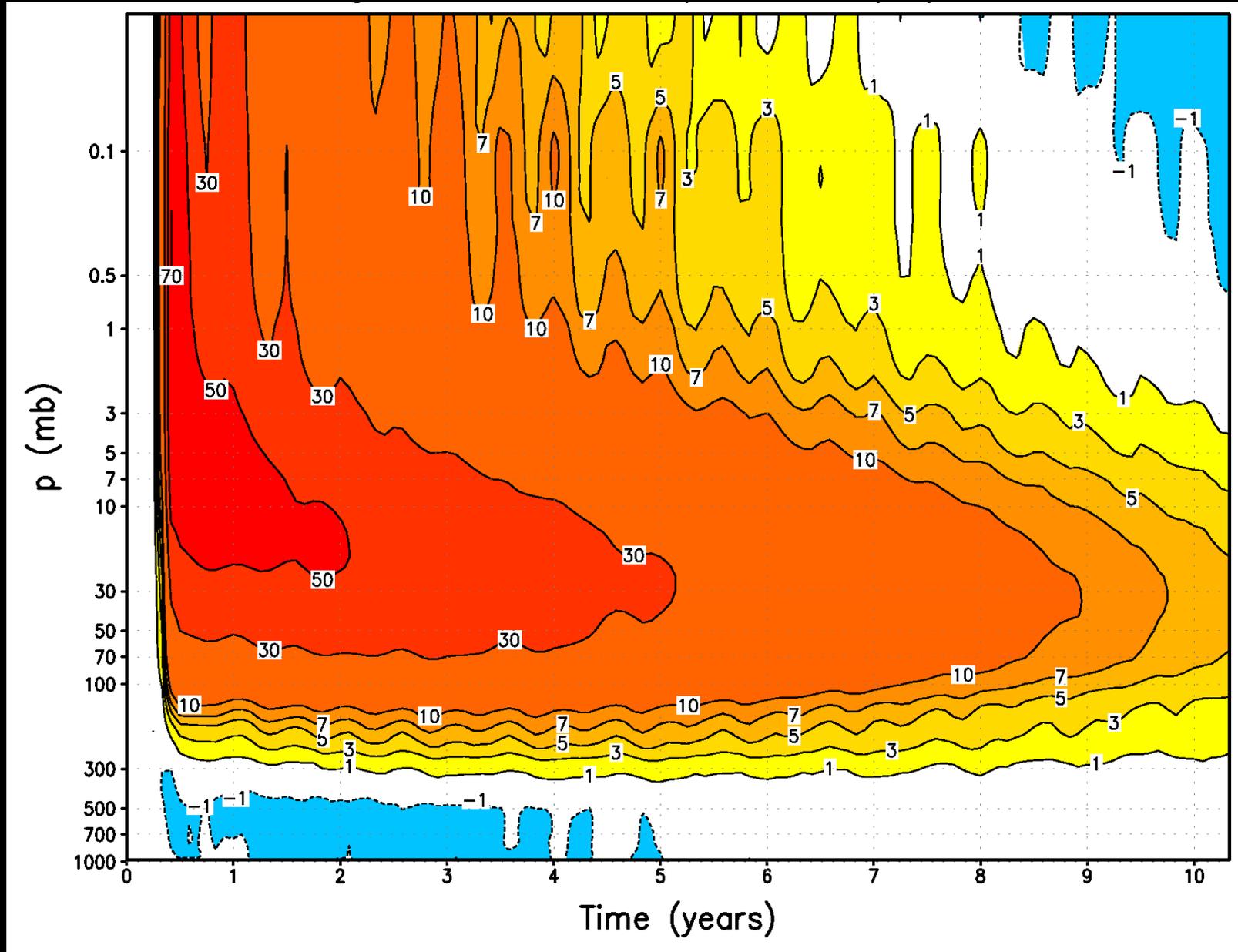
Temperature decline following regional nuclear war with 100 explosions causes coldest temperatures since the ice age



Growing Season Shortened by 1 Month or more in years 2-6



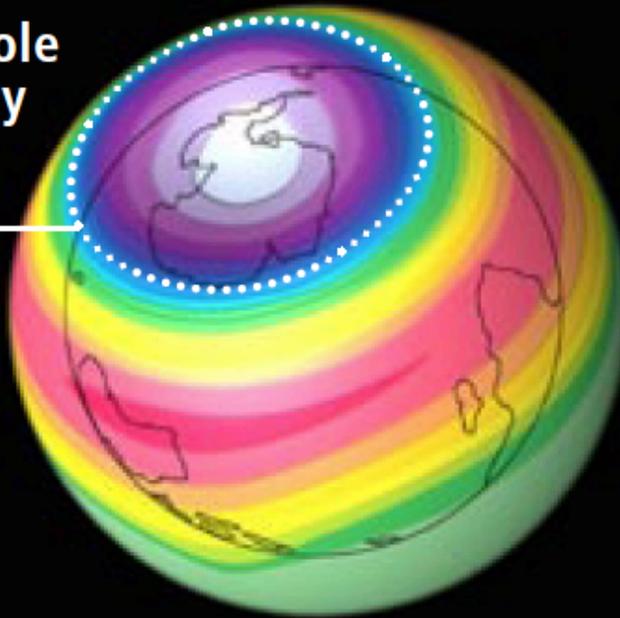
Stratospheric temperatures increase



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

TYPICAL OZONE DISTRIBUTION
(October 2008)

Ozone hole
boundary
(220 Du)



OZONE 17 MONTHS
AFTER WAR



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

	<u>First 5 years</u>	<u>Second 5 years</u>
US maize	-20%	-10%
US soybeans	-15%	-10%
China maize	-20%	-15%
China middle season rice	-20%	-15%
China spring wheat	-35%	-25%
China winter wheat	-40%	-25%



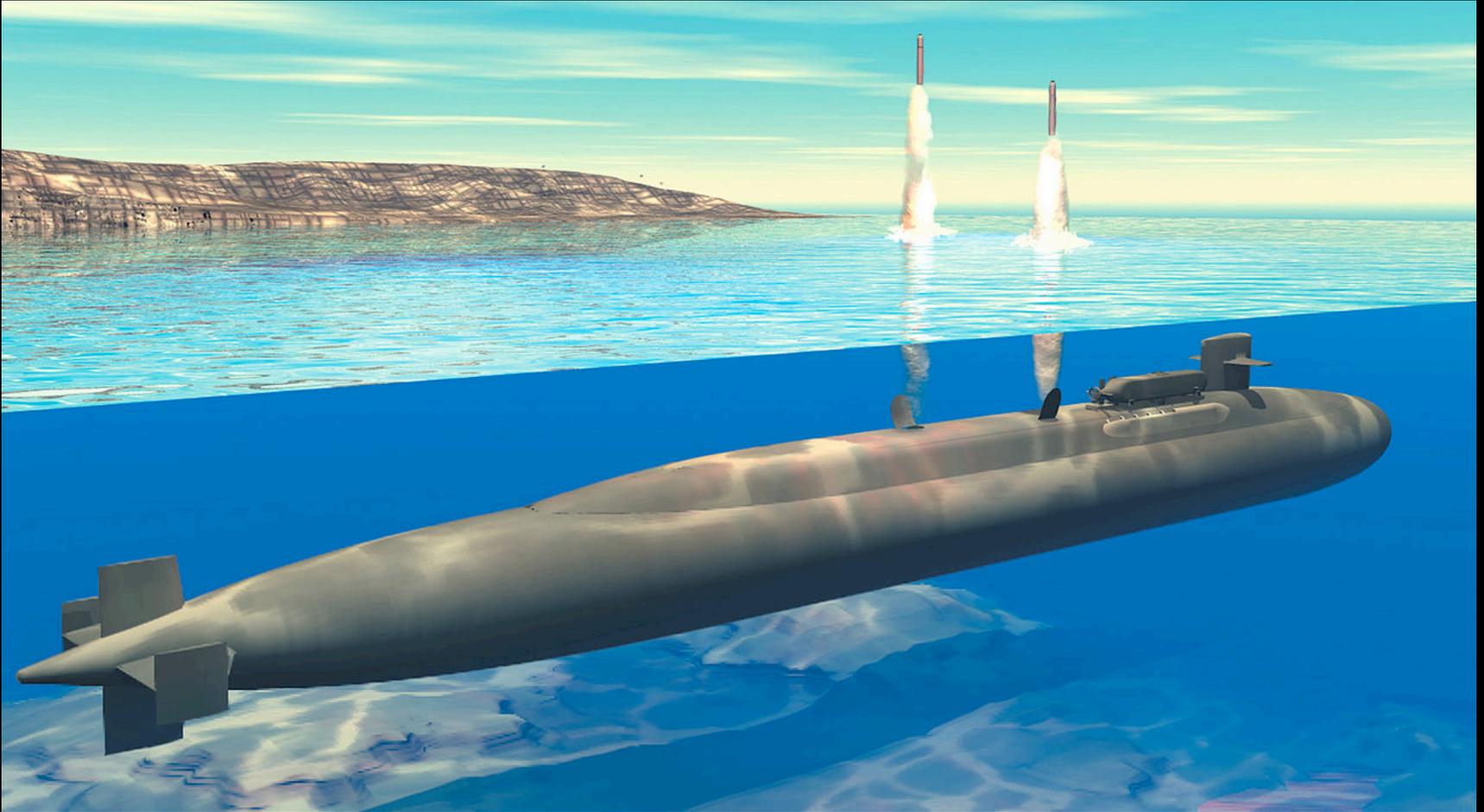
**Those with chronic malnutrition today
likely to die**

**925 million people at or below minimum
daily calorie requirement**

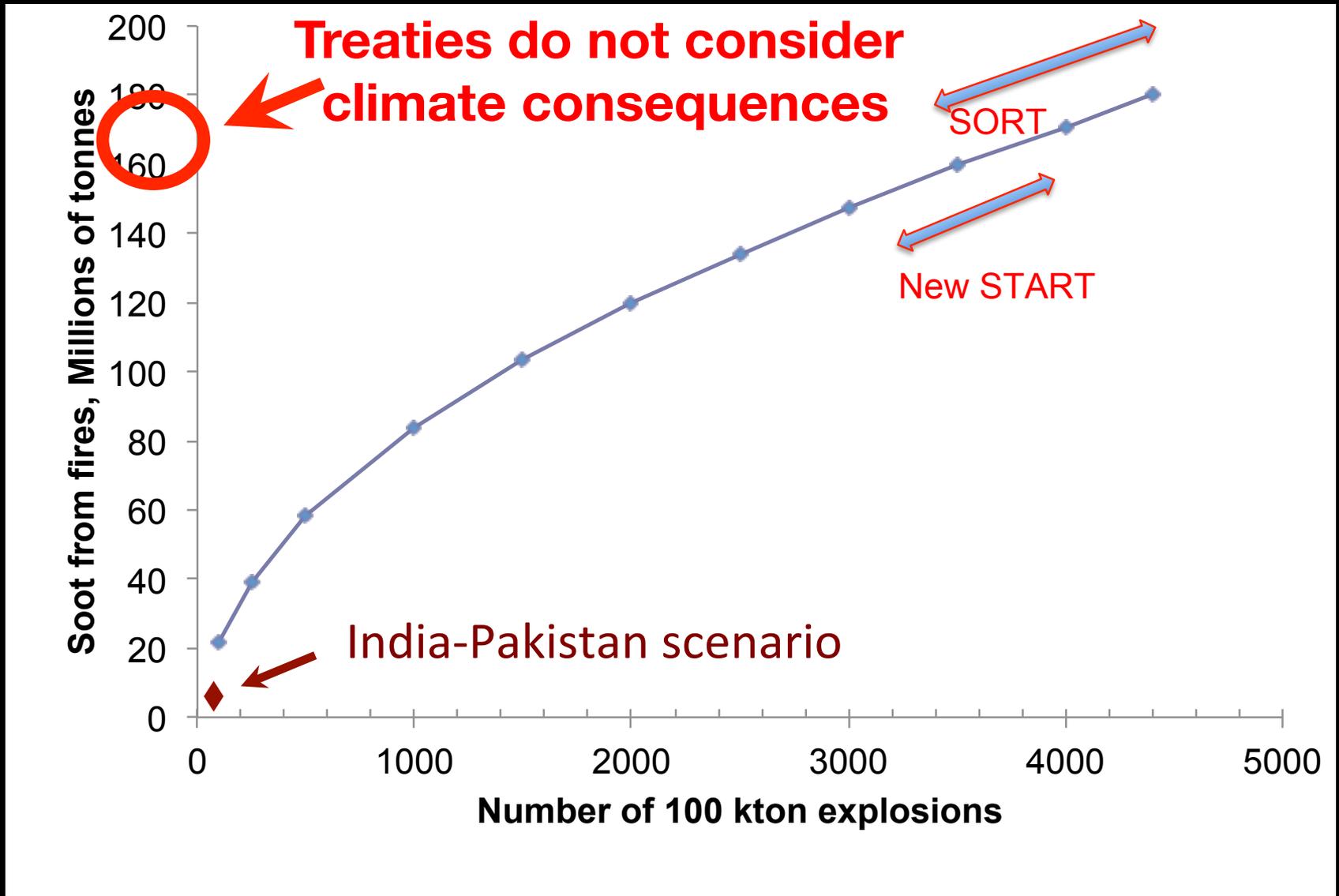
A regional nuclear war would be bad, but effects of SORT and START arsenals catastrophic



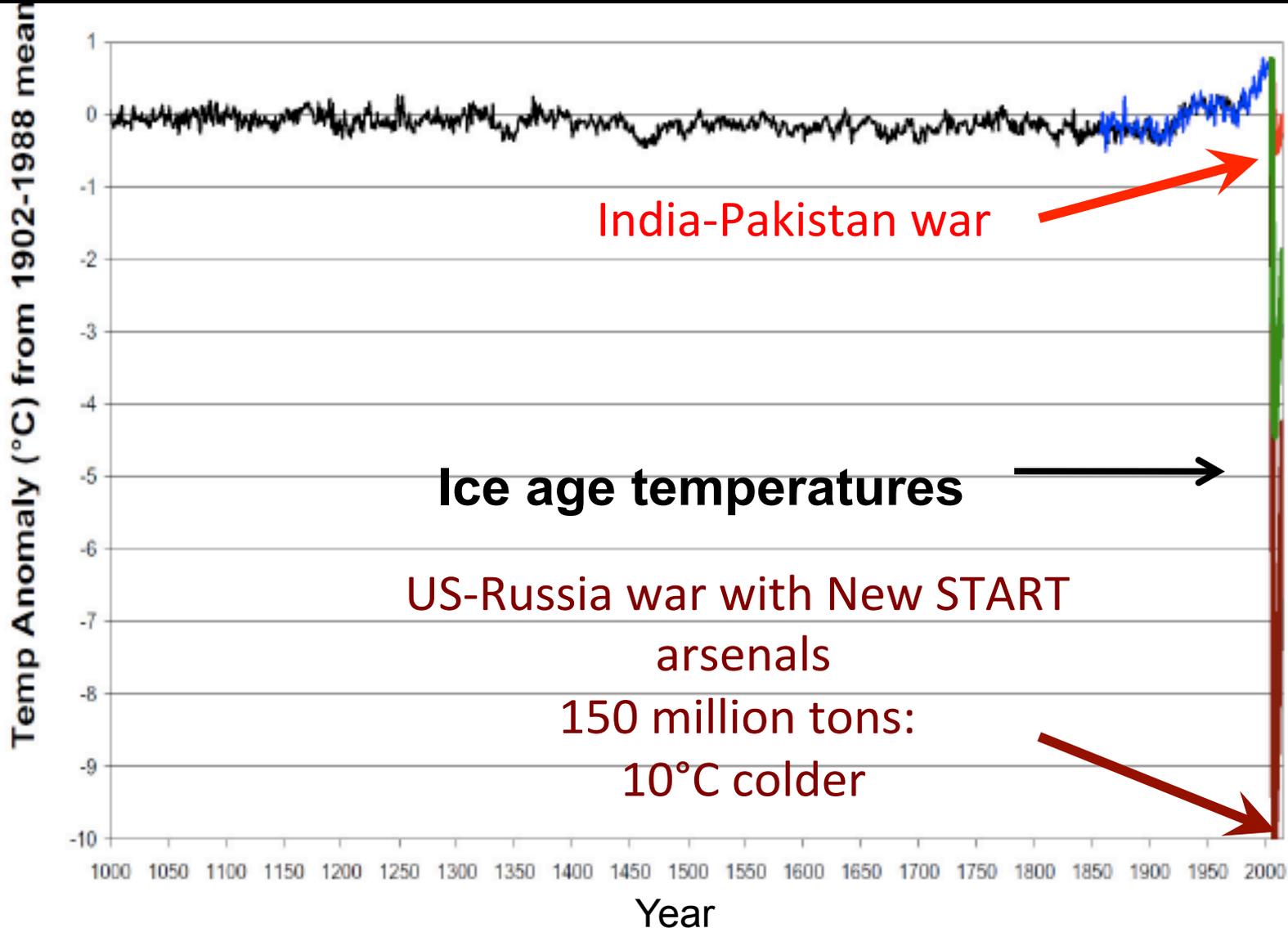
One Trident submarine is more powerful than 1000 Hiroshima bombs.



A regional nuclear war would be bad, but effects of US/Russia arsenals under New START catastrophic

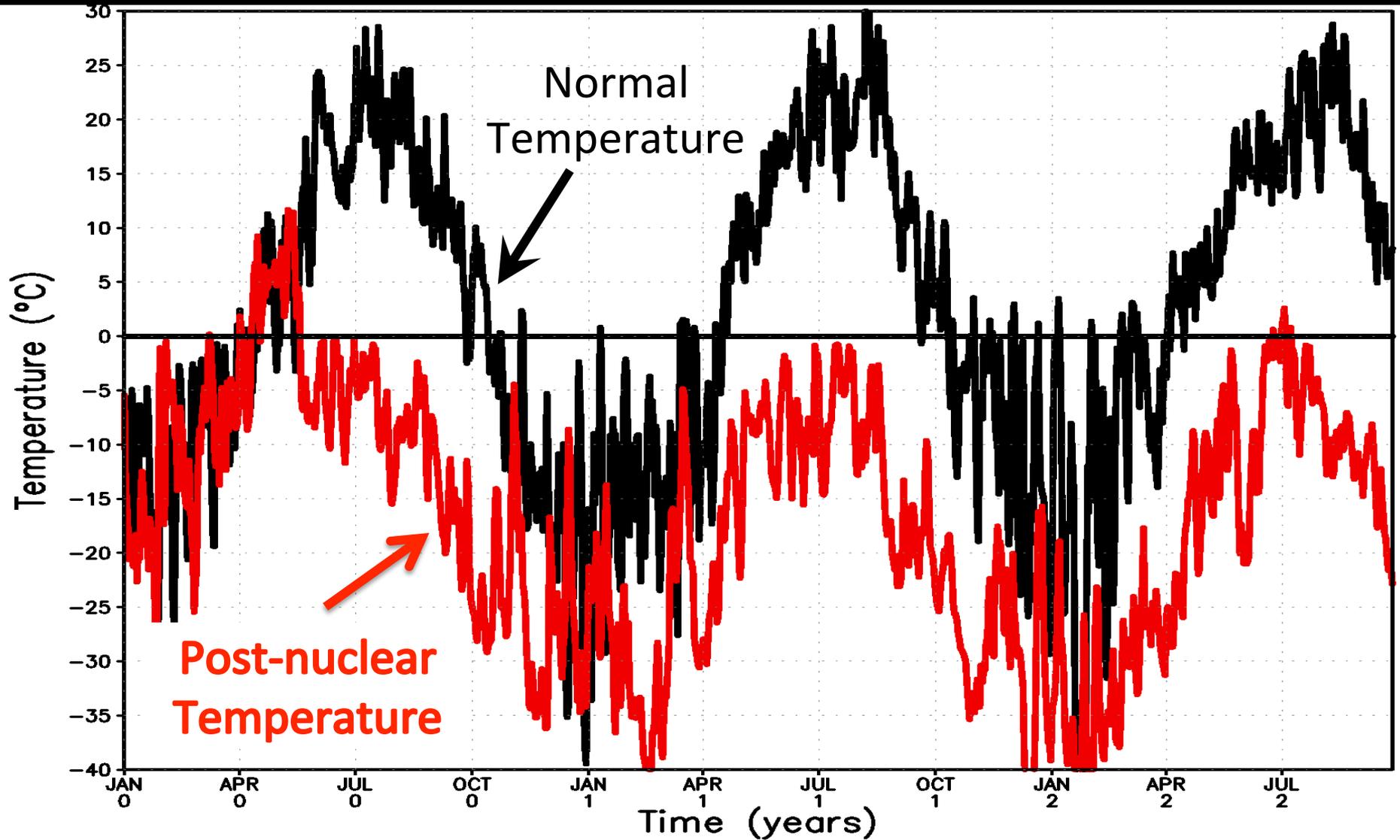


Surface temperature declines after global conflict to ice age conditions

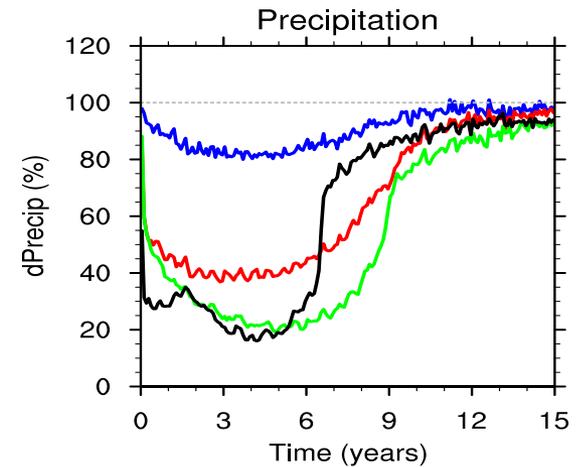
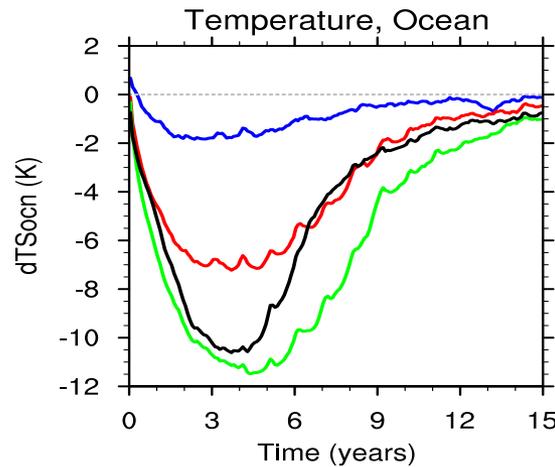
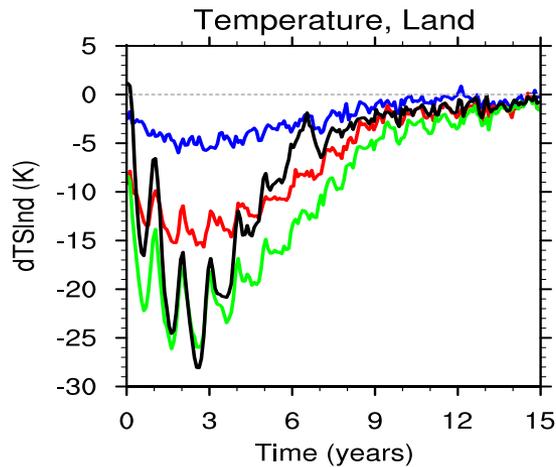
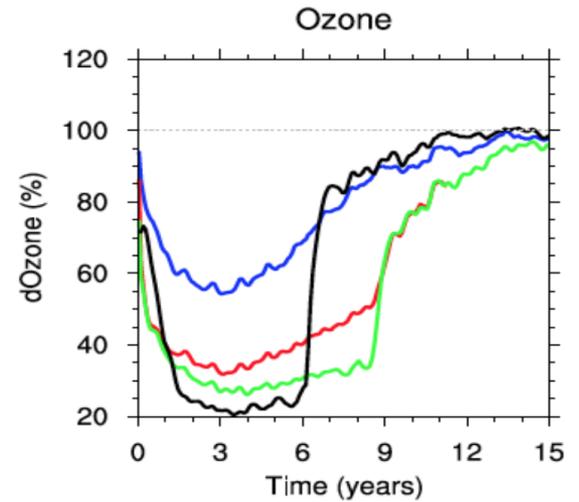
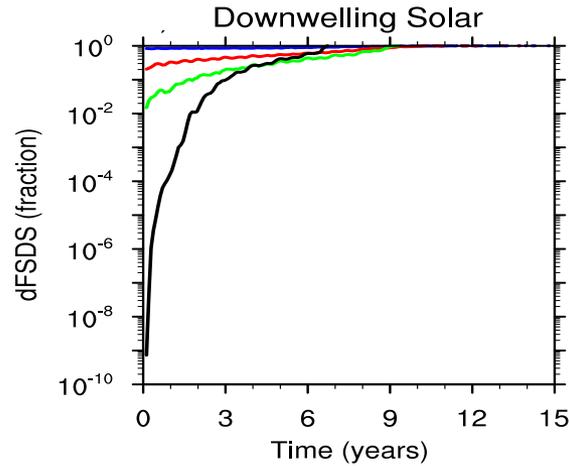
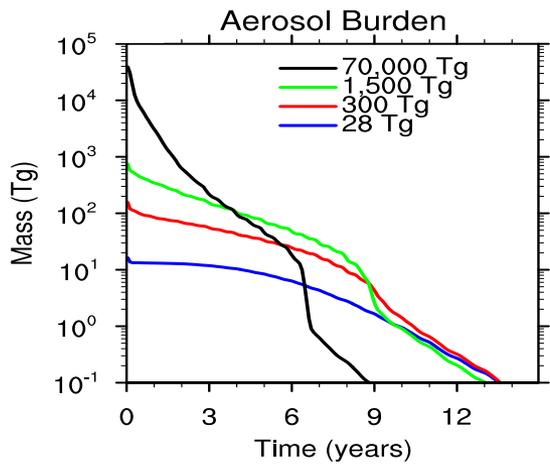


Climate consequences of a US-Russia war using New START arsenals would be catastrophic

Temperature in Ukraine



Comparing K-Pg impact and nuclear war



Right now we can't stop an asteroid impact, but we are working on it



It remains to be seen if we can prevent a nuclear conflict and global starvation

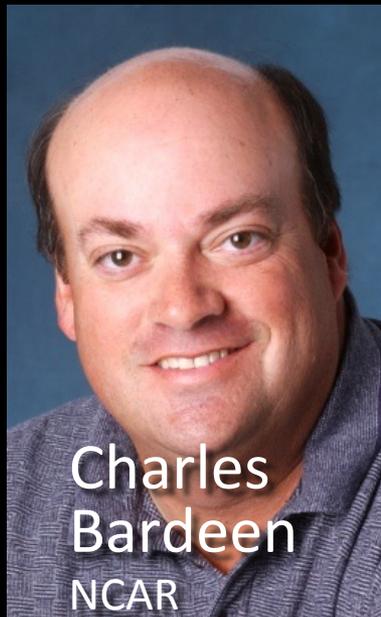
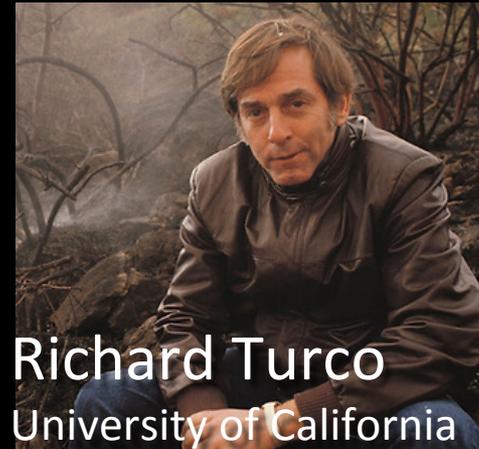
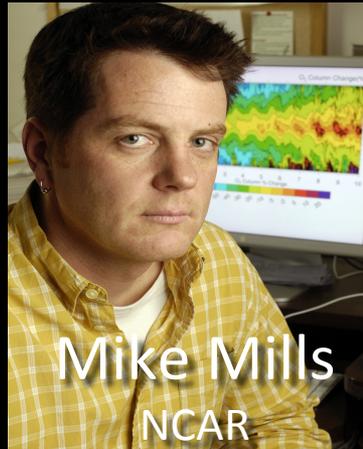
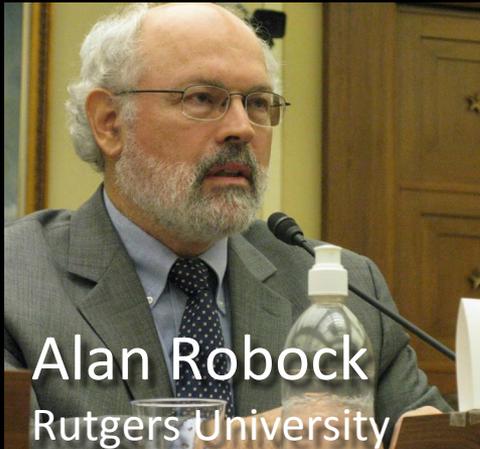
But history shows the world scientific community can help eliminate nuclear weapons



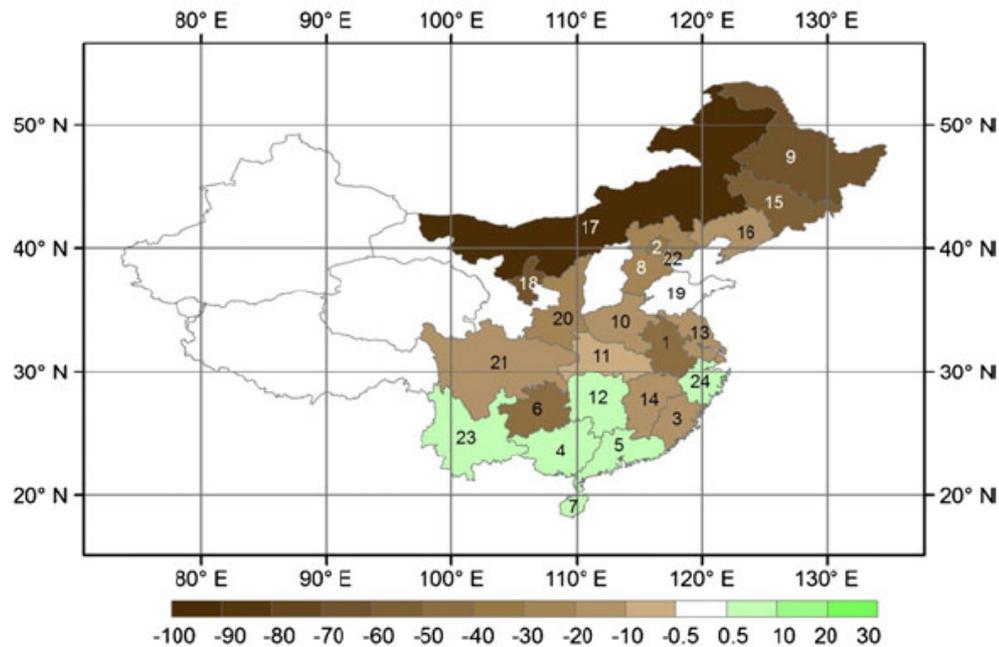
What could you do?

- **Impacts**
- Little work has been done on physical effects
- We don't have the technology to stop a collision
- **Nuclear environmental effects**
- Very few people have worked on this problem. More research is needed.
- Politicians are not aware of environmental effects of nuclear war. Education and analysis by national science academies is needed.

This work is done in collaboration with



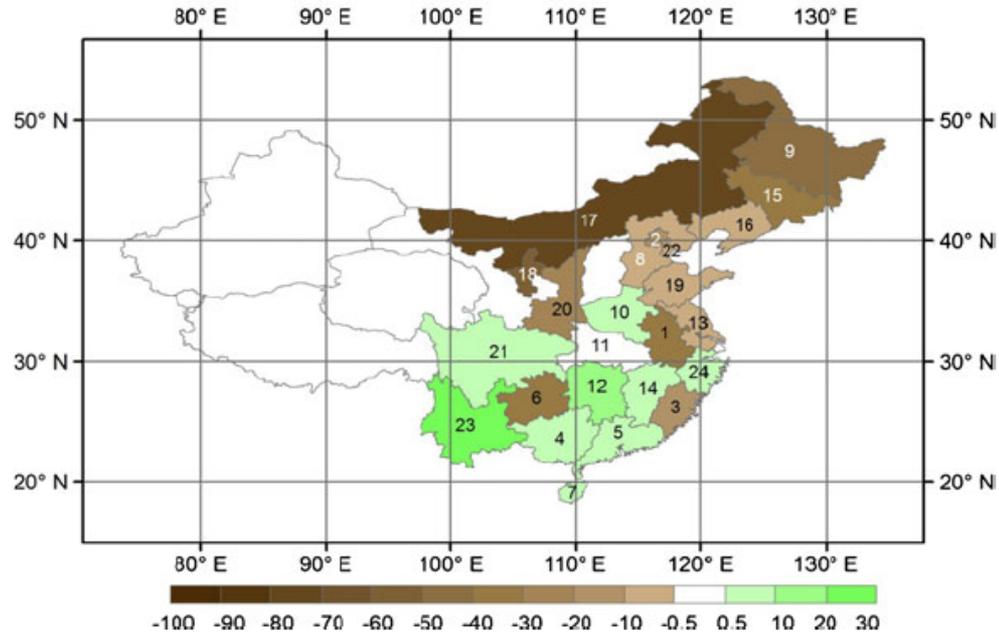
Rice Yield Change (%) Average from year 0 to year 3



Calculated changes in crop yield can be large.

Xia&Robock Climate change, 116, 357,2013

Rice Yield Change (%) Average from year 4 to year 9



Chinese Winter Wheat Production after a Regional Nuclear War

