Global Famine after a Regional Nuclear War: Overview of Recent Research

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Local devastation…

Effects of one 15 kiloton atomic bomb on Hiroshima

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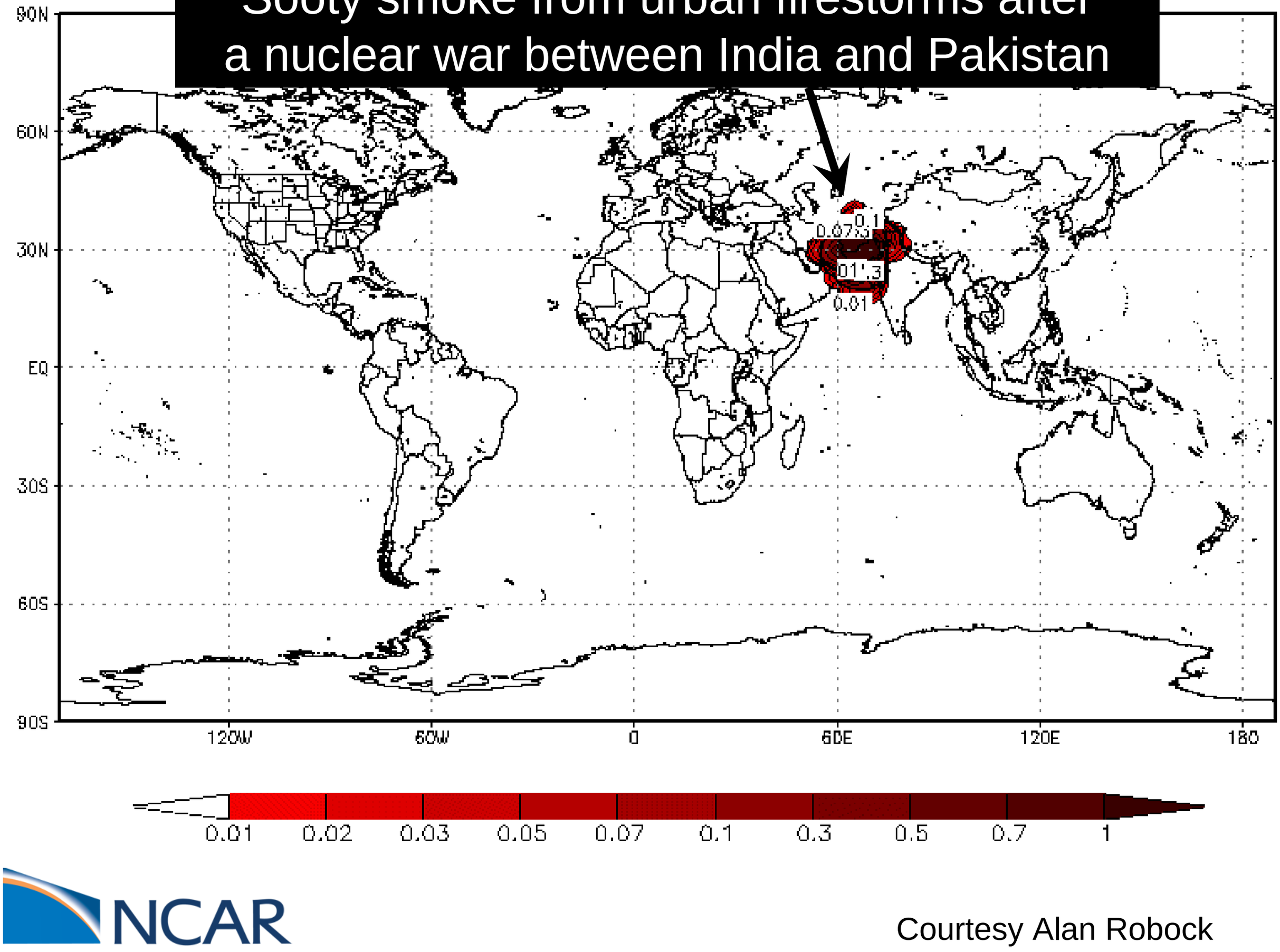
…global suffering

Earth surrounded by smoke:
cloudless sky at noon after 100 atomic bombs detonated in cities

Image from illustration in January 2010, *Scientific American,* “Local Nuclear War, Global Suffering”, by Robock and Toon

Sooty smoke from urban firestorms after a nuclear war between India and Pakistan



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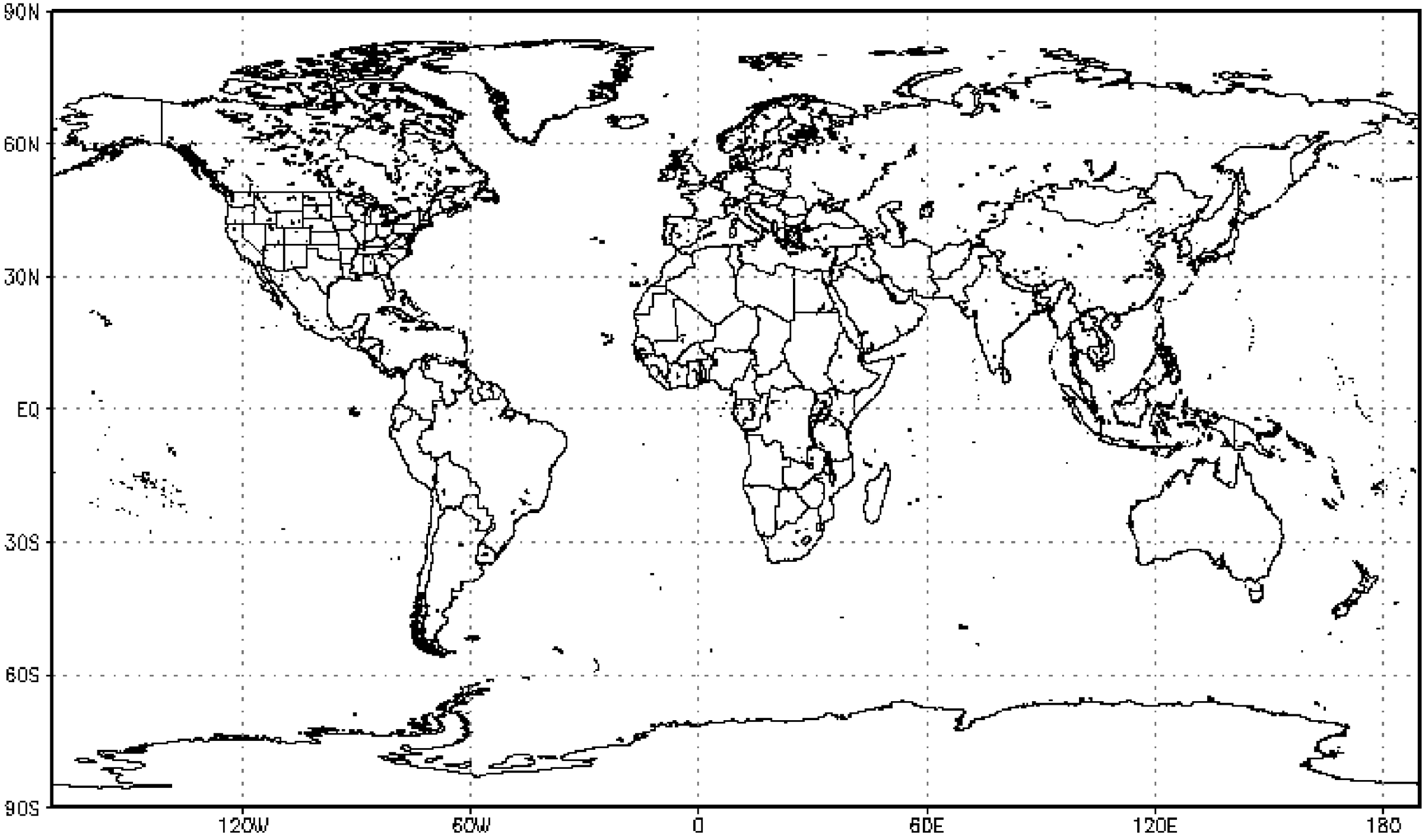
Courtesy Alan Robock

BC Absorption Optical Depth May 14th



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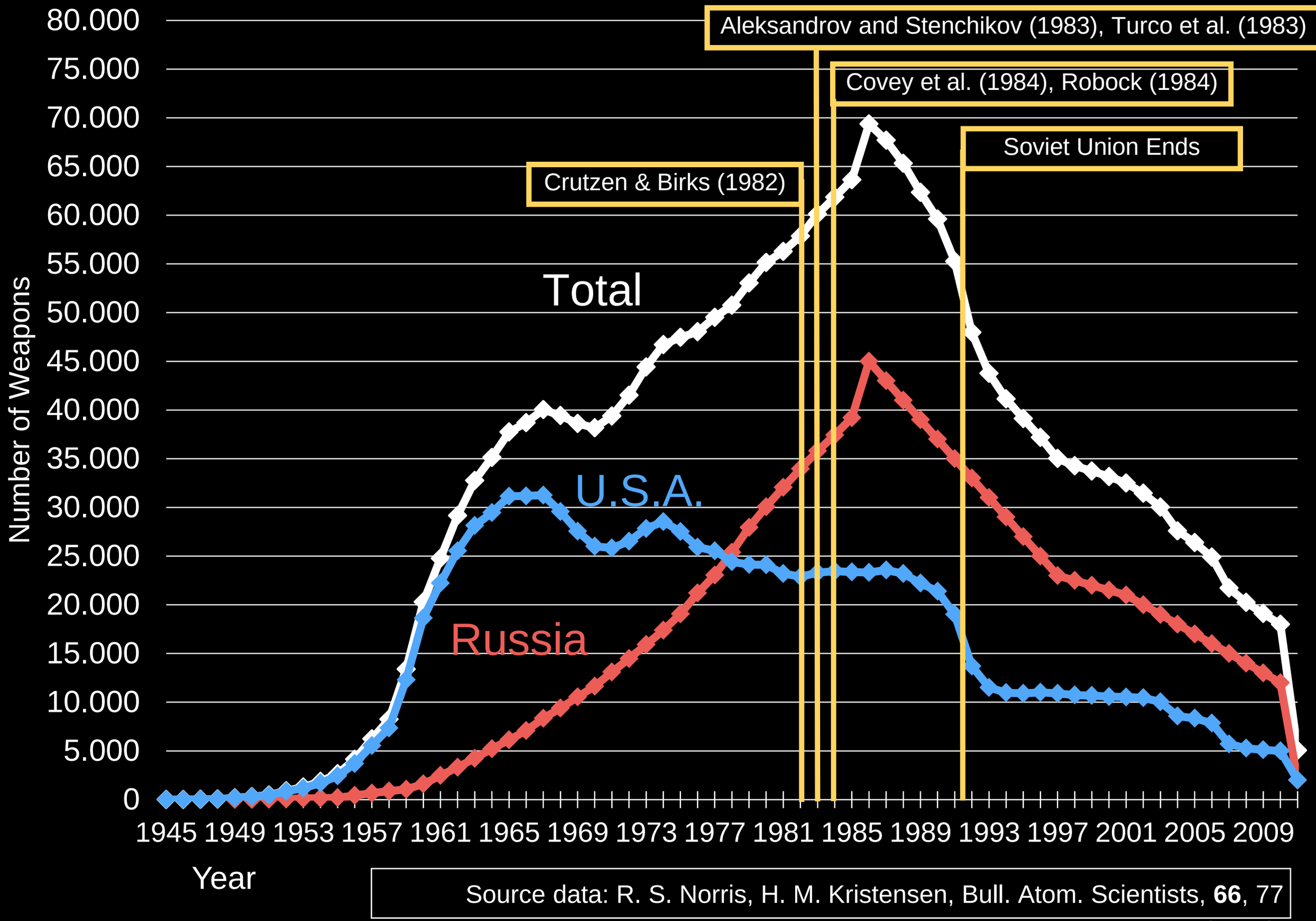
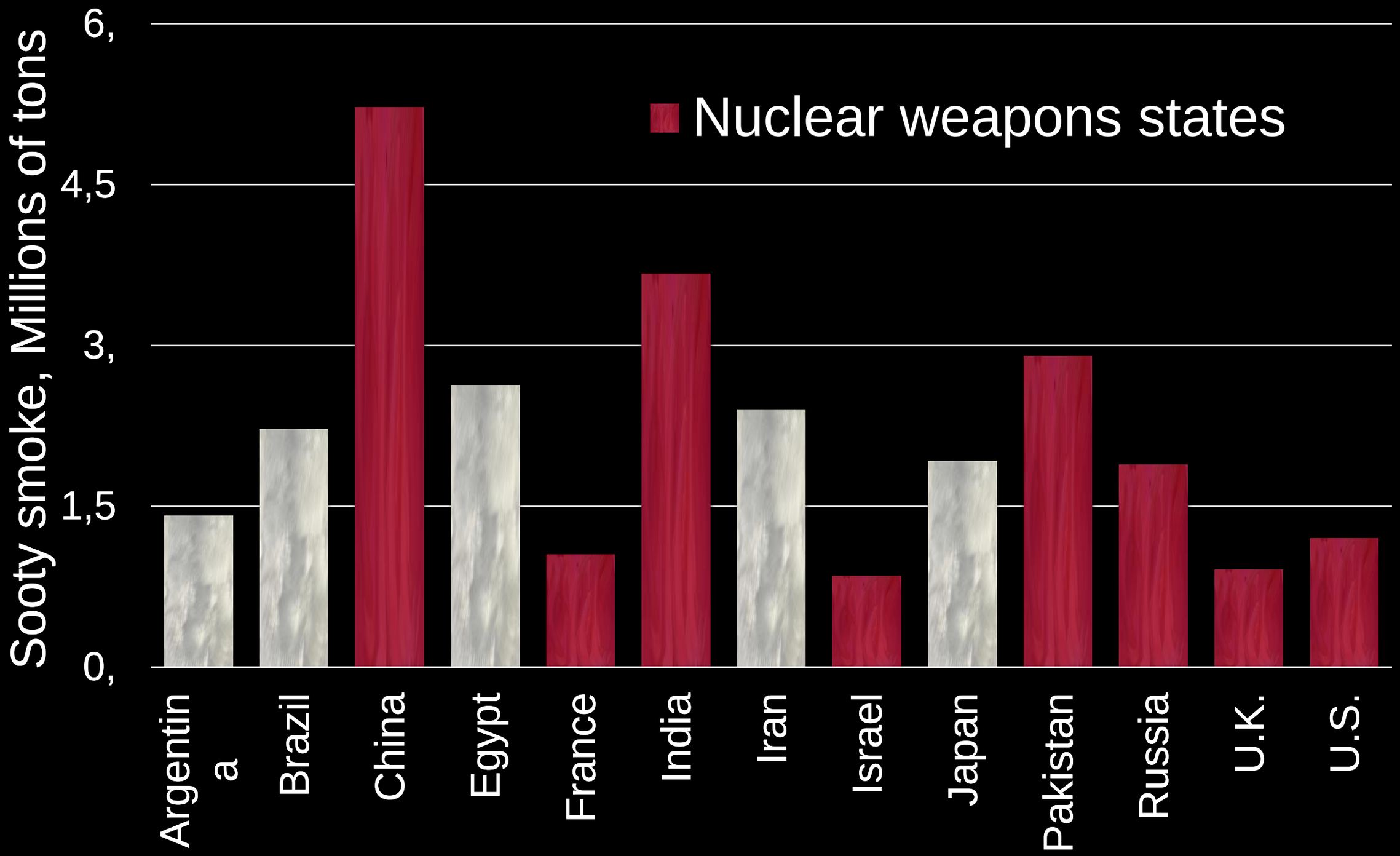
Courtesy Alan Robock

History of Nuclear Warheads



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

Black carbon smoke from 50 x Hiroshima-sized weapons producing firestorms in modern cities



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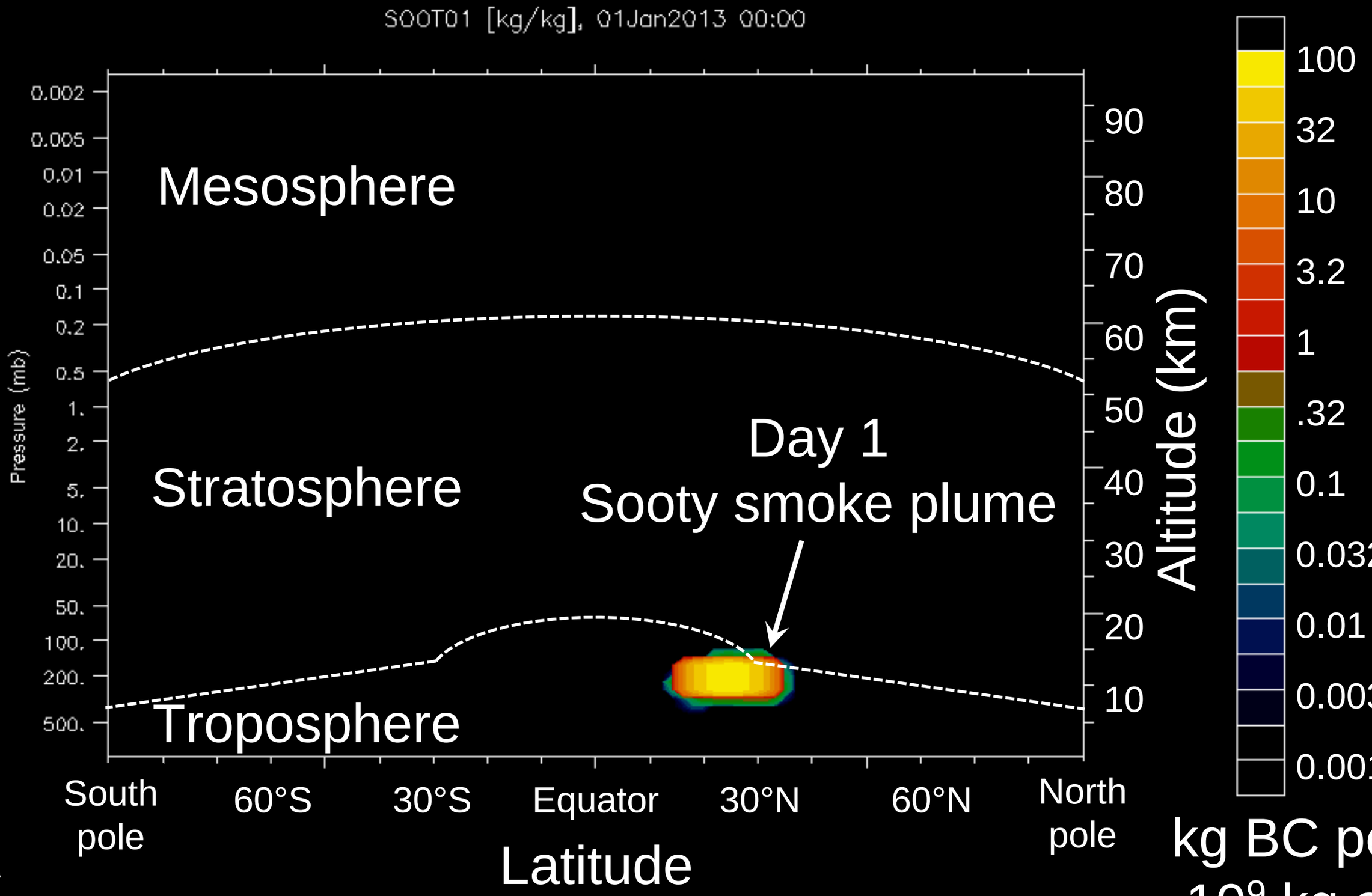
Source data: Toon et al., (2007), *Atmos Chem Phys*, 7, 1973–2002, doi:10.5194/acp-7-1973-2007.

Black carbon mass mixing ratio



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Mills et al., Multidecadal global cooling and unprecedented ozone loss following a regional nuclear conflict, *Earth's Future*, *2014*.

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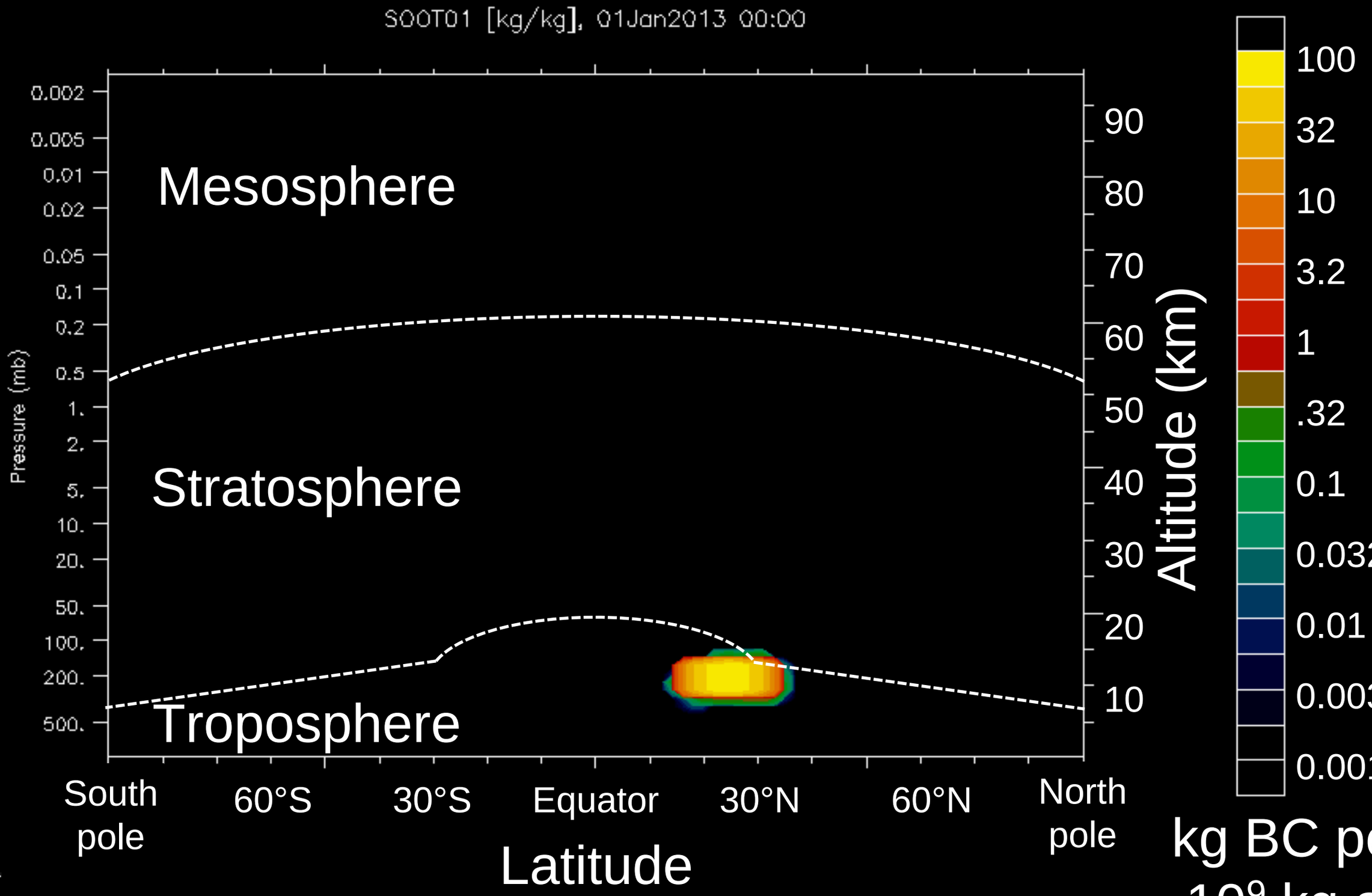

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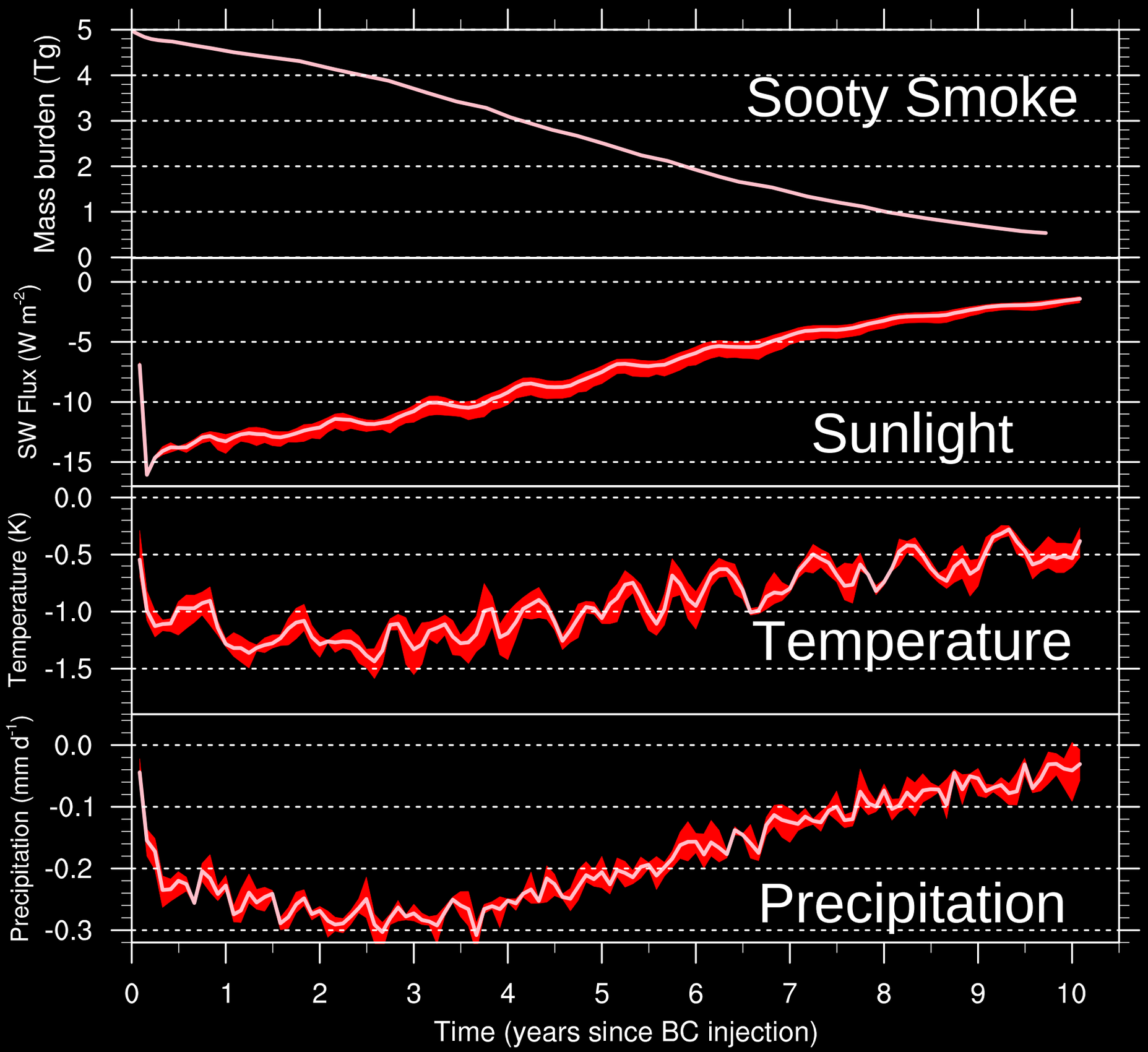
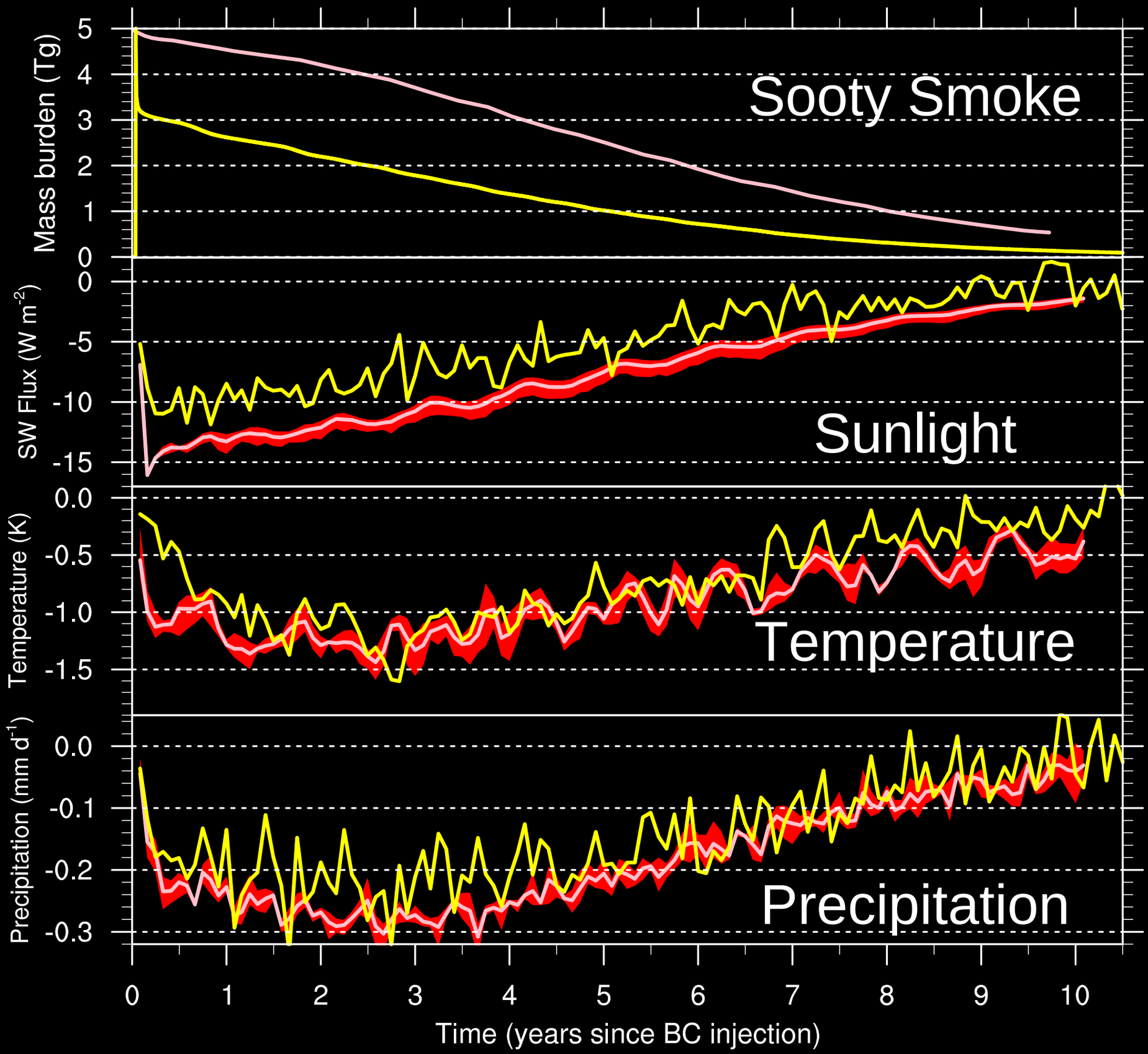
Global climate response to regional war



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

Global climate response to regional war



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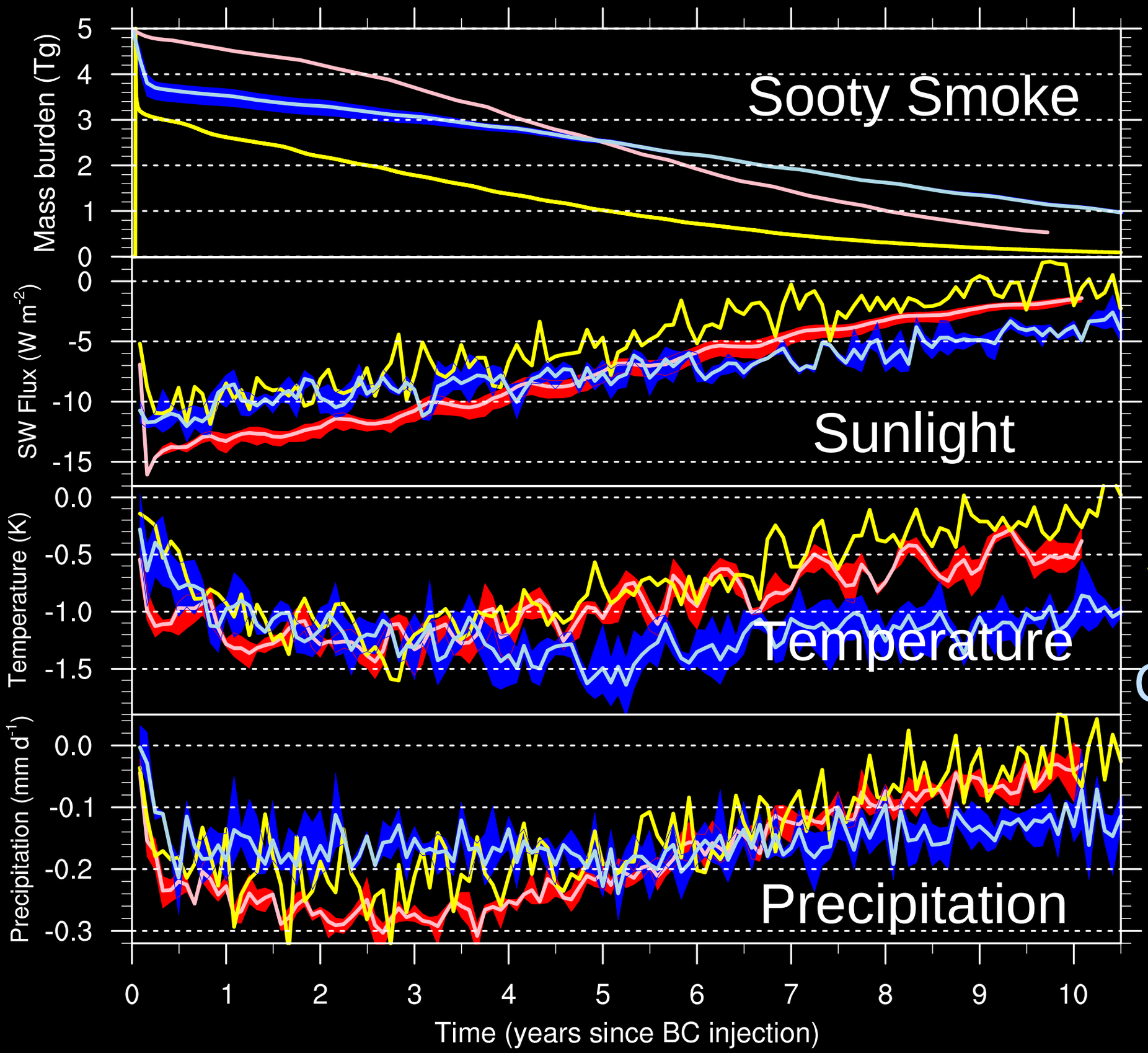

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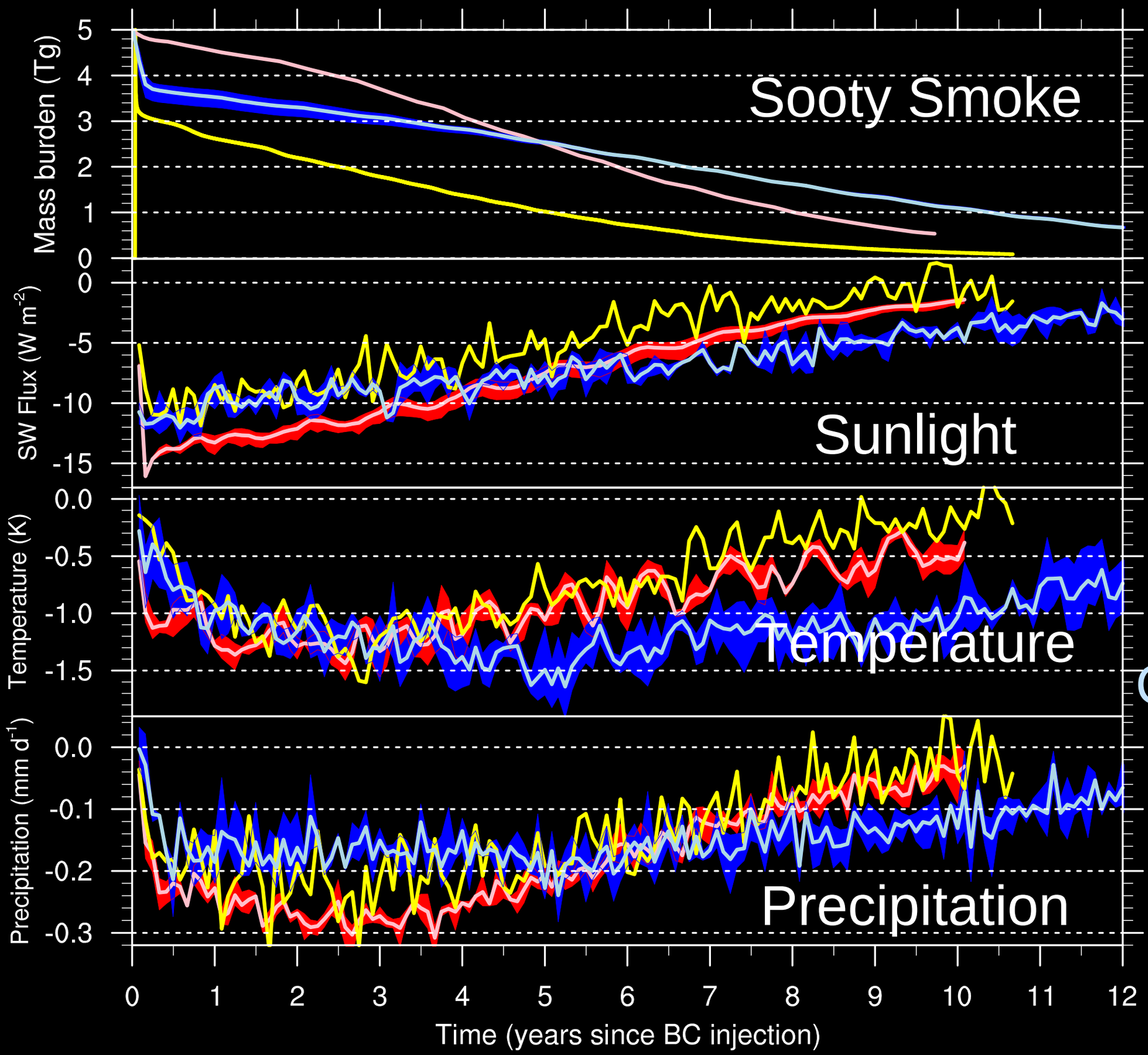

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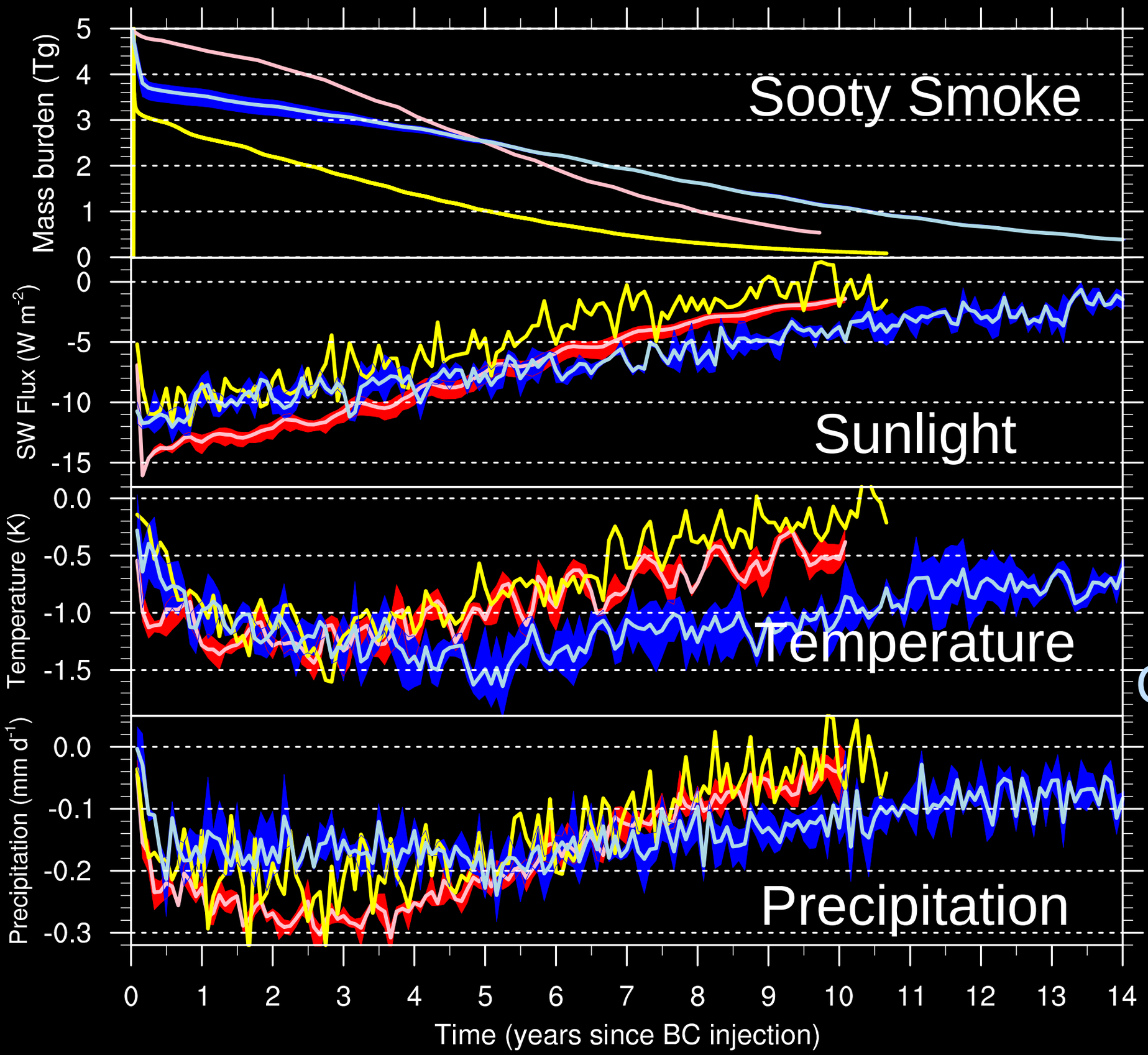

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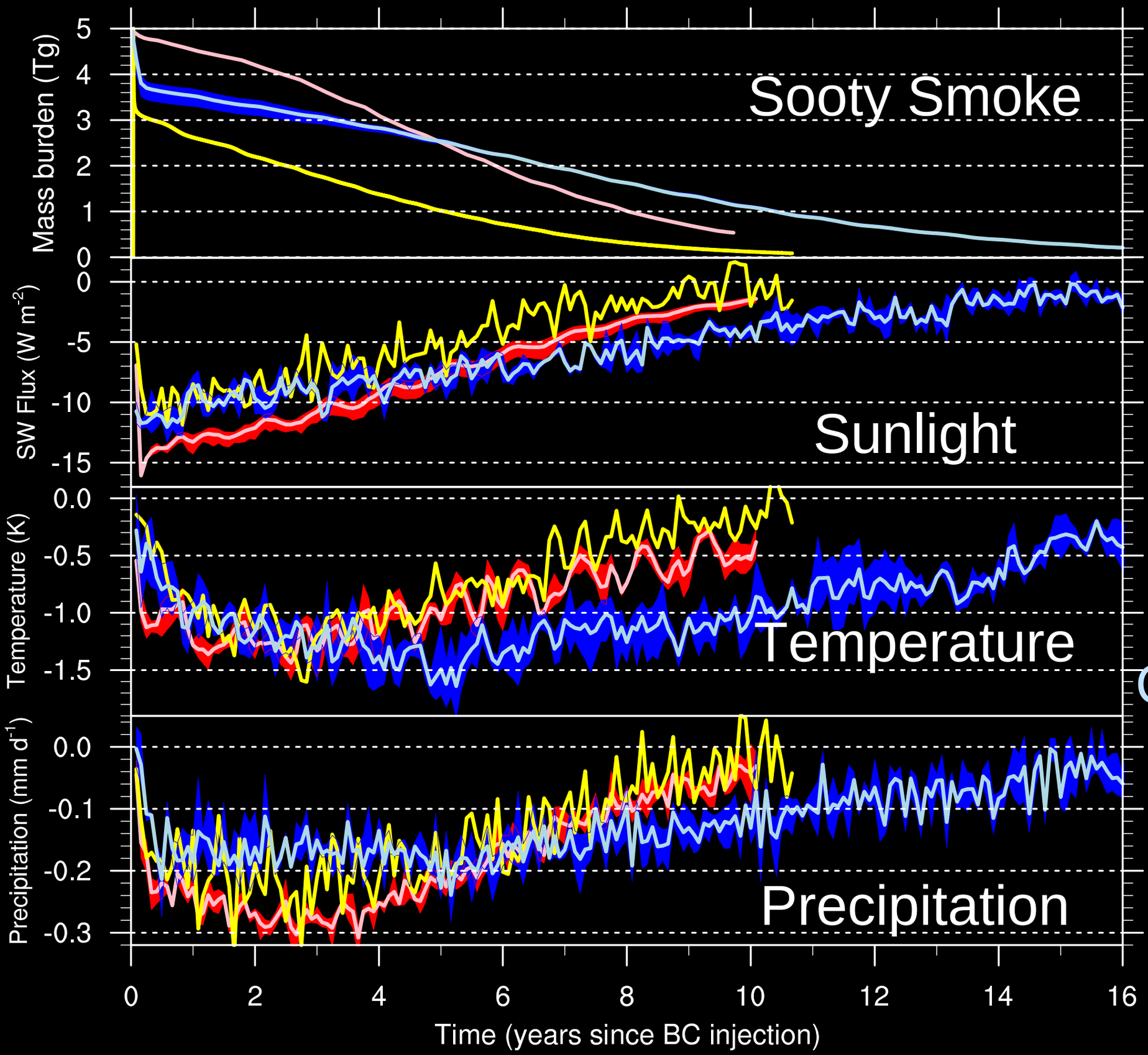

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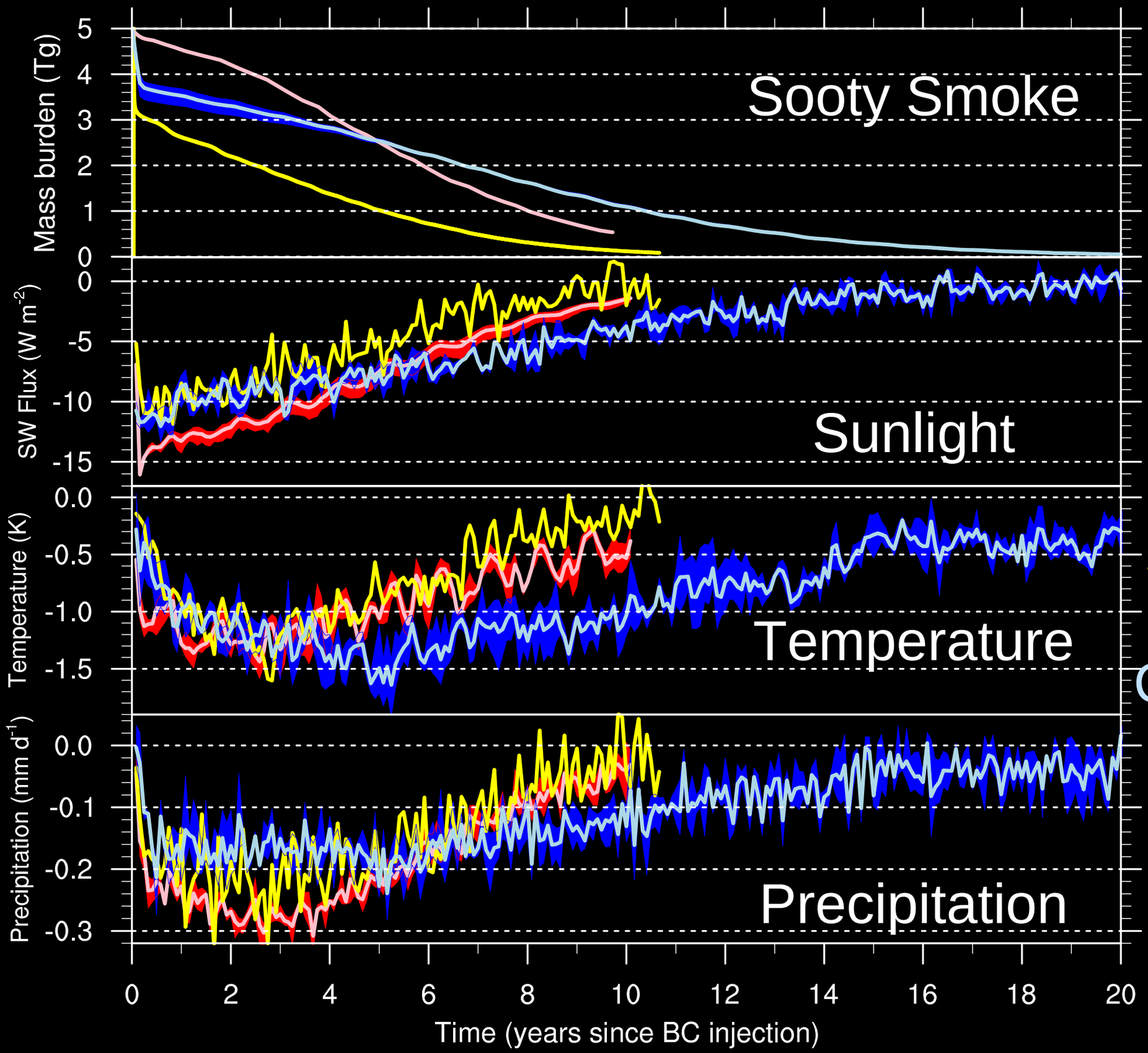

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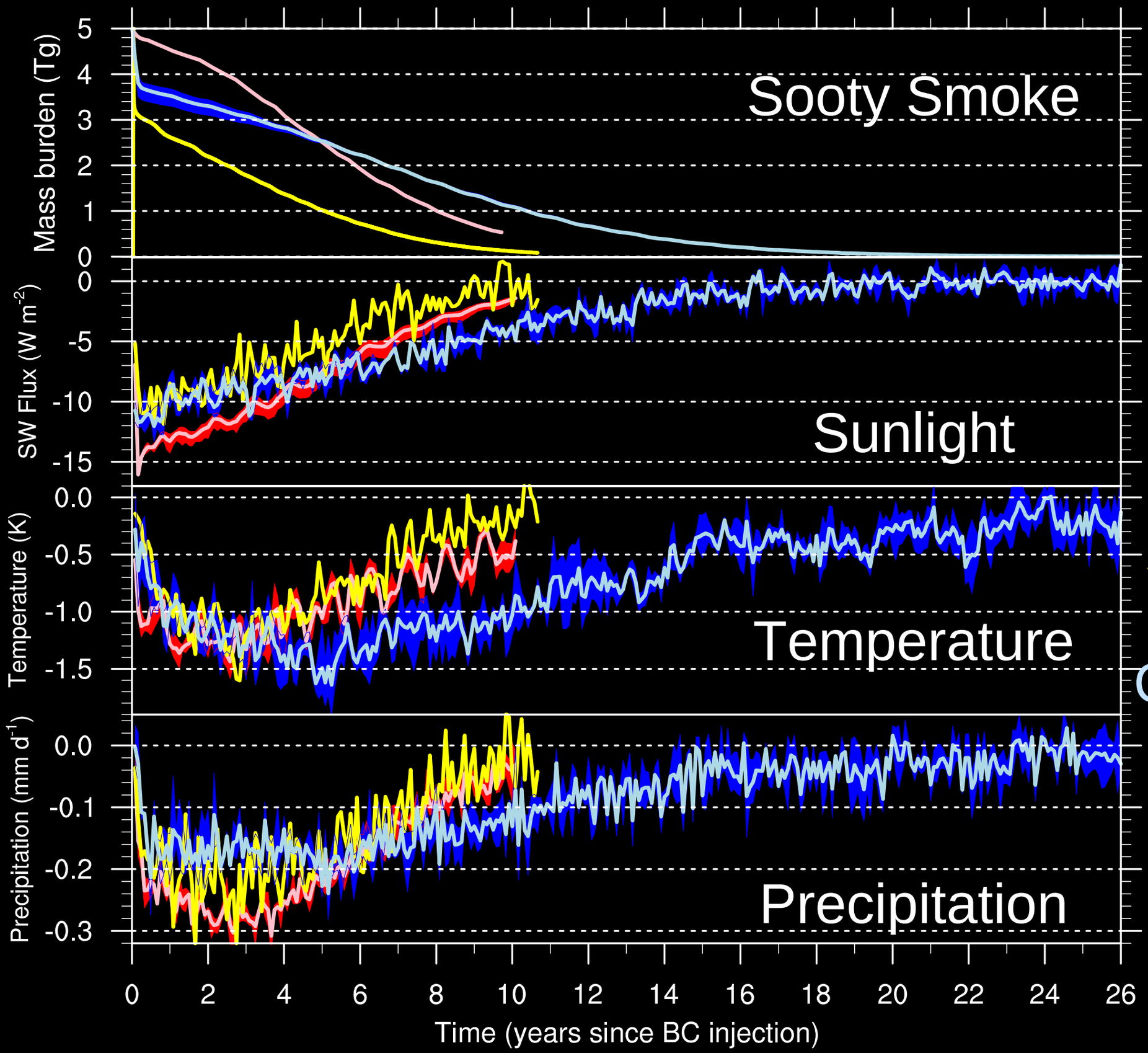

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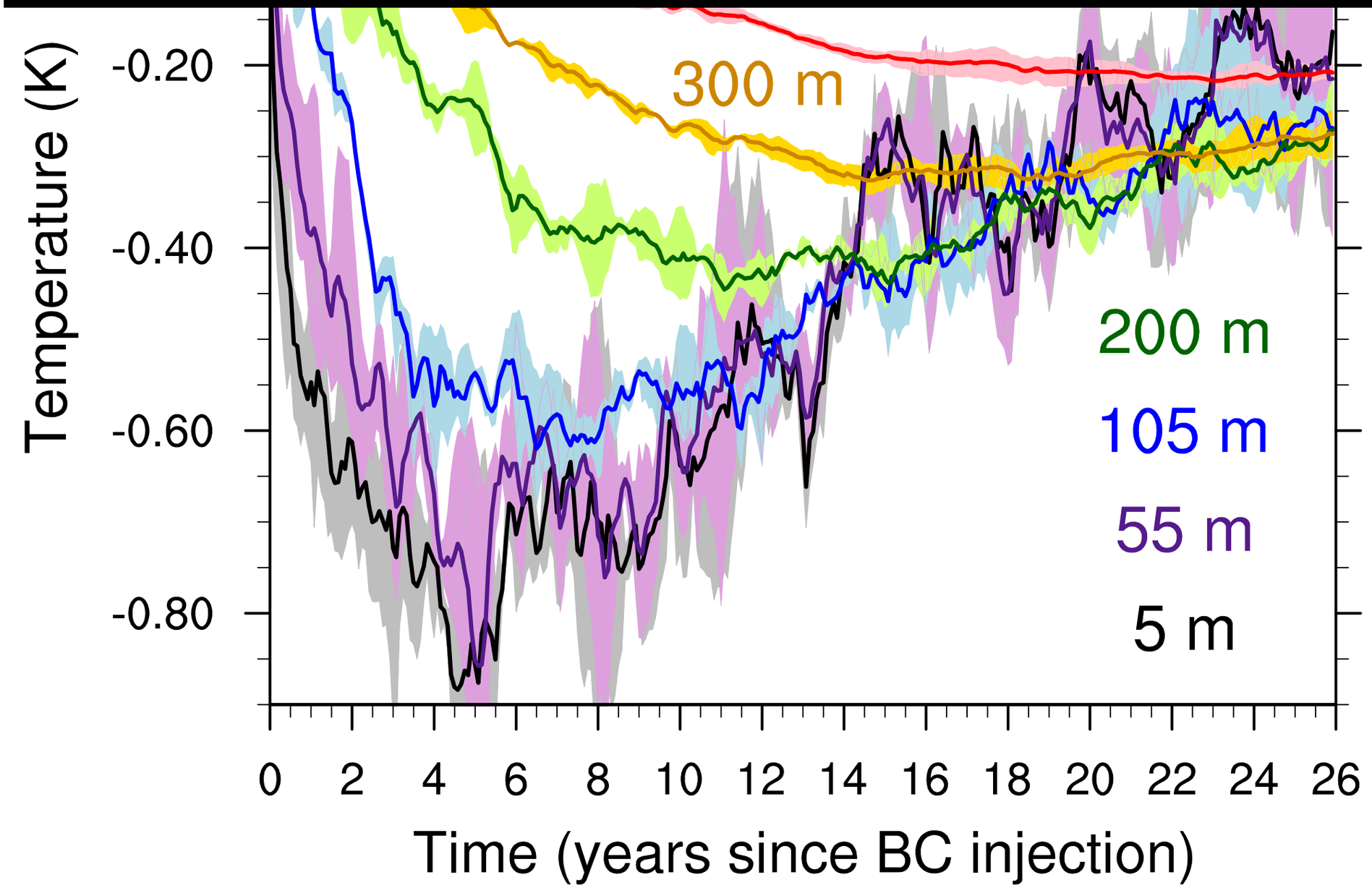
New results show large ocean cooling

Significant disruptions for ocean biota expected
(e.g. Harley et al., The impacts of climate change in coastal marine systems, *Ecology Letters*, *2006)*



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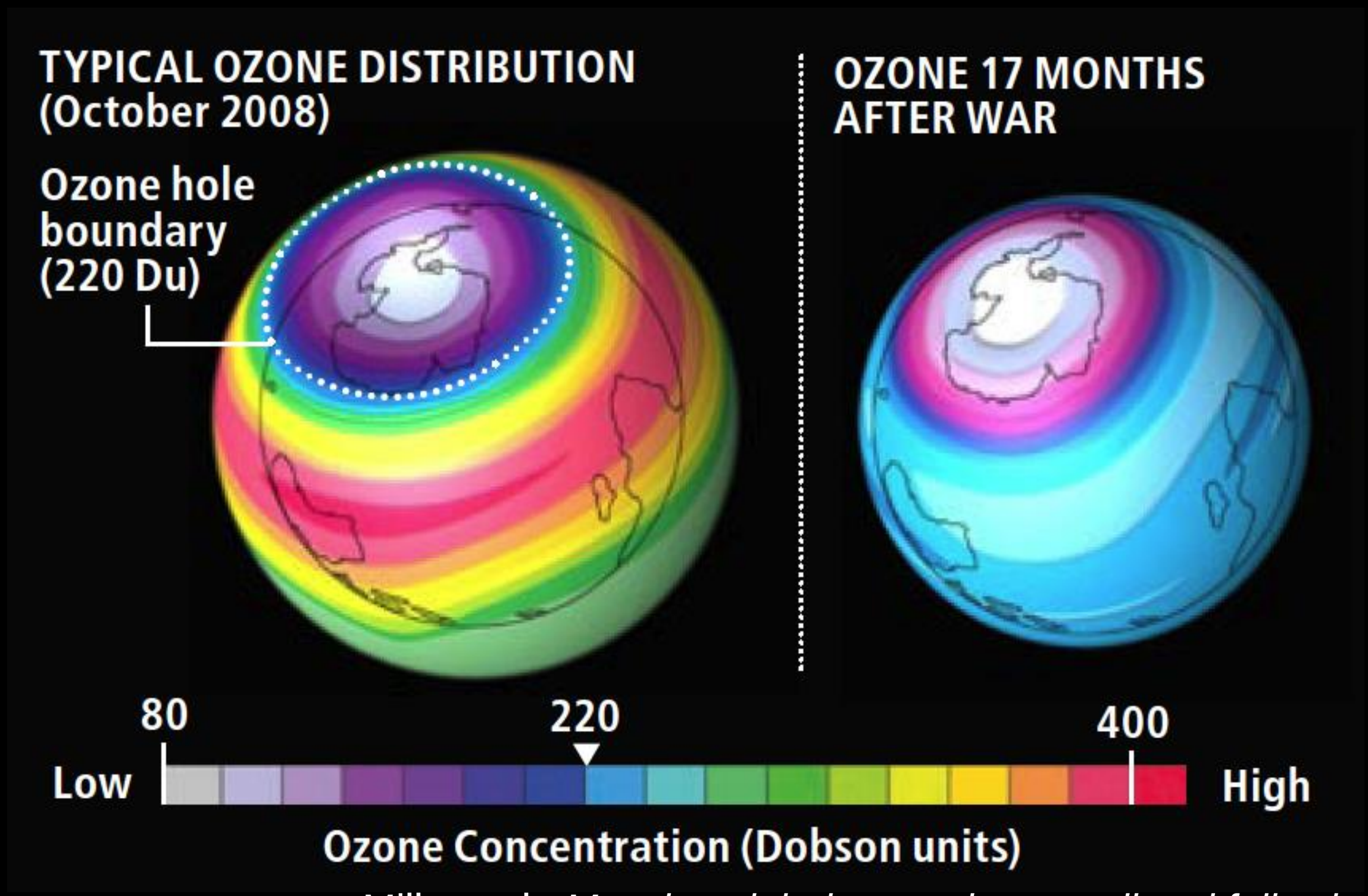
Mills et al., Multidecadal global cooling and unprecedented ozone loss following a regional nuclear conflict, *Earth's Future*, *2014*.

Global ozone hole after regional nuclear war



Mills et al., *Massive global ozone loss predicted following regional nuclear conflict*, Proc. Nat. Acad. Sci., 2008

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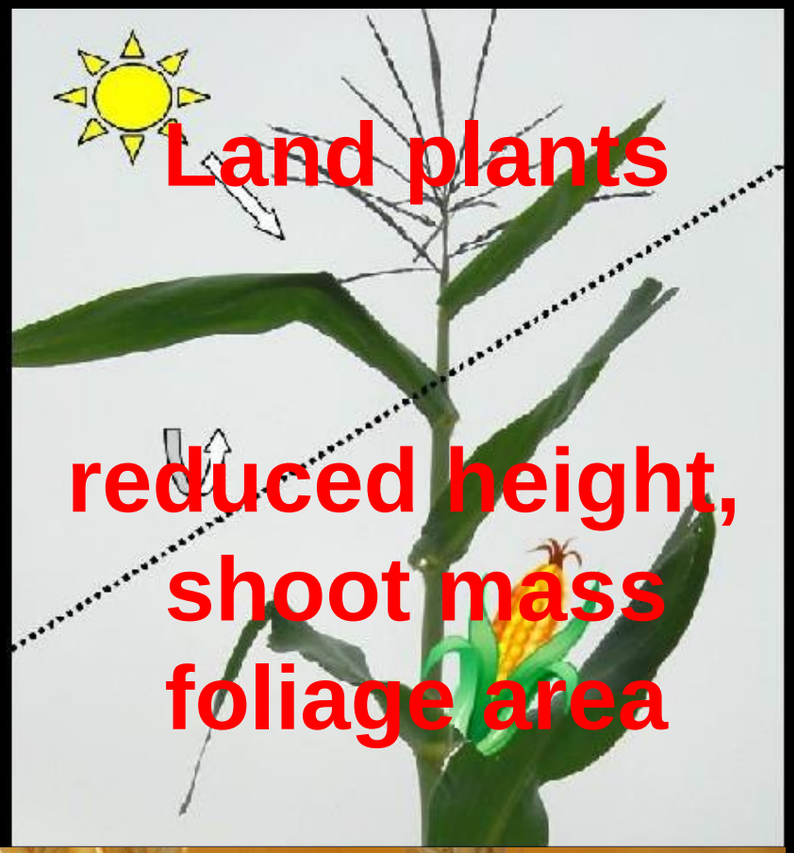
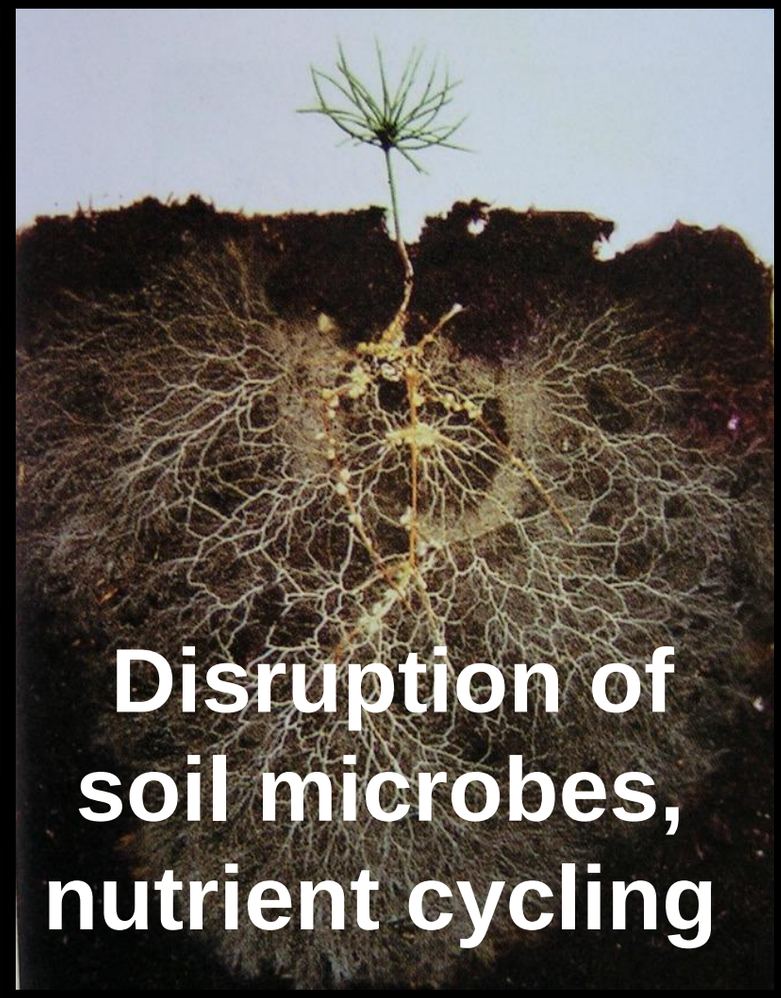
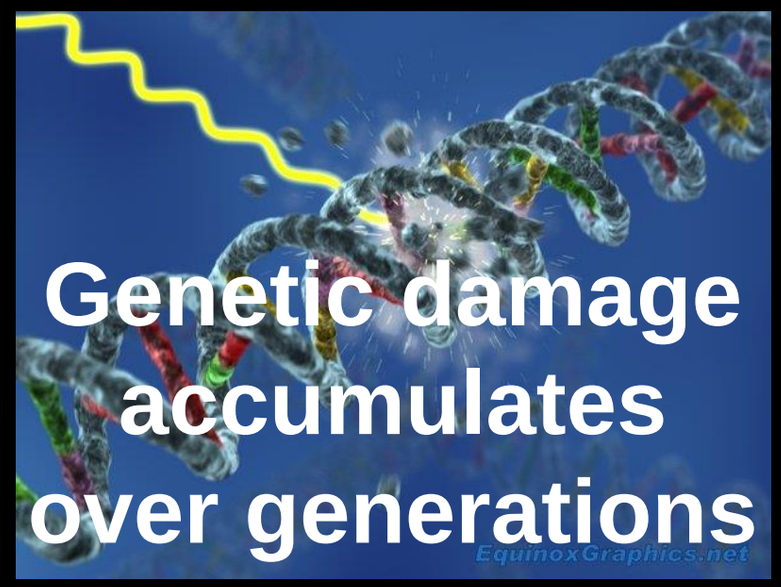
Consequences of severe ozone loss





See discussion and references in Pierazzo,et al., Ozone perturbation from medium-size asteroid impacts in the ocean, *Earth and Planetary Science Letters*, 2010.



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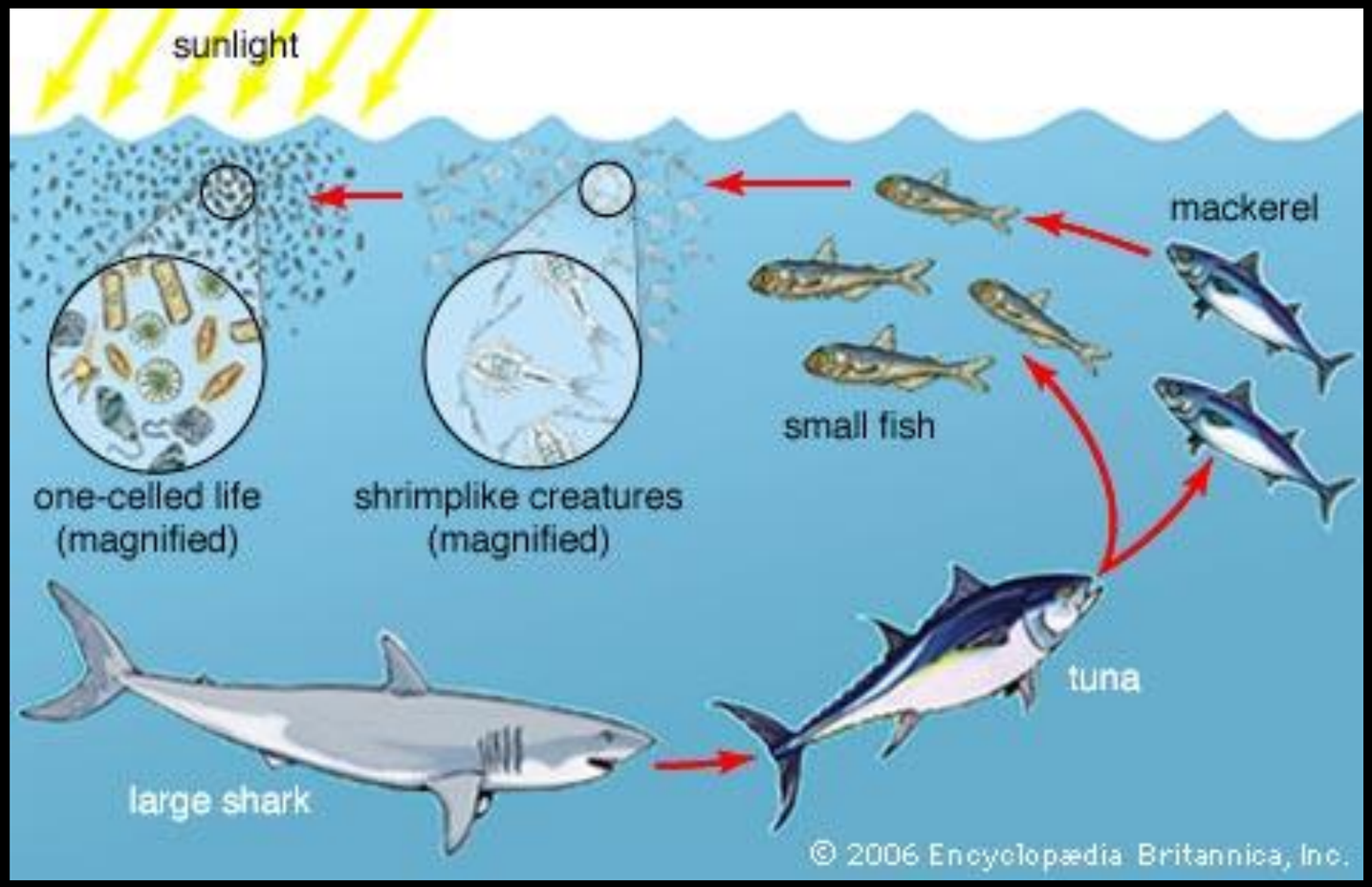

Aquatic ecosystems supply more than 30% of the animal protein consumed by humans.

The combined effects of elevated UV levels alone on terrestrial agriculture and marine ecosystems could put significant pressures on global food security.

Hader et al., Effects of increased solar ultraviolet radiation on aquatic ecosystems - Publications of the IAS Fellows, *Ambio*,1995.

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Ways agriculture can be affected by a nuclear war

- **Colder temperatures**
  - shortened frost-free growing season
  - cold spells during growing season
  - slower growth → lower yield
- **Darkness**
- **Less rainfall**
- **Enhanced ultraviolet radiation from ozone lo**
- Radioactivity
- Toxic chemicals in atmosphere, soil, and water
- Lack of water supplies
- Lack of fertilizer
- Lack of fuel for machinery
- Lack of pesticides (but not of pests)
- Lack of seeds (and those that do exist are genetically engineered for the current climate)
- Lack of distribution system

} Not yet modeled

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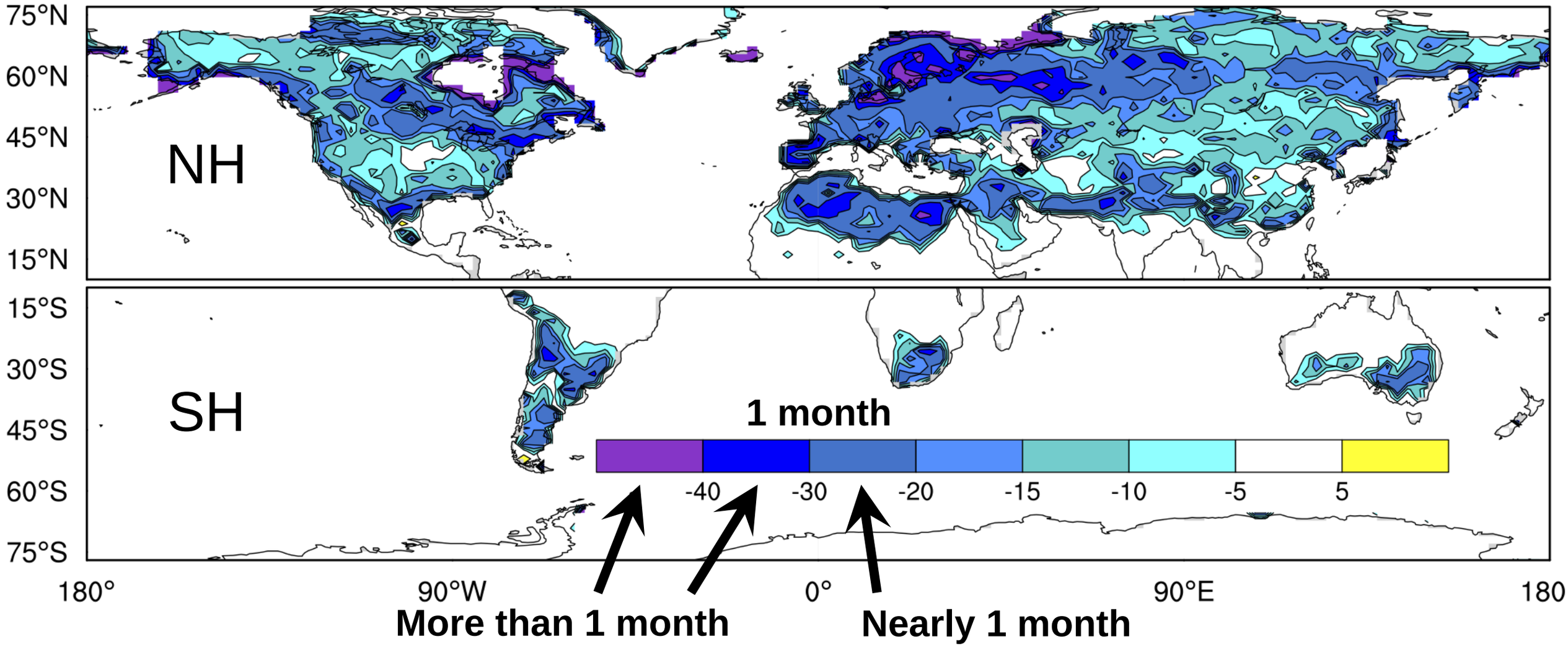
Change in growing season (days), years 2-6 average



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Mills et al., Multidecadal global cooling and unprecedented ozone loss following a regional nuclear conflict, *Earth's Future*, *2014*.

Following a nuclear war between India and Pakistan, reduced global temperatures, precipitation, and sunlight reduce food production globally

	First 5 years	Second 5 years
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%**

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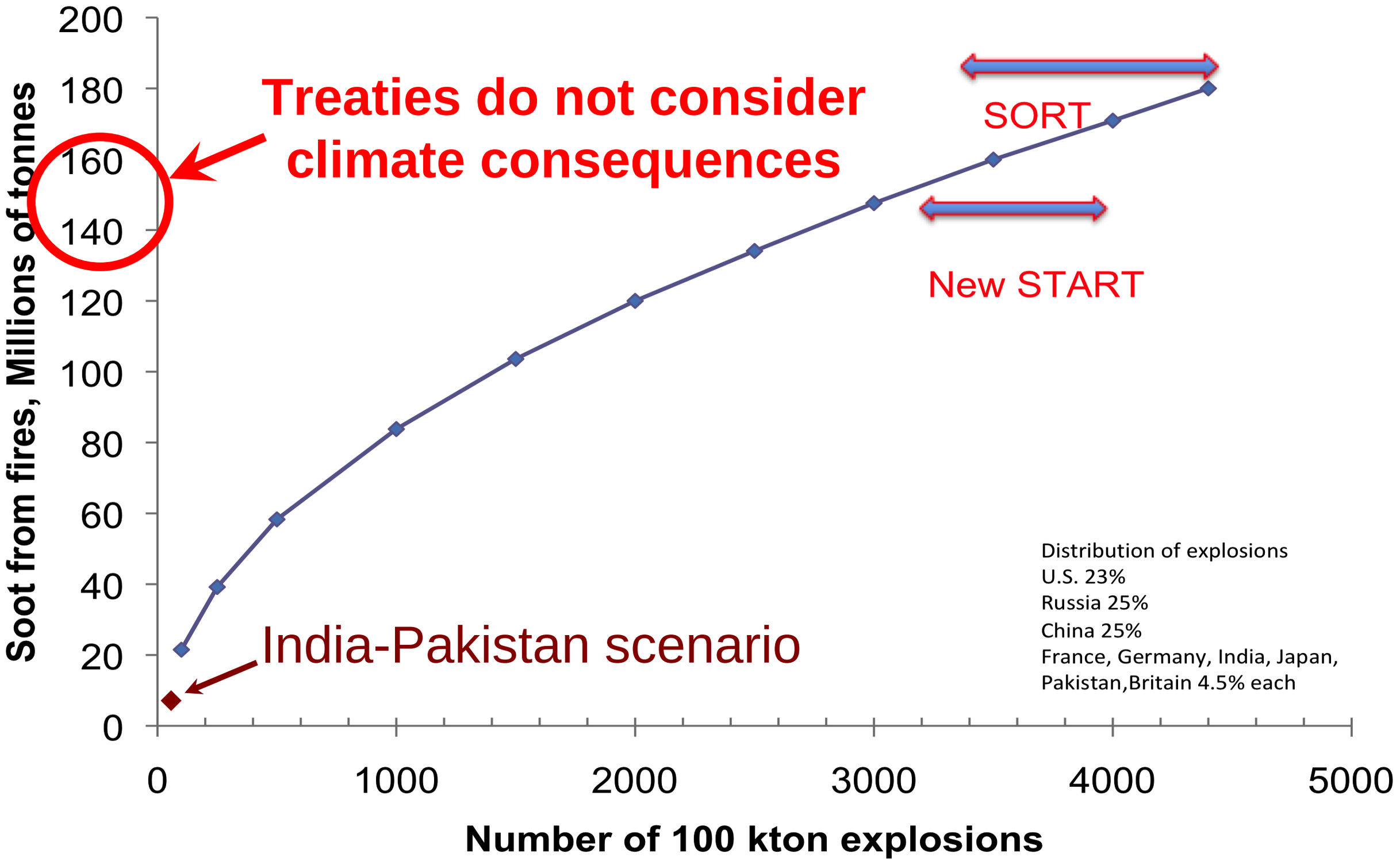
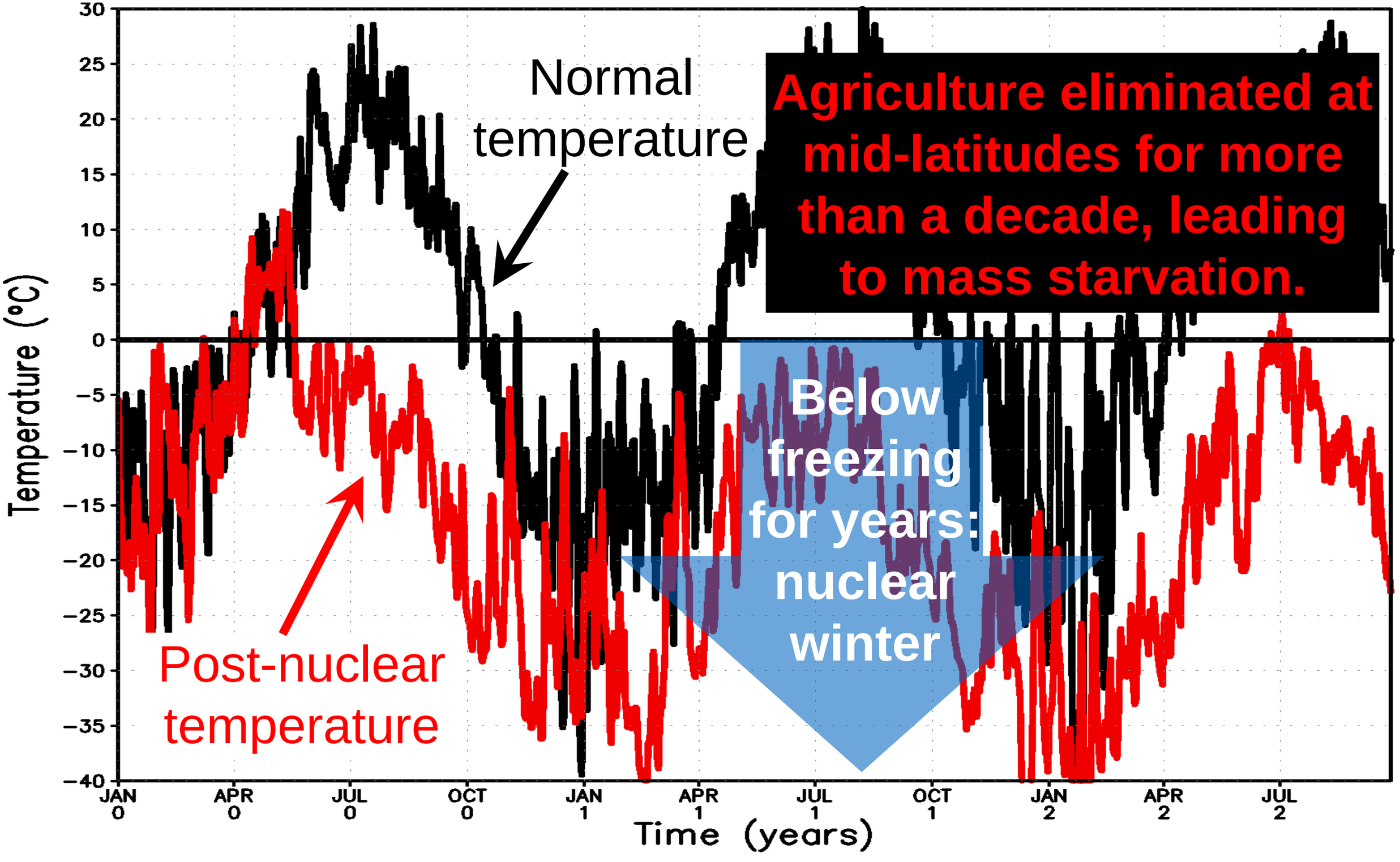
Özdoğan et al., Impacts of a nuclear war in South Asia on soybean and maize production in the Midwest United States, *Climatic Change*, 2012.
Xia et al., Global Famine after a Regional Nuclear War, submitted to *Earth's Future*, 2014.

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

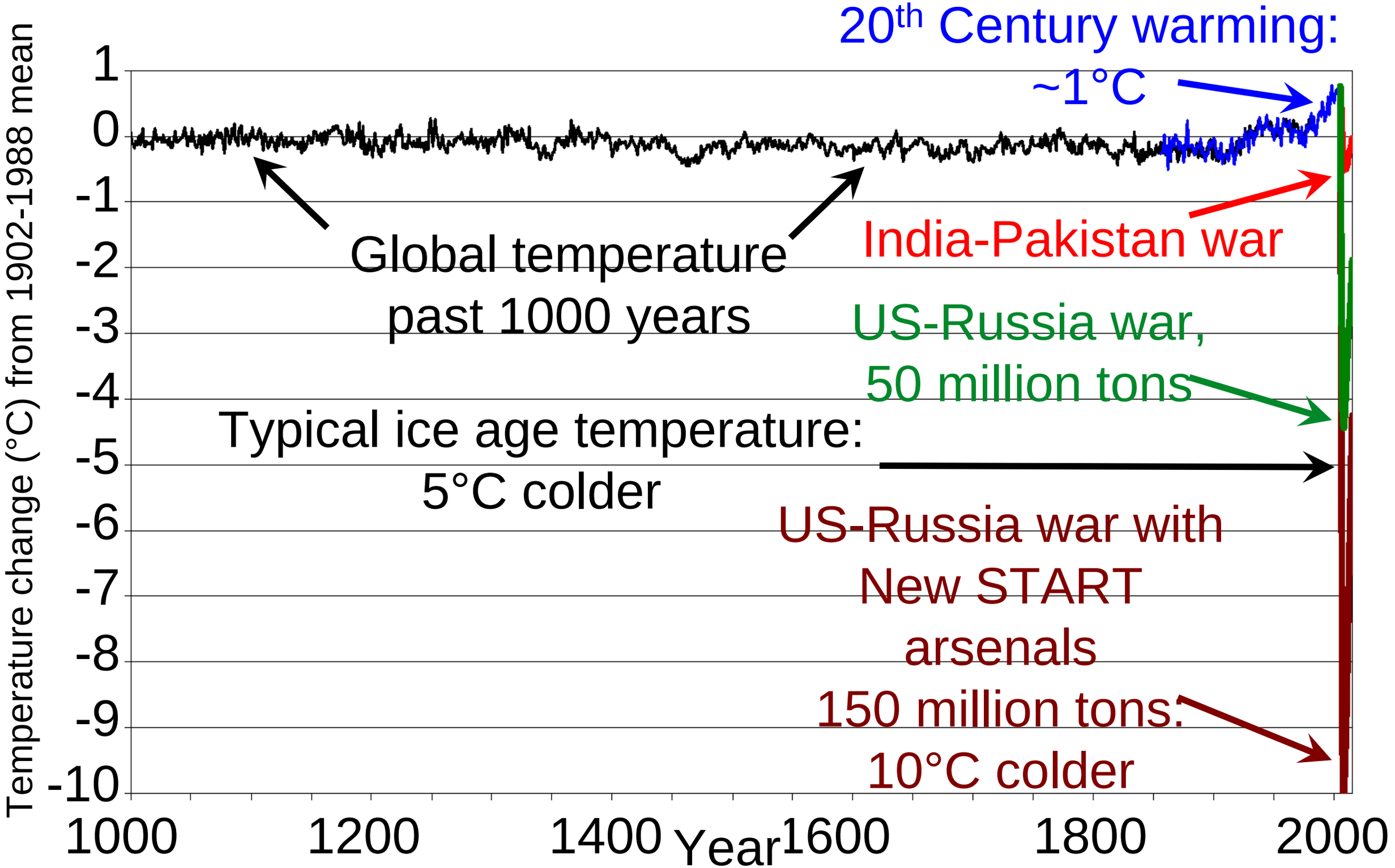


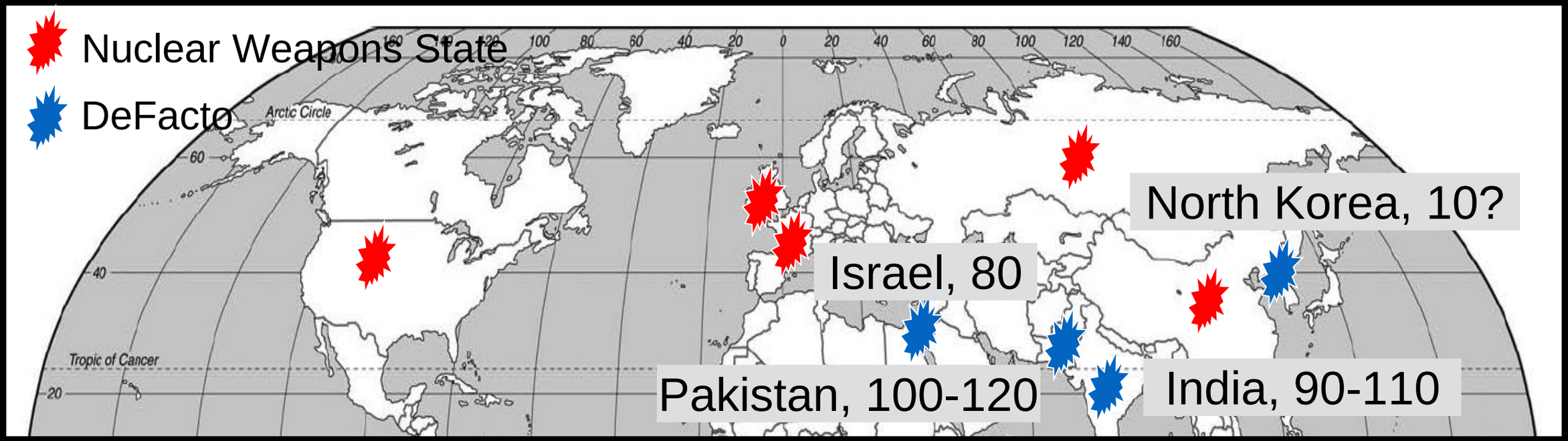
Climate consequences of a US-Russia war using New START arsenals would be catastrophic

Temperature (°C) in Ukraine



Surface temperature after global conflict drops to ice age conditions





- A nuclear war between new nuclear states would produce global climate change lasting decades, unprecedented in human history, even though they are using much less than 1% of the current nuclear arsenal .
- Recent calculations suggest a regional nuclear war would produce crop losses of tens of percent, and could produce a global famine.

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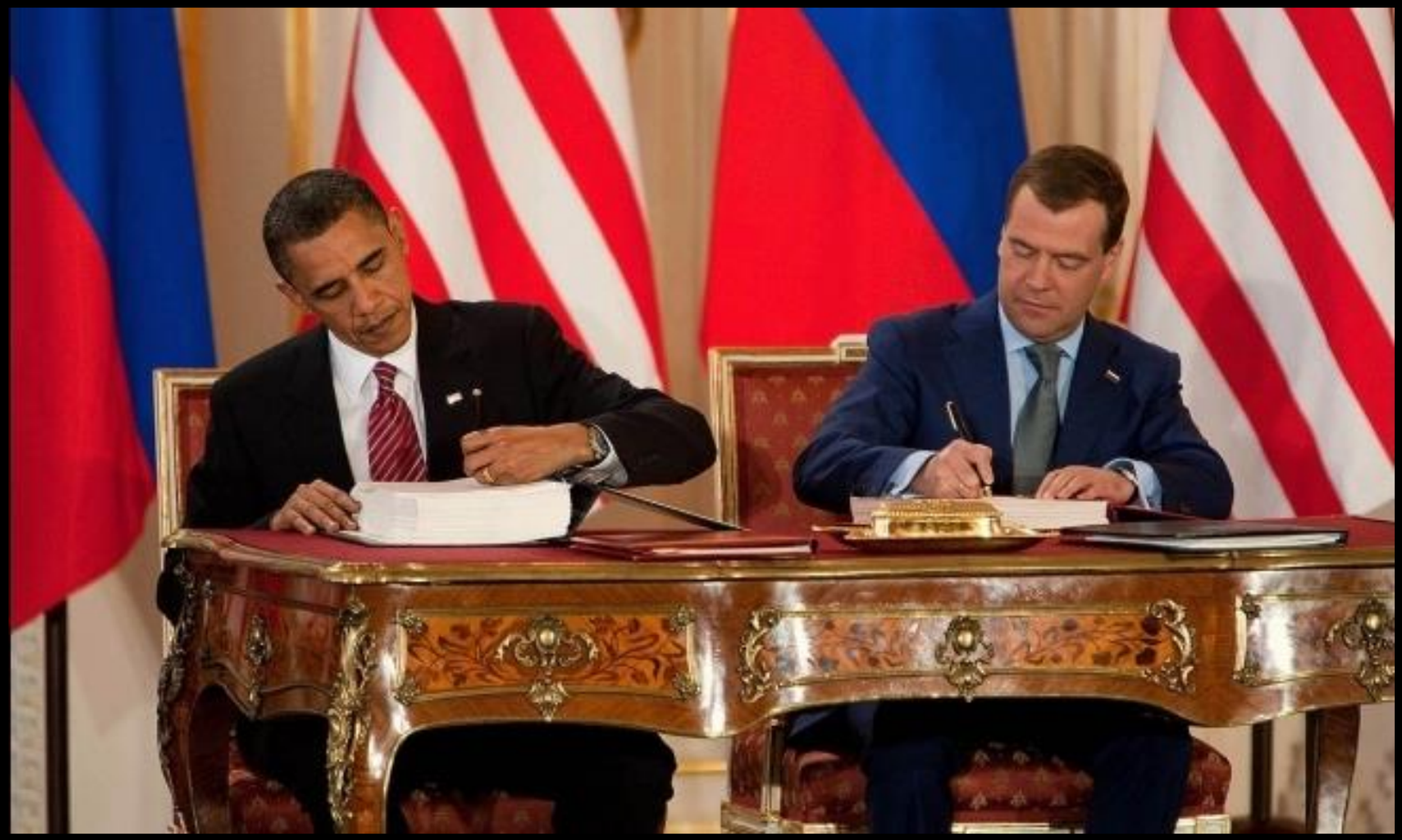

- The arsenals of Russia and the US under New START can still produce nuclear winter.
- Current climate models show that nuclear winter theory is correct.
- Nuclear winter would eliminate agriculture at mid-latitudes for decades and lead to mass-starvation.

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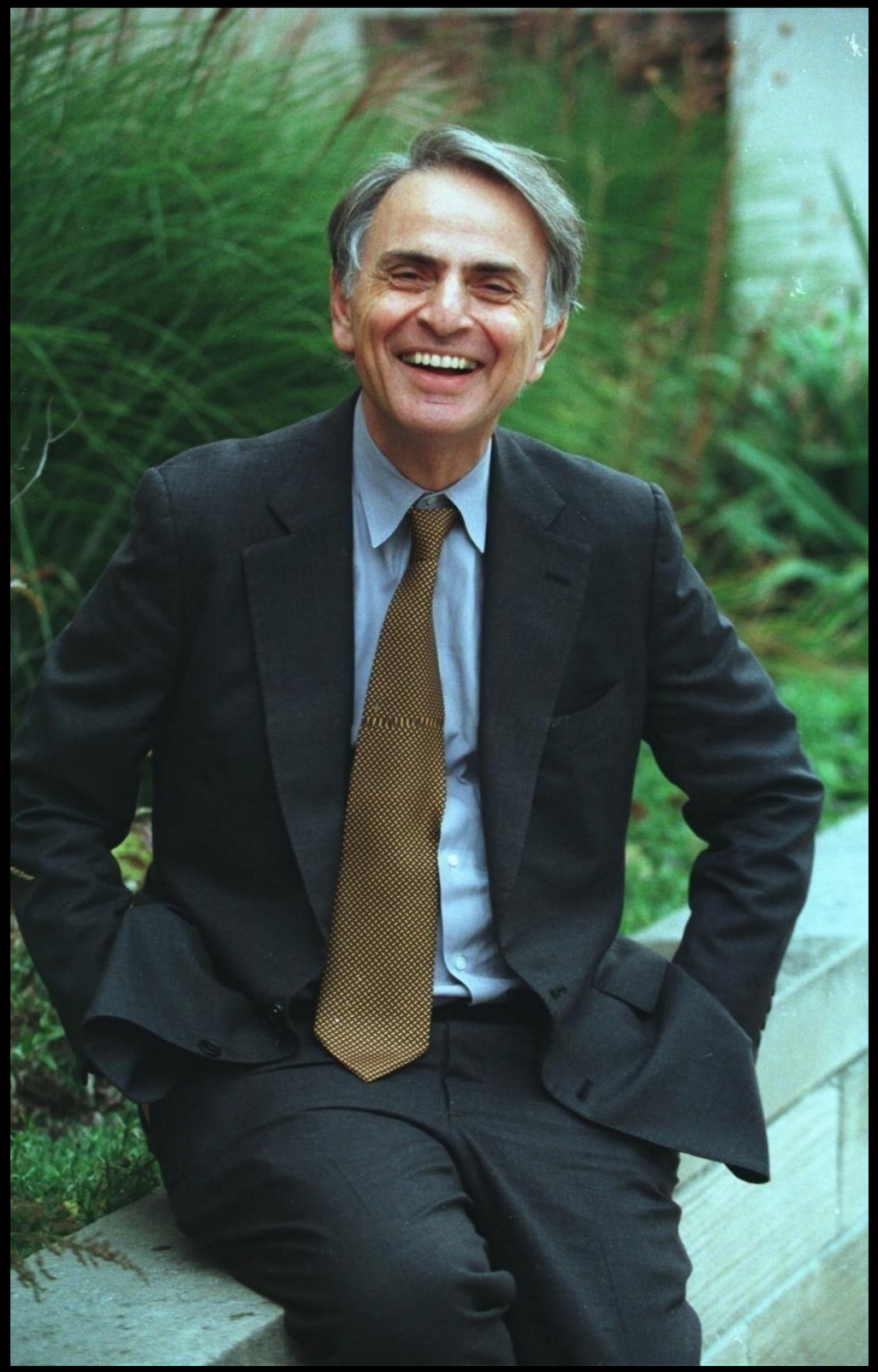

“For myself, I would far rather have a world in which the climatic catastrophe cannot happen, independent of the vicissitudes of leaders, institution, and machines. This seems to me elementary planetary hygiene, as well as elementary patriotism.”

-Carl Sagan

“Elementary planetary hygiene” demands that we eliminate nuclear weapons faster.

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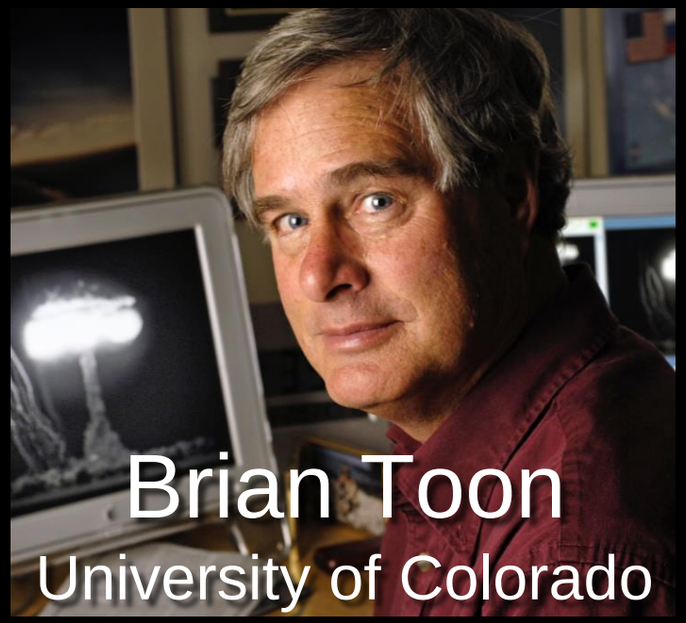
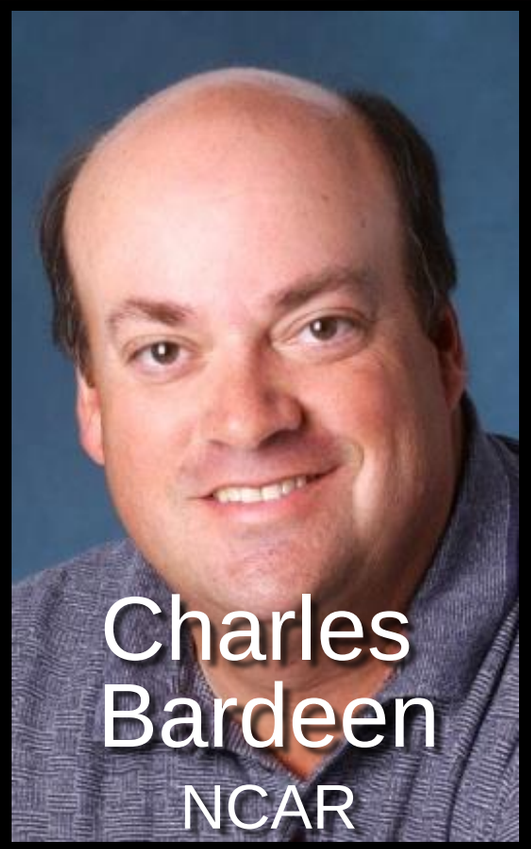
This work is done in collaboration with





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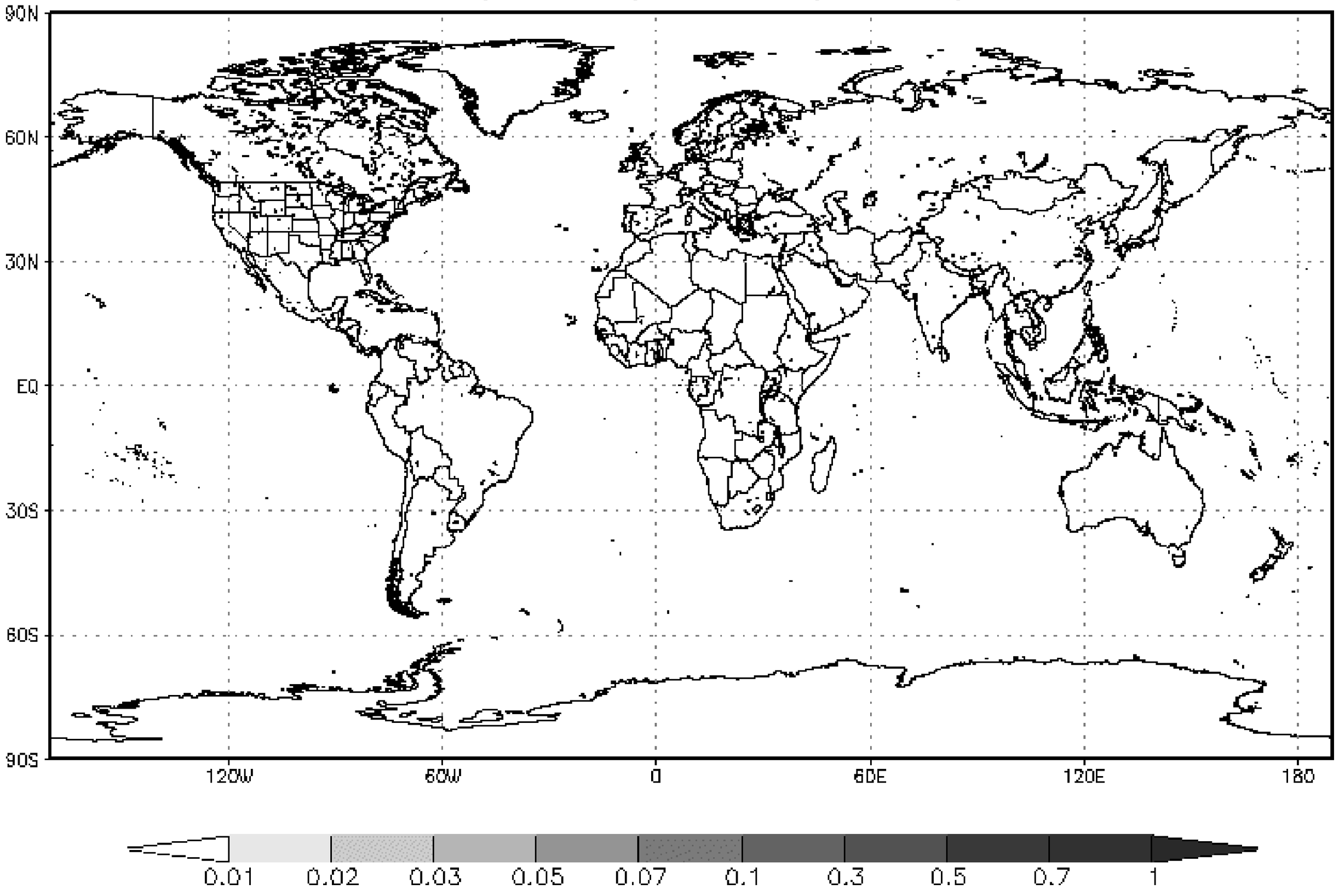
Extra slides

Cloudless sky after US-Russian nuclear war, 70% of sunlight blocked by global stratospheric smoke layer

adapted from Scientific American, (2010)
“Local Nuclear War, Global Suffering”, Robock & Toon

BC Absorption Optical Depth May 14th



Daily Minimum Temperature (°C) 42°N 95°W

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)

- 10% reduction in average caloric intake in China. More than 1 billion Chinese poor would experience disproportionate deprivation.
- January-May 2008 global rice crisis: small food price pressures amplified by export restrictions, producing severe shortages globally
- 870 million people in the world are chronically malnourished today. A 10% decline in their food consumption would put this entire group at risk.
- 2 billion at risk of starvation after regional war?

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Consequences of severe ozone depletion on flora

E. Pierazzo *et al*. (2010)

- “recorded general effects of increased UV-B exposure include plant height reduction, decreased shoot mass, and reduction in foliage area (Caldwell *et al.*, 2003).”
- “During extended increased UV-B exposure, not all DNA damage may be fully repaired; as a result, damage may accumulate over time and carry-over to following plant generations, affecting the genetic stability of plants by increasing the frequency of mutations (e.g., Walbot, 1999).”
- “changes in the susceptibility of plants to attack by insects and pathogens and changes in competitive balance of plants and nutrient cycling (e.g., Mpoloka, 2008).”
- “may also affect important soil surface processes, such as nitrogen fixation by cyanobacteria (Solheim et al., 2002).”

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Consequences of severe ozone depletion on sea life

E. Pierazzo *et al*. (2010)

- “Over 30% of the world's animal protein for human consumption comes from the sea, mostly in the form of finfish, shellfish and seaweed, and particularly in the developing countries, this percentage can be significantly higher (Hader et al., 1995).”
- “Increased UV-B levels associated with Antarctic ozone hole levels have been shown to inhibit phytophankton activity in the upper ocean layer (Smith et al., 1992).”
- “Hader et al. (1995) estimated that a 16% ozone depletion could result in a 5% loss in phytoplankton, which, based on estimates of Nixon (1988), could cause a reduction in fishery and aquaculture yields of about 7% and a loss of about 7 million tons of fish per year.”
- “Solar UV-B radiation has also been found to cause damage to early developmental stages of fish, shrimp, crab and other animals. The most severe effects are decreased reproductive capacity and impaired larval development (USEPA, 1987).”

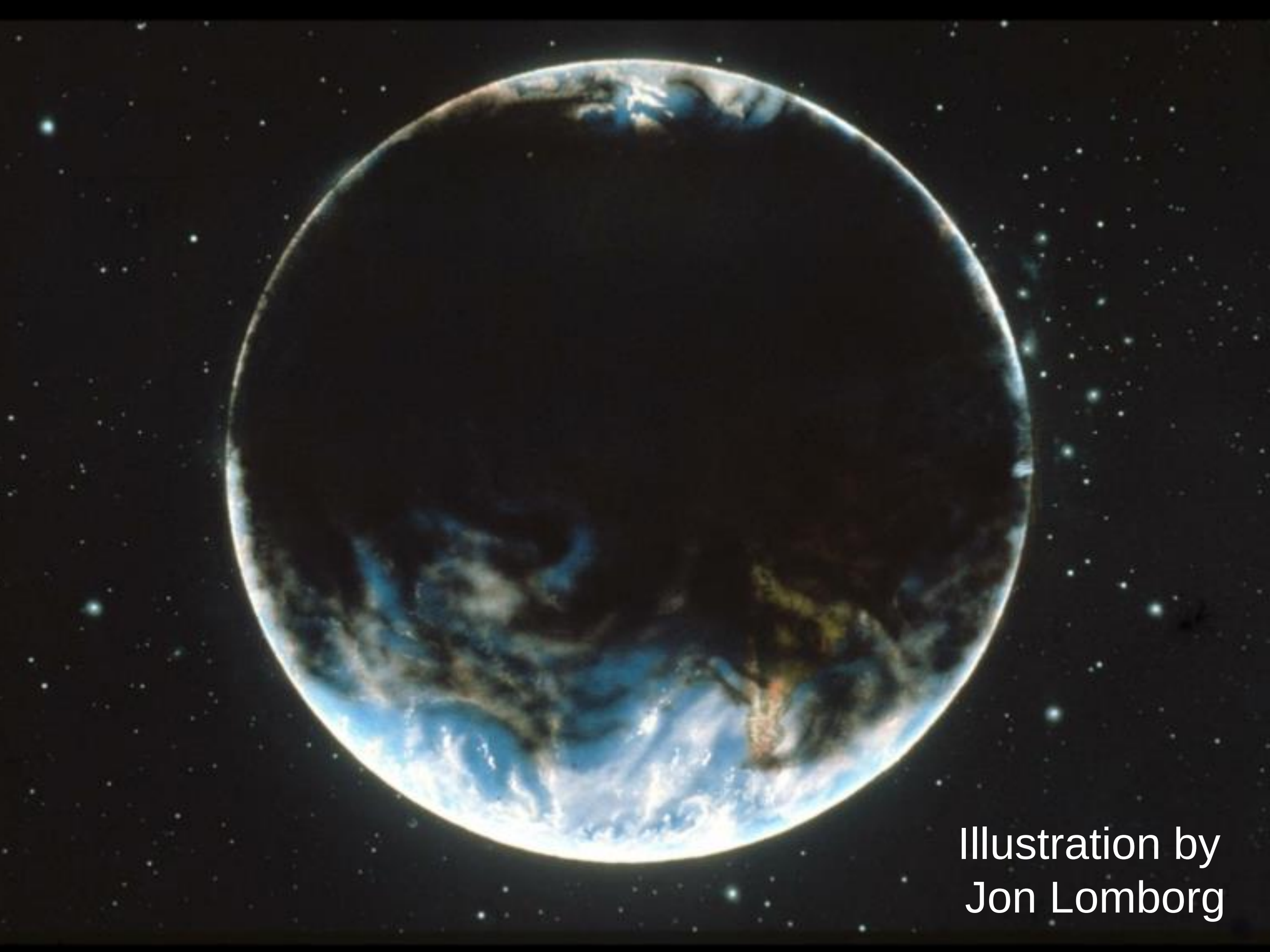


Illustration by
Jon Lomborg

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

Rapid, large surface temperature drops

Devastation to global agriculture and ecosystems

Ronald Reagan:

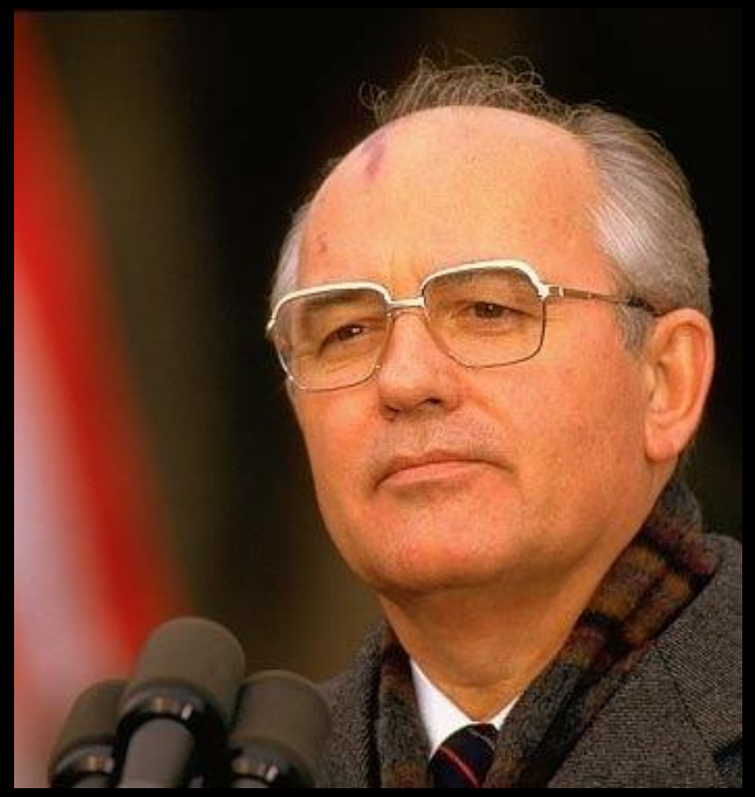
When asked about the effects of nuclear war in a February 12, 1985 interview in the New York Times said,

“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 ...”

Courtesy Alan Robock

Mikhail Gorbachev:

commented in an interview in 1994 that when he received control over the Soviet nuclear arsenal,

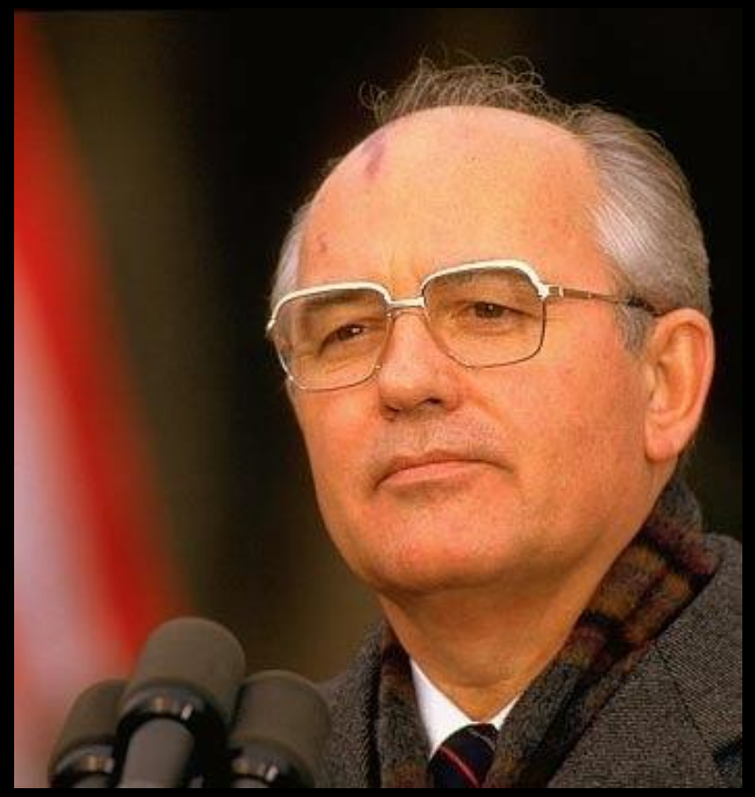


“Perhaps there was an emotional side to it…. But it was rectified by my knowledge of the might that had been accumulated. One-thousandth of this might was enough to destroy all living things on earth. And I knew the report on ‘nuclear winter.’”

Courtesy Alan Robock

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.”

Courtesy Alan Robock

Igniting Cities

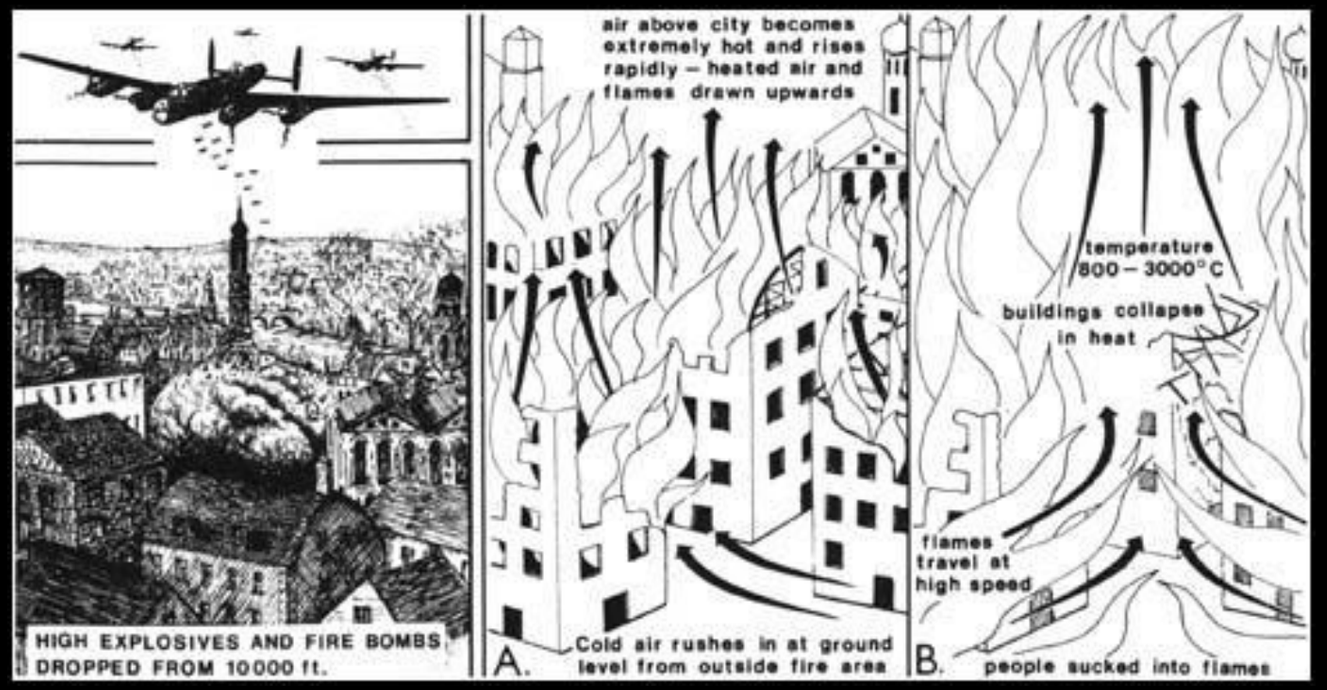


Illustration from spartacus-educational.com

“On **July 27, 1943** nearly a thousand British bombers dropped over two thousand tons of bombs on **Hamburg**, most of them incendiaries, turning that city into a burning, **melting quagmire of horror**. The temperature reached **one thousand degrees** in the center of town, igniting the world's first firestorm. **The superheated air rose so fast it sucked in outside air in the form of hurricane-strength winds which force-fed the fire still further** and blew helpless people like leaves into the burning center of destruction where they actually melted into pools of burning fat. On the outskirts of the storm other people were stuck in **molten asphalt, suffocating and igniting**. More than **40,000 people died** that night. In the early spring of 1945 the American Twentieth Air Force topped the RAF's record by burning **Tokyo**, starting a conflagration that totaled sixteen square miles of intensely populated city, killing more than **80,000 people**.”

- *Fire and Ice*, David Fisher

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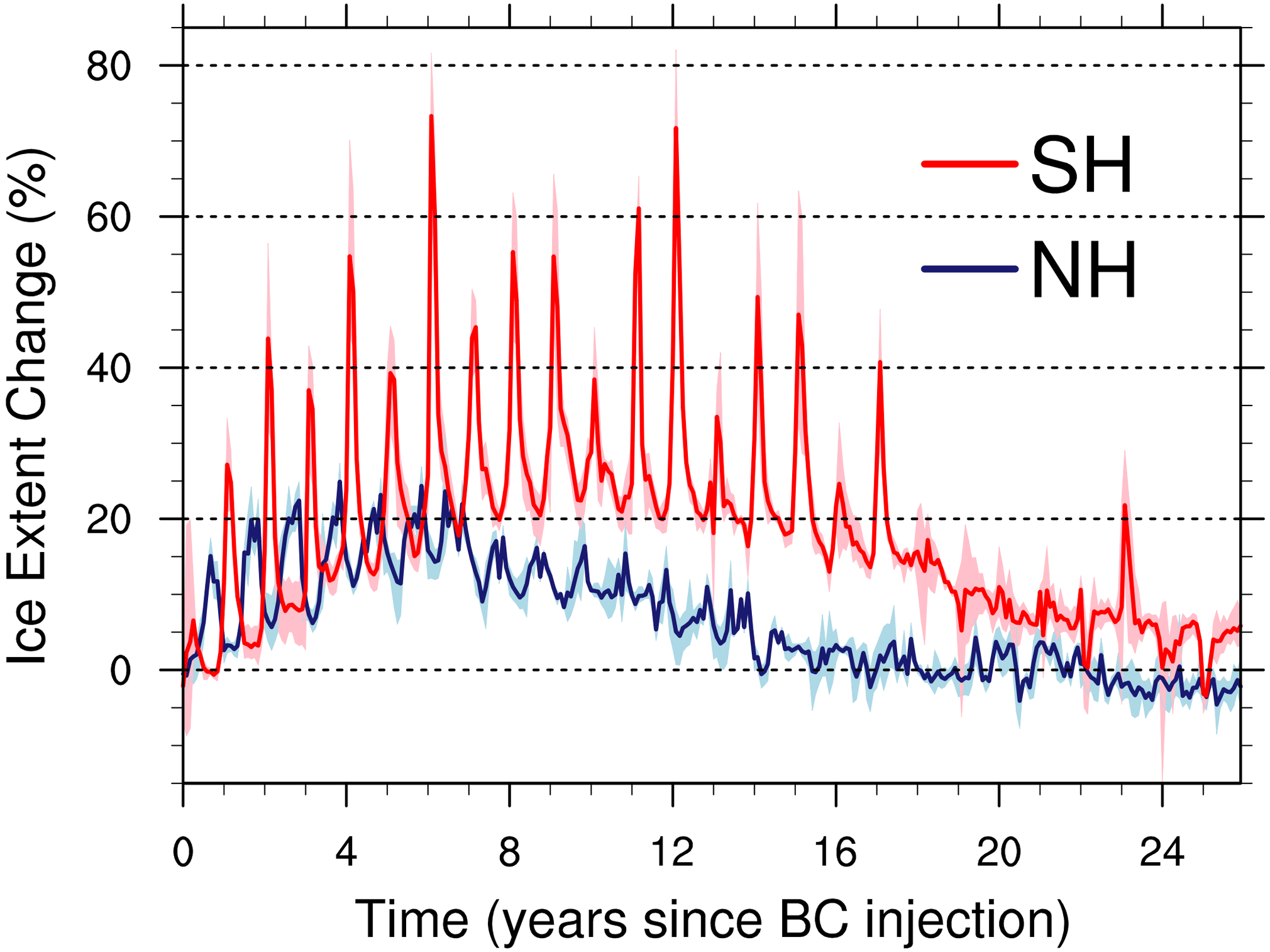
Sea ice extent



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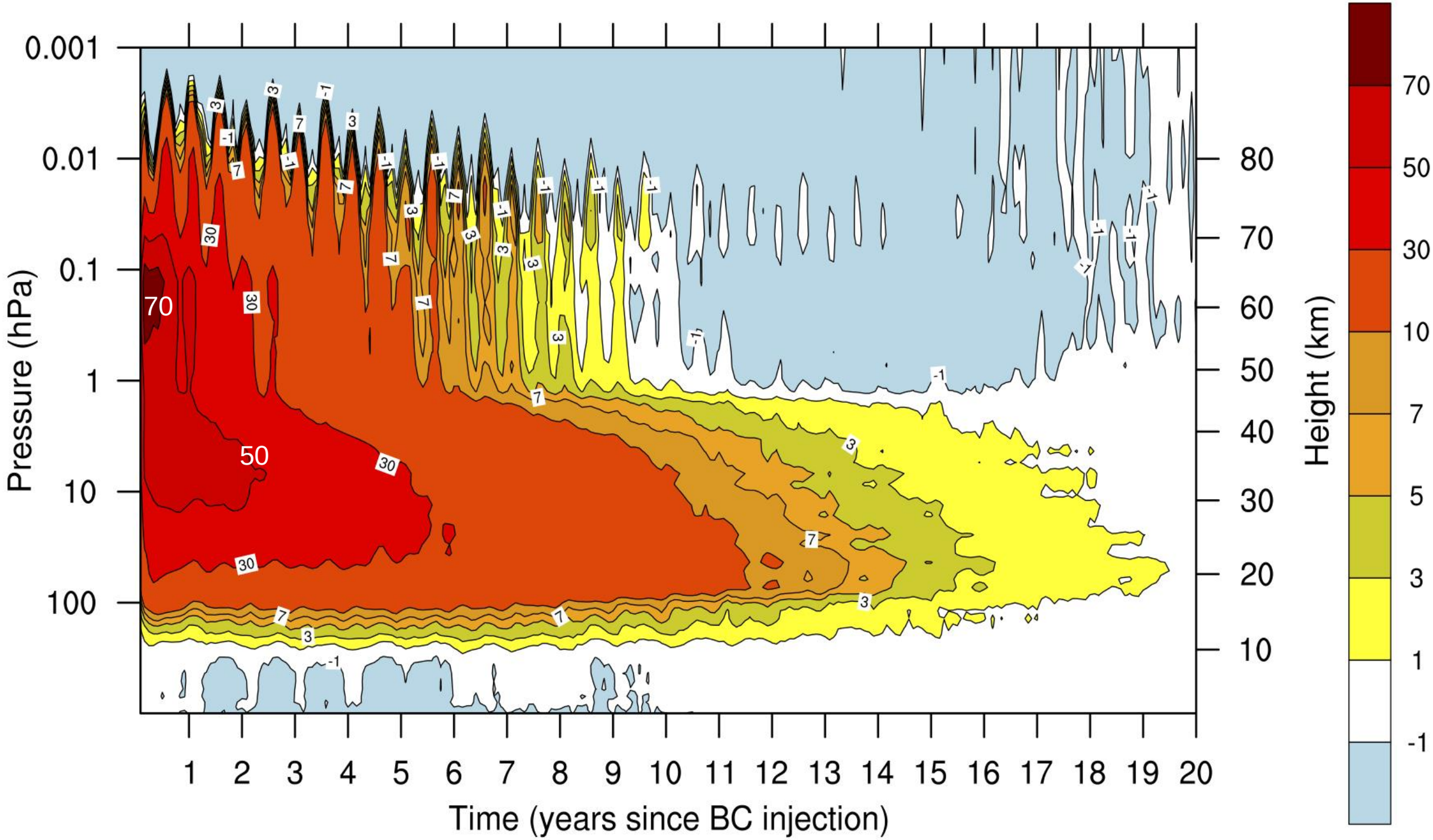
Change in global temperature profile (°C)



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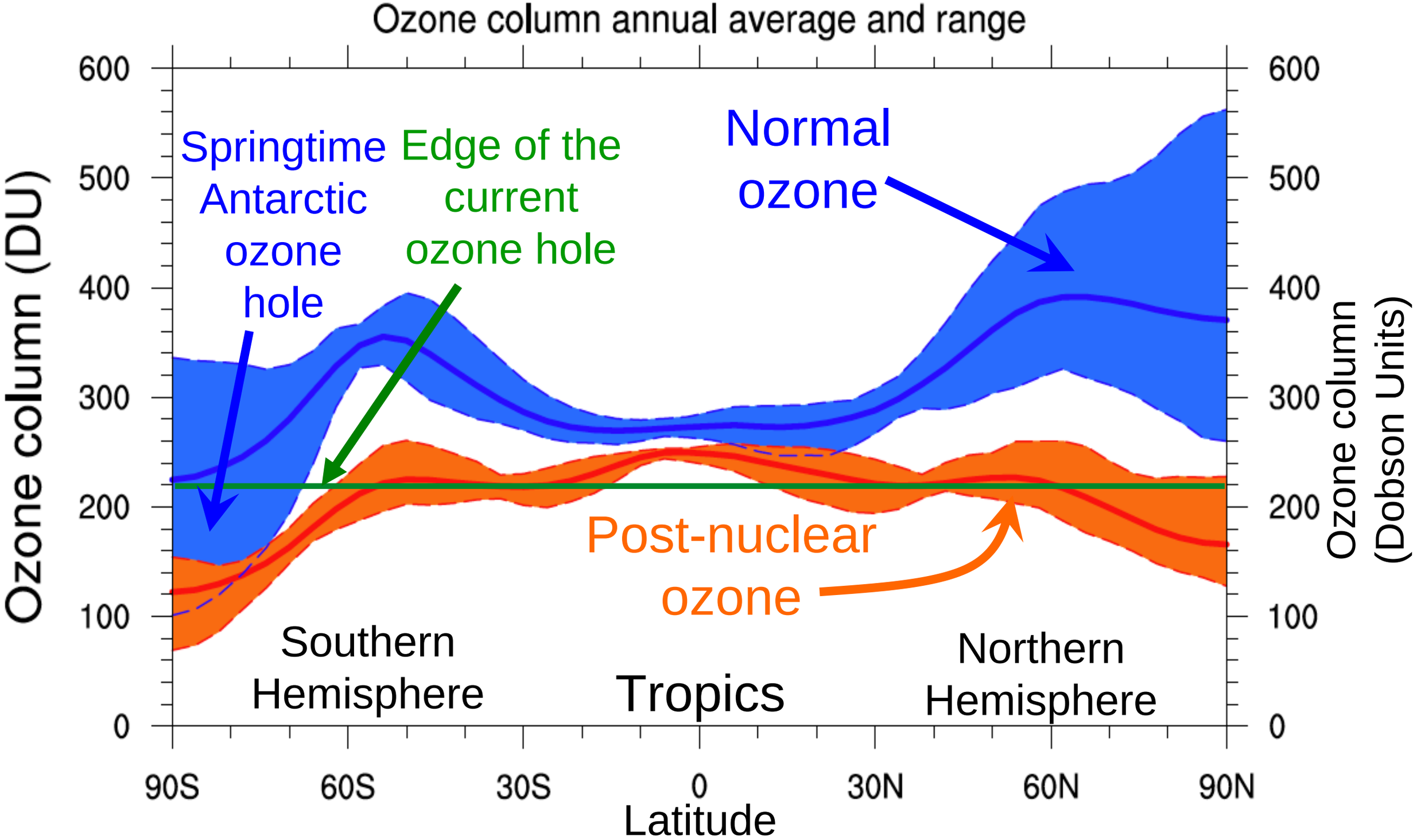
Ozone depletion 3 years after soot injection



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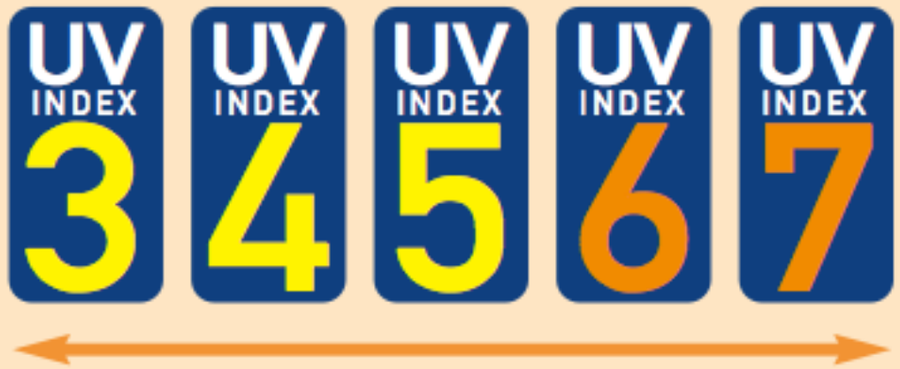
Mills, Michael J., Owen B. Toon, Richard P. Turco, Douglas E. Kinnison, and Rolando R. Garcia, 2008: Massive global ozone loss predicted following regional nuclear conflict, *Proc. Nat. Acad. Sci.,* **105**, 5307–5312.

NO PROTECTION REQUIRED

You can safely stay outside!



PROTECTION REQUIRED

Seek shade during midday hours!

Slip on a shirt, slop on sunscreen and slap on a hat!

EXTRA PROTECTION

Avoid being outside during midday hours!
Make sure you seek shade!

Shirt, sunscreen and hat are a must!

The Global Solar UV Index is a measure of the flux of harmful ultraviolet rays reaching the Earth's surface. Levels greater than 11 are considered extreme.

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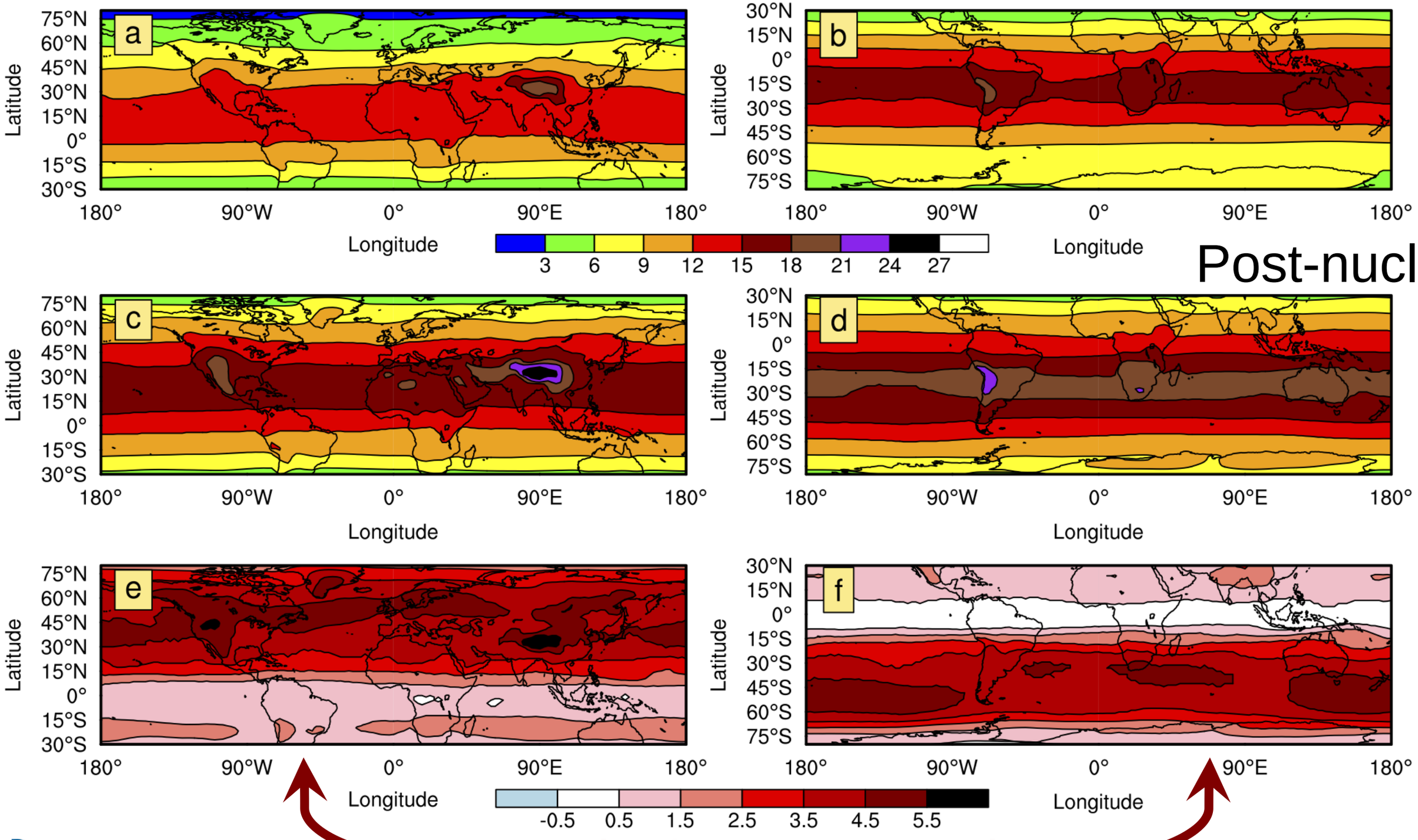
UV Index, Year 3

June

December

Normal



Post-nuclear

Normal minus post-nuclear

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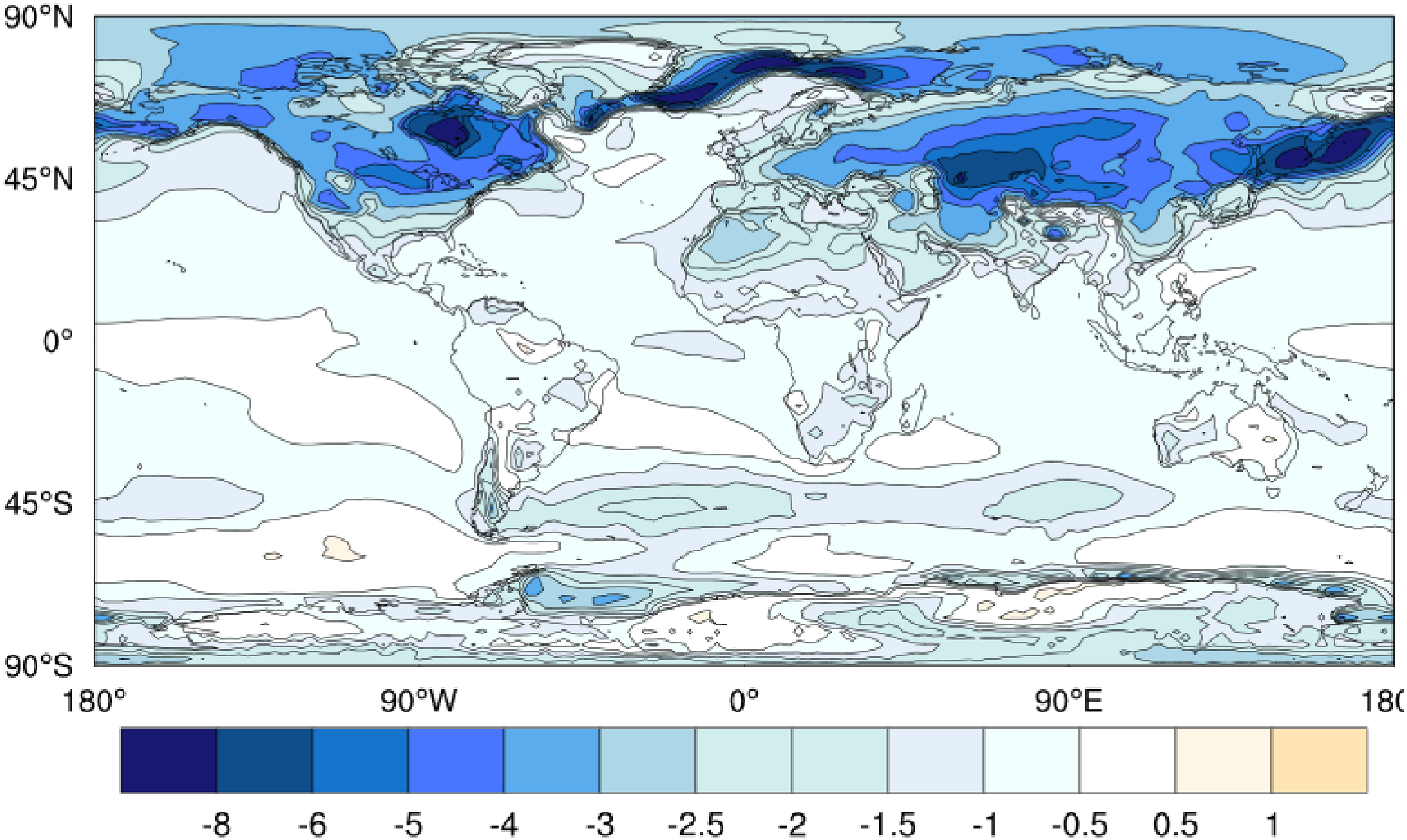
Surface temperature change (°C)



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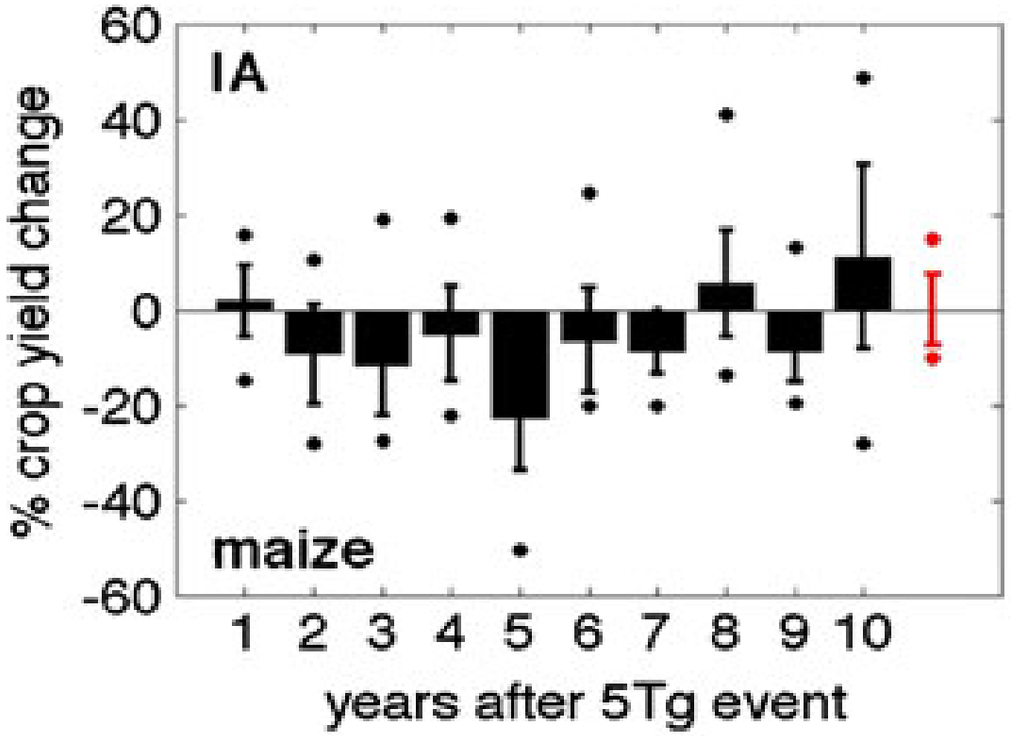
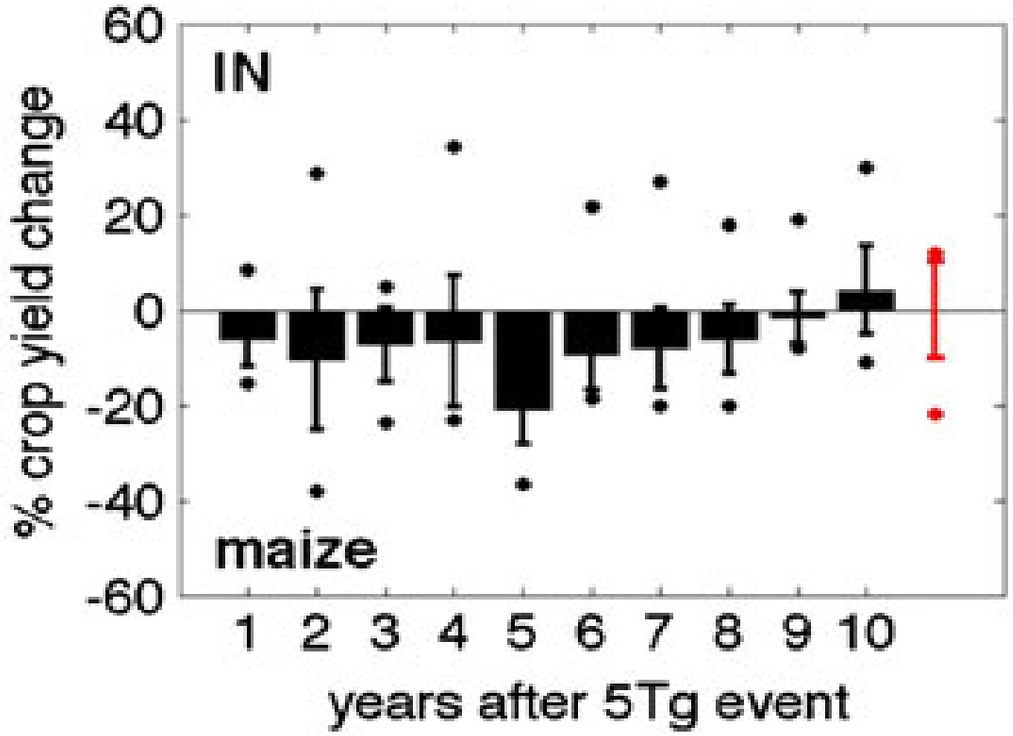
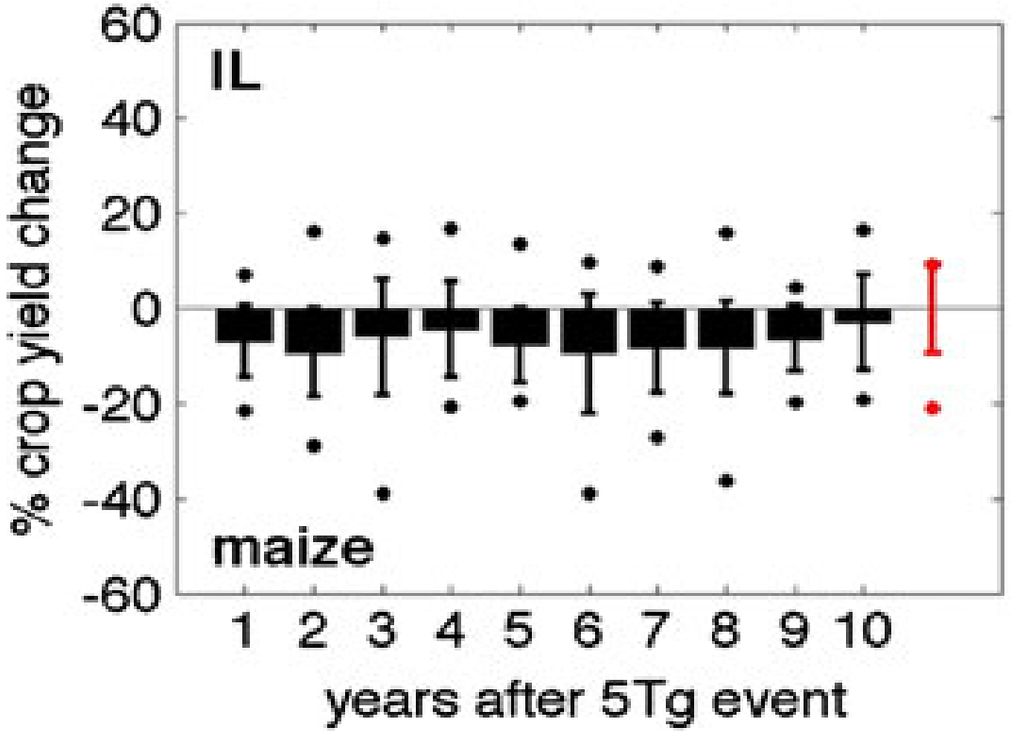
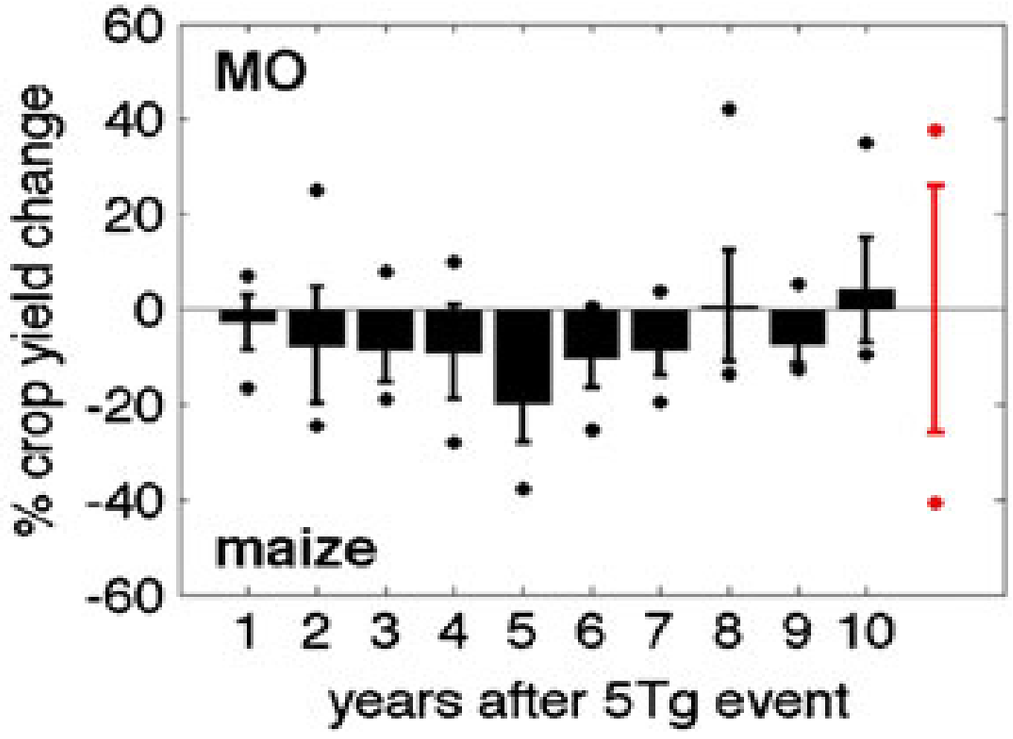
DJF average, years 1-5

Change in US Midwest maize yield









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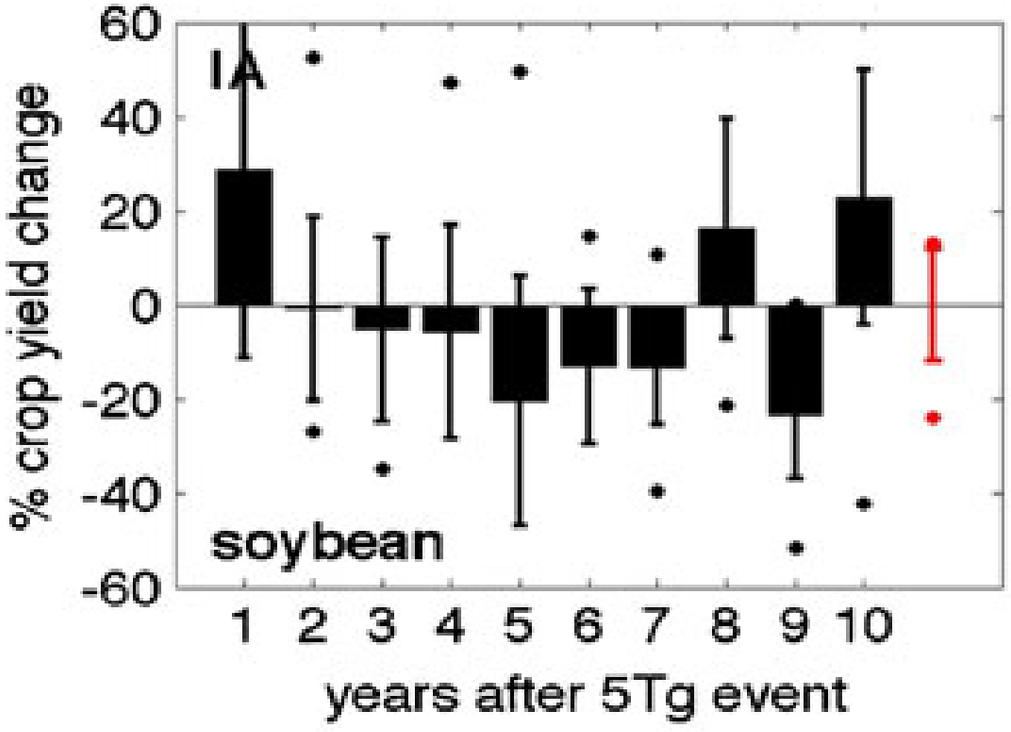
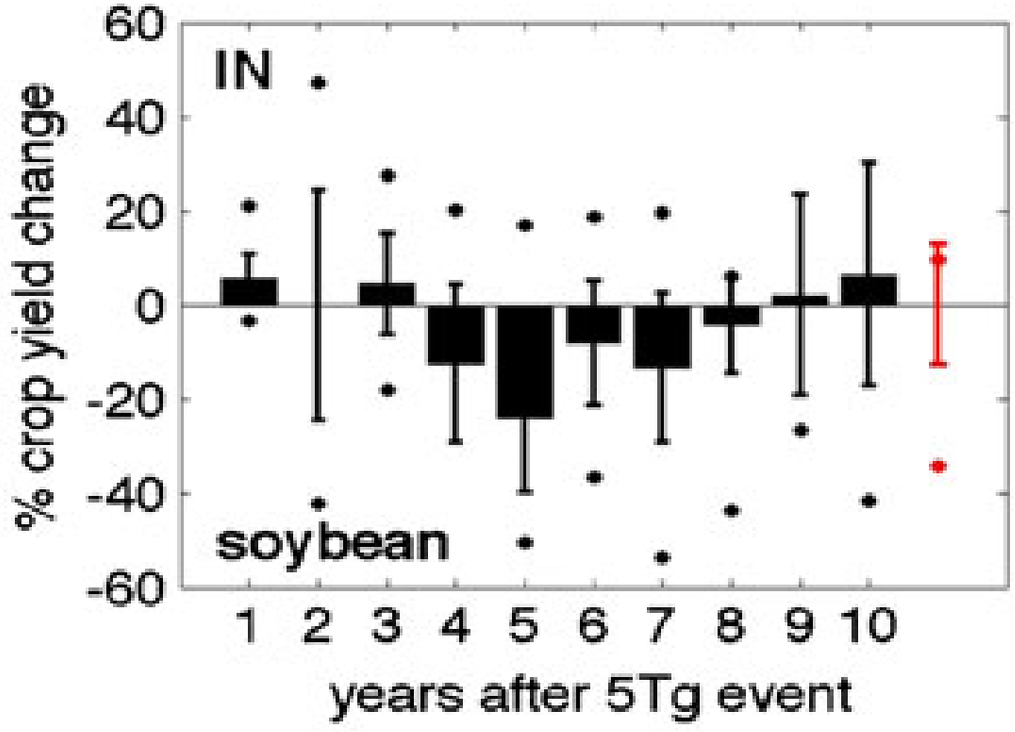
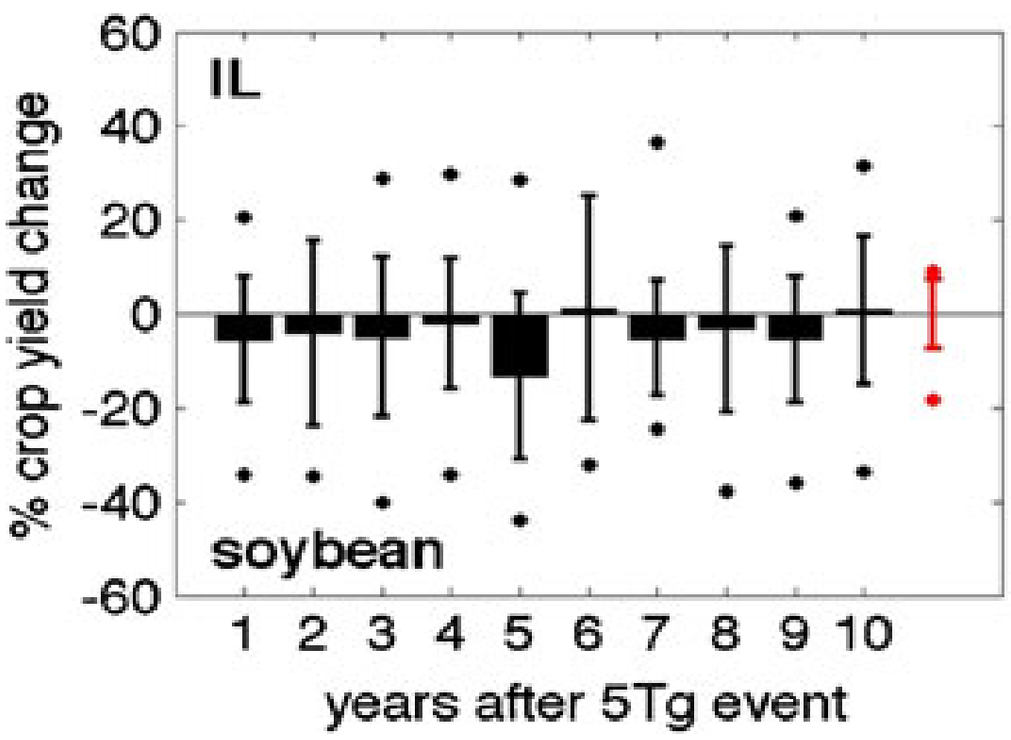
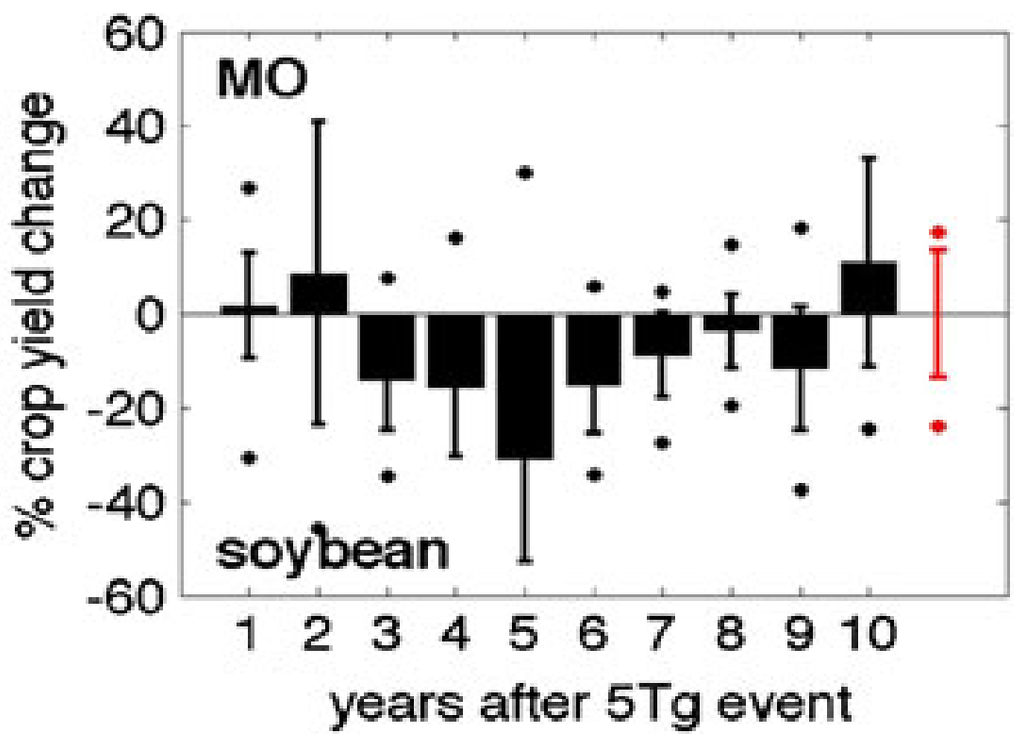
Özdoğan, M., A. Robock, and C. J. Kucharik (2012), Impacts of a nuclear war in South Asia on soybean and maize production in the Midwest United States, *Climatic Change*, *116*(2), 373–387, doi:10.1007/s10584-012-0518-1.

Change in US Midwest soybean yield









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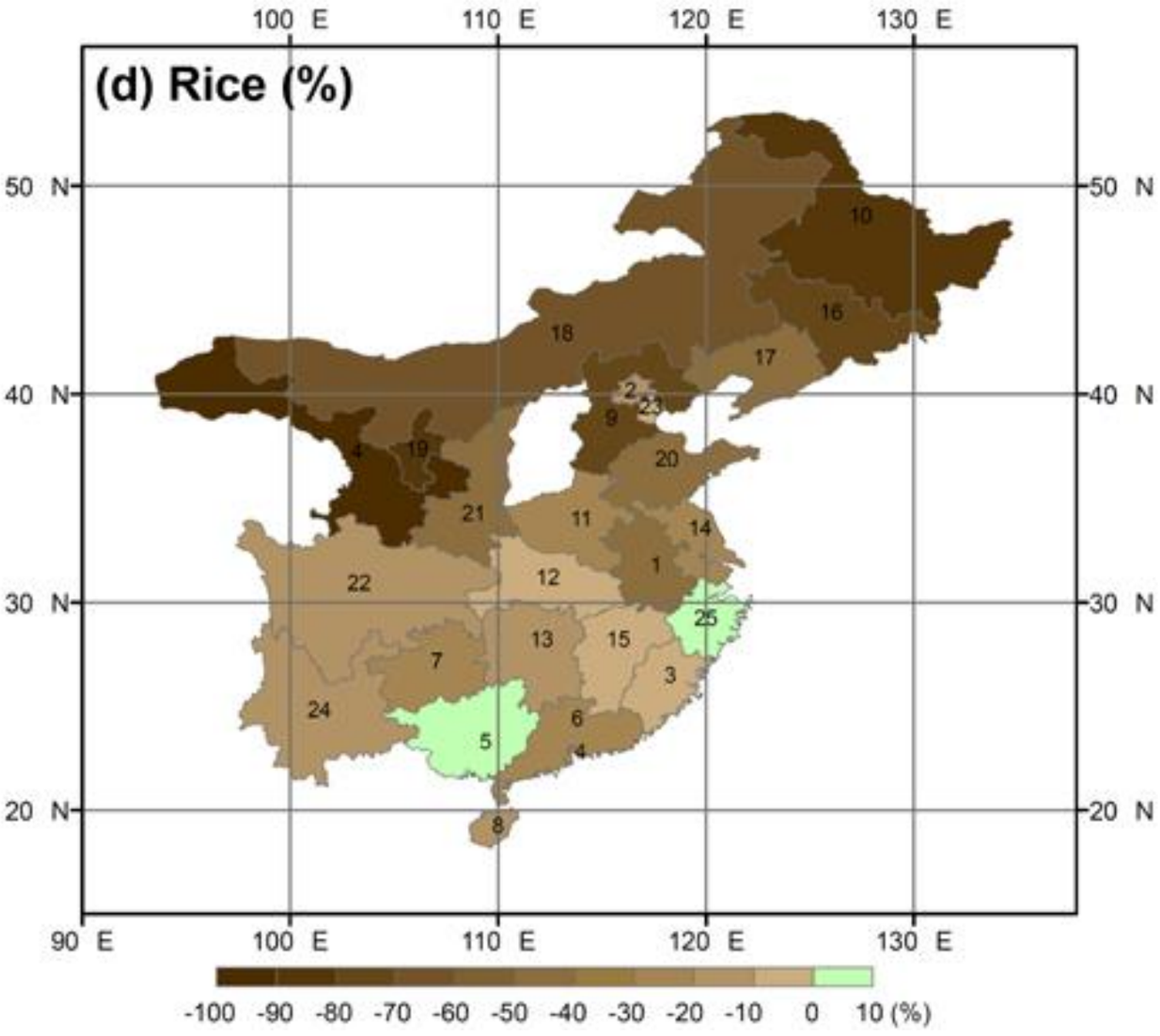
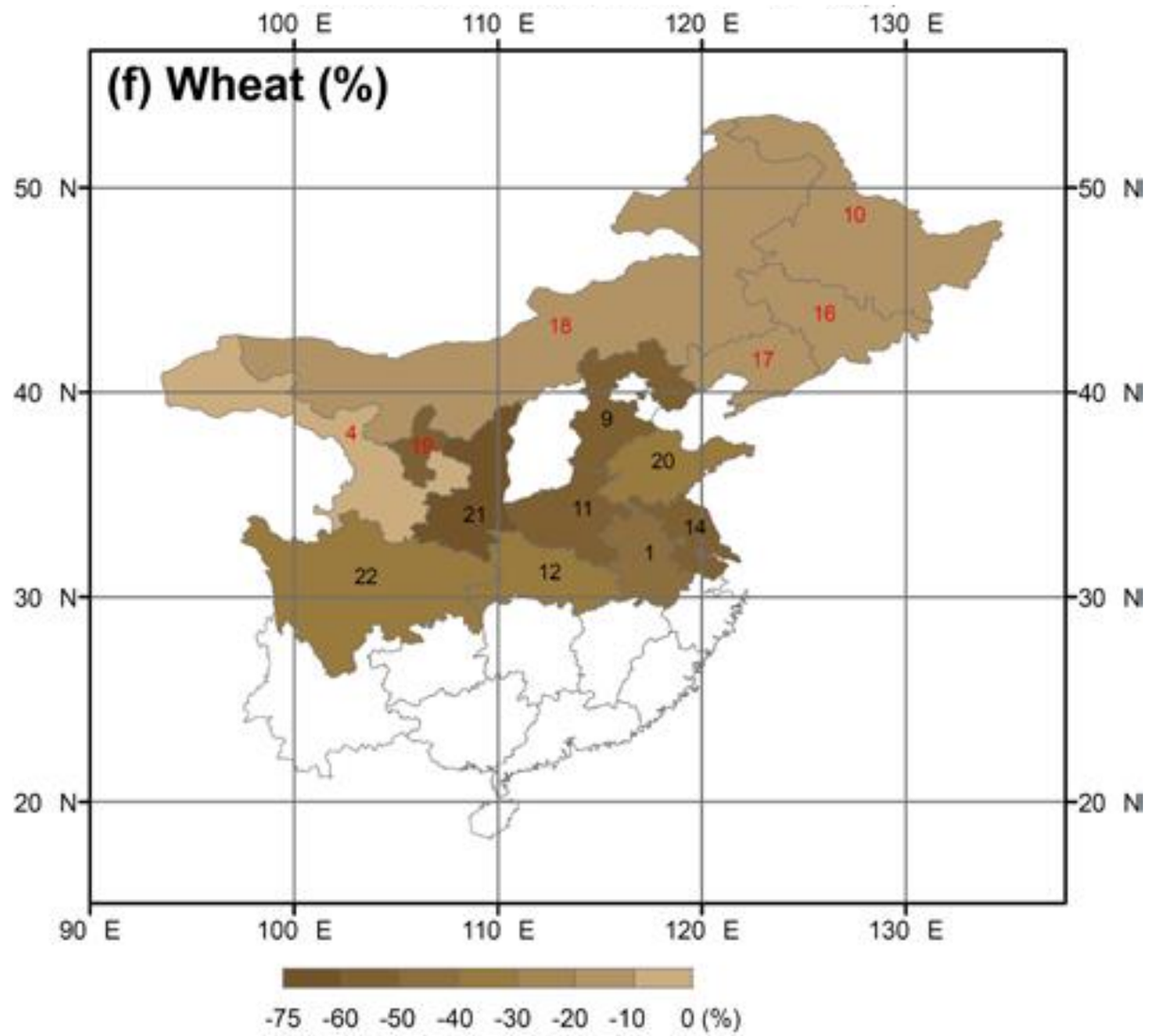
Change in China crop yield in year 1





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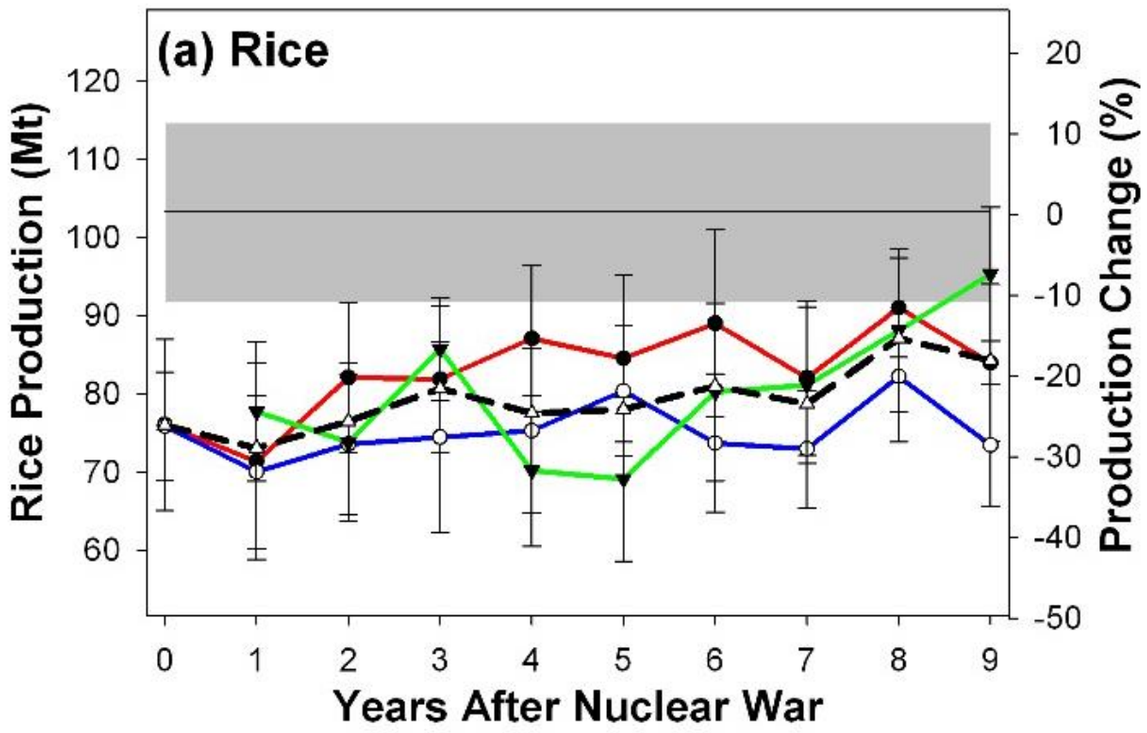
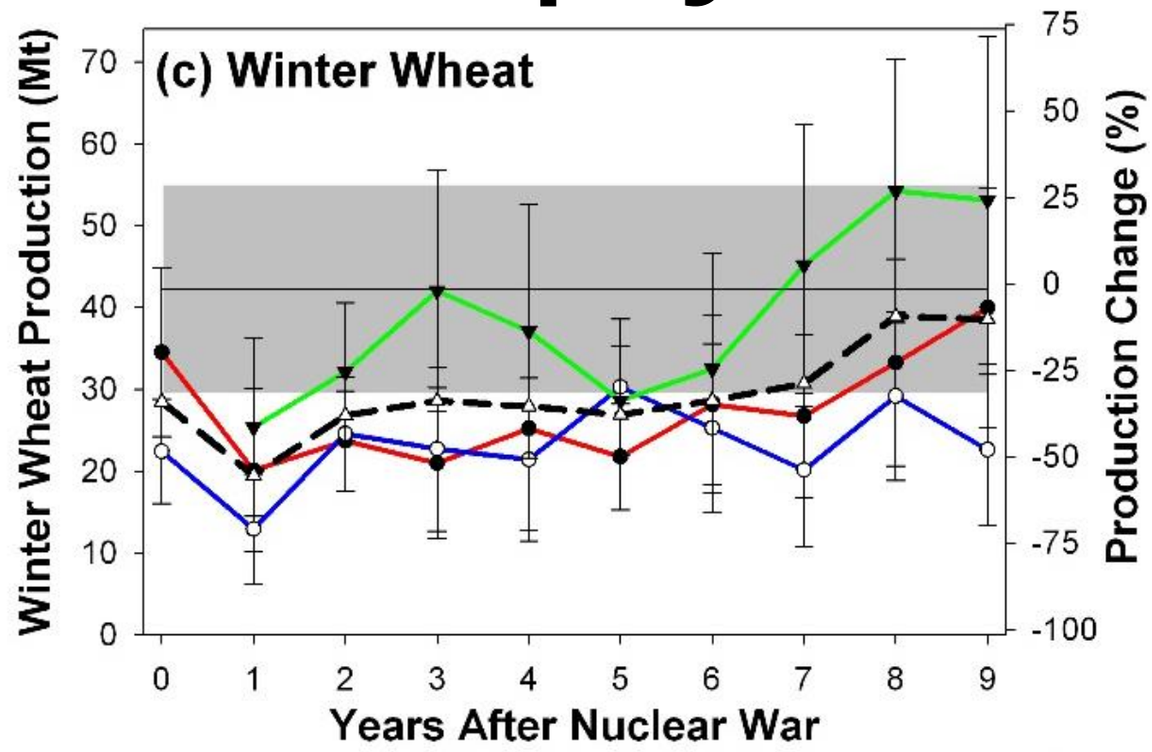
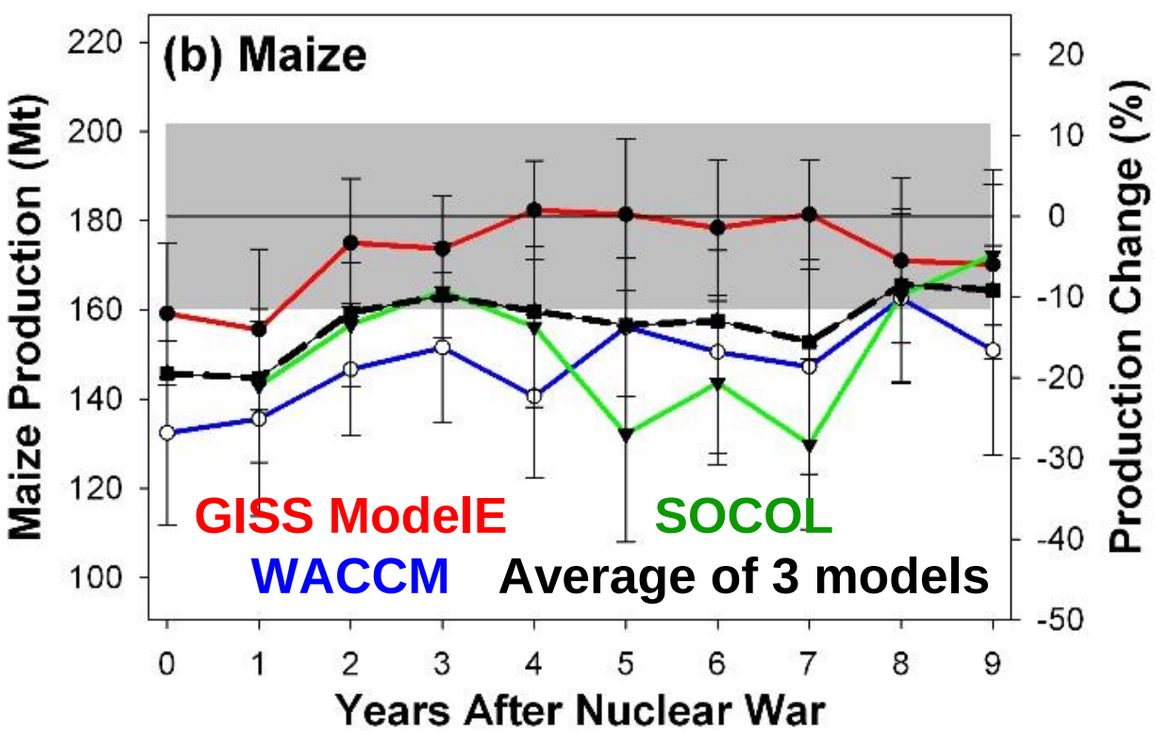
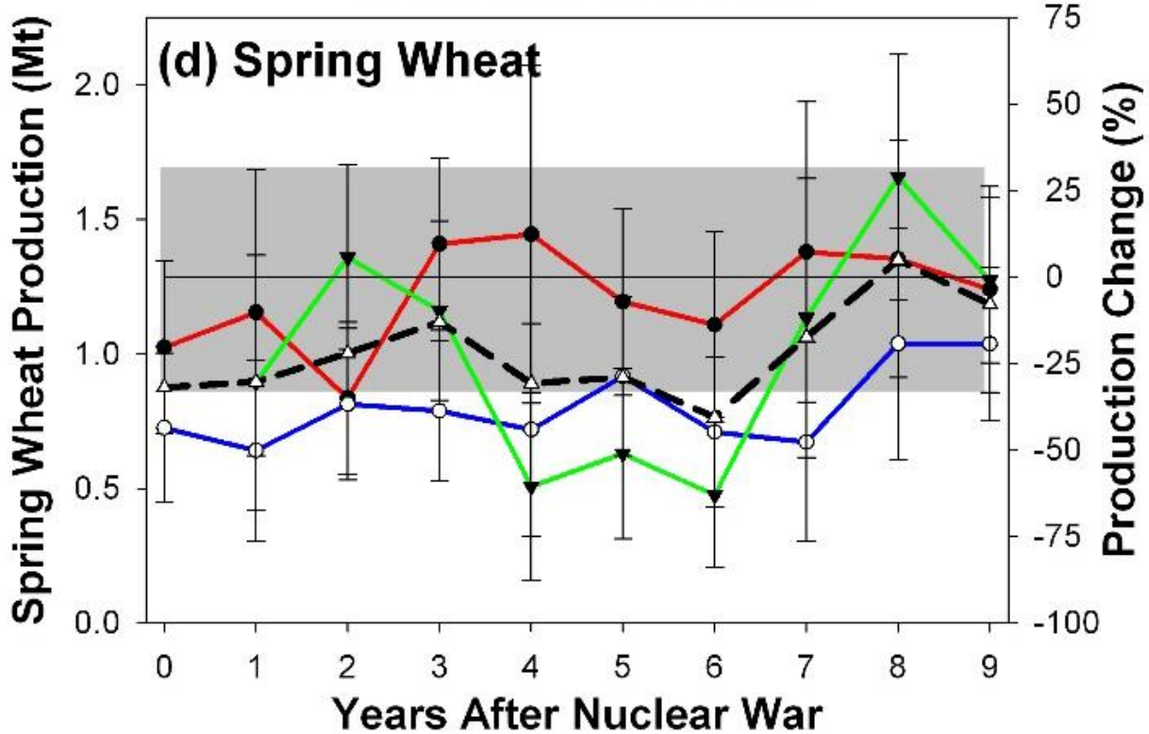
Xia, L., A. Robock, M. J. Mills, A. Stenke, and I. Helfand (2014), Global Famine after a Regional Nuclear War, submitted to *Earth's Future*, 2014.

Change in China crop yield









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