## Case

#### No impact to ocean acidification from AGW in this century – adaptation, resiliency and alt causes

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Recent laboratory experiments to investigate the variation in the coral calcification rate of the scleractinian coral *Siderastrea siderea* - an abundant reef-builder in the Caribbean Sea - with warming and changes in pH found that under a more-or less constant temperature of 28.C, calcification rates increased as atmospheric carbon dioxide was increased from near-pre-industrial levels of 324 ppm to 447 ppm, remained relatively unchanged at the predicted end-of-century value of 604 ppm and then returned to near-pre-industrial rates at 2500 ppm.105 It also found that while holding the carbon dioxide level at 488 ppm, calcification rates increased as the temperature increased from 25.C to 28.C, but it declined by 80% when temperature was increased to 32.C. These results suggest that rapid ocean warming will pose a threat to S. siderea in the longer term but that ocean acidification will be little or no threat for several centuries. Moreover, the experimentally determined calcification rates might have been adversely affected by the disruption to the coral due to the need to cut, transplant and prepare it for analysis. No less important is the fact that the changes in pH and temperature were imposed over a period of just a few months. In the real world such changes would occur over a century or more, which means some adaptation cannot be precluded, for example via symbiont shuffling.106¶ By far the largest peer-reviewed-analysis of the effect of ocean acidification upon marine life came to a strikingly unfashionable conclusion. Hendriks et al. studied the results of 372 experiments involving raised carbon dioxide levels on 44 species and found ‘limited experimental support’ for the theoretical predictions of negative impacts of ocean acidification. Marine organisms, they conclude, are ‘more resistant to ocean acidification than suggested by pessimistic predictions...’, and thus this phenomenon ‘may not be the widespread problem conjured into the 21st century’.107¶ Although some corals are growing more rapidly because of increases in calcification rates perhaps due to, rather than despite, higher sea surface temperatures108 and, possibly, higher carbon dioxide levels, in other areas they are being lost or degraded. The primary causes for the loss, however, are overfishing, pollution, coastal development, and dredging and blasting rather than manmade global warming. 109,110

#### No ocean acidification impact---their evidence assumes far higher CO2 levels than we’ll ever reach, adaptation solves, and research is systemically biased toward alarmism

Howard I. Browman 16, Institute of Marine Research, Marine Ecosystem Acoustics Disciplinary Group, Austevoll Research Station, Norway, “Applying organized scepticism to ocean acidification research,” *ICES Journal of Marine Science*, Volume 73, Number 3, February/March 2016, pp. 529-536

[OA = Ocean Acidification]

The first articles on OA were descriptions of the process itself (CO2-driven changes in the biogeochemistry of seawater and sediments) and its implications. This was followed by an explosion of work (mainly laboratory-based) on the possible effects of OA on various marine organisms, at first mainly calcifiers or the calcified hard parts of organisms without calcarious shells. These were mostly restricted to part of one generation (a limited number of life history stages), or at most a single complete life cycle, with one or a small number of biological endpoints measured as effect indicators. In early work, treatment exposure levels often greatly exceeded those predicted to occur hundreds of years into the future even without any reduction in CO2 emissions. The majority of these early works reported significant negative effects of high CO2, from which it was inferred that there would be a detrimental effect of OA over the coming decades–centuries. Thereafter, longer-term effect studies began to appear, which first included single-generation carry-overs and then multiple generations. By necessity, these have been on organisms with short generation times. As the approach to CO2 exposures matured, very high treatment levels became less common. More studies that showed no effect of high CO2 (predicted for the next century)—and even beneficial effects (e.g. for some phytoplankton and macrophytes)—appeared. Upwelling and vent systems were used as in situ case studies of natural future OA-like conditions. Some in situ work mimics such systems by injecting CO2 and following the response of organisms/communities locally. Results of experiments that included multiple stressors in addition to CO2 were published. The most common of these has been temperature, but salinity, oxygen, and a variety of others have also been included (in a global climate change context). Such studies typically report that the additional driver(s) has a stronger effect than CO2, although it is difficult to isolate the effect of the individual variables. The reality that the functional response curve of each driver will likely differ, as will the organism's ability to adapt to them, further complicates interpretations of multiple driver experiments. Studies on the effect of CO2 on trophic interactions (indirect effects) are sparse—such experiments are logistically complex and difficult to interpret. A small number of recent studies integrate the results of the preceding body of work into risk assessments and scenario modelling, typically on economically important species of fish and shellfish; most conclude that the prognosis is dire, although in the context of what follows, that conclusion might be premature.¶ The preceding describes how OA research has matured. The following describes how it still has a way to go.¶ Applying organized scepticism to research on the effects of OA¶ Scientific or academic scepticism calls for critical scrutiny of research outputs before they are accepted as new knowledge (Merton, 1973). Duarte et al. (2014) stated that “…there is a perception that scientific skepticism has been abandoned or relaxed in many areas…” of marine science. They argue that OA is one such area, and conclude that there is, at best, weak evidence to support an OA-driven decline of calcifiers. Below, I raise some of the aspects of OA research to which I contend an insufficient level of organized scepticism has been applied (in some cases, also to the articles in this theme issue). I arrived at that conclusion after reading hundreds of articles on OA (including, to be fair, some that also raise these issues) and overseeing the peer-review process for the very large number of submissions to this themed issue. Importantly, and as Duarte et al. (2014) make clear, a retrospective application of scientific scepticism such as the one that follows could—and should—be applied to any piece of/body of research.¶ Exposure levels, water chemistry, and limits to making inferences about the effect of a long-term driver from a short-term experiment¶ Many early studies on OA applied treatment levels that greatly exceeded even worst-case climate change scenarios and did not report water chemistry in sufficient detail to determine if the treatment mimicked future OA-driven seawater conditions. Although most recent work has improved with respect to treatment levels, mimicking future water chemistry remains tricky.¶ A rationale commonly used to justify high CO2/low pH treatments is the need to identify at what levels organisms are affected. However, the limits to making inferences about how an organism or ecosystem will respond to a climate-change scale variable (i.e. one that changes over decades–centuries) from their response during a short-term challenge experiment (i.e. hours–days–weeks) has not been adequately addressed—or even mentioned—in most studies. This is reflected in a confusion of terms common in OA studies—when describing the outcome of a short-term CO2 challenge, authors often make the inferential leap and use “OA” when discussing their results, without any caveats. Oddly, incorporation of the extensive toxicology literature is almost entirely missing from OA studies, either when it comes to adopting established exposure protocols or to framing the inferences that can/cannot be drawn from short-term experiments. Also missing from most studies is anything more than a superficial statement about the possibility for acclimation, adaptation, or evolution, something that is necessary to extend the outcome of a short-term challenge experiment into an inference about the effect of a long-term driver (see below).¶ Spatio-temporal variability in CO2 and pH¶ Biogeochemists are well aware of the spatio-temporal variability in CO2 and pH—daily (high productivity areas), seasonal (blooms), interannual (higher temperatures), horizontal (coastal upwelling areas, high turbidity zones), and vertical (deep vs. surface waters) ranges in these can be extensive (e.g. Wootton et al., 2008; Hofmann et al., 2011; Waldbusser and Salisbury, 2014; Kapsenberg et al., 2015). Biologists have struggled to incorporate this variability into experiments designed to test the effects of OA, and into their interpretations of the outcomes (Eriander et al., 2016). Some researchers have pointed out that organisms that are exposed to large ranges in CO2 and pH during their daily lives (e.g. vertical migrators), life cycles (e.g. organisms that reside offshore as larvae but move to the coast as juveniles or adults), or somewhere in their distributional ranges, should be more tolerant of OA (e.g. Lewis et al., 2013).¶ Imbalanced focus on individuals that are affected and insufficient focus on inter-individual variability and within-experiment selection bias interpretations of ecological impacts¶ Almost all CO2 challenge experiments produce a range of responses in the test organism—some individuals are badly affected, others less, and some not at all. There are several issues associated with all such experiments that it is important to be cognizant of and account for: (i) analyses and interpretations should not ignore or minimize individuals that are little affected or unaffected (after all, these are the ones whose genes will be passed on to the next generation); (ii) inter-individual variability should be highlighted; (iii) the longer that the experiment runs the more likely it is that an internal selection process for the tolerant individuals has occurred. All of these are important in the context of the next section.¶ Acclimation, generational carry-over effects, adaptation, epigenetics, and evolution¶ Almost all experiments conducted to assess OA are short-term toxicity challenges. Therefore, using them as the basis from which to make inferences about a process that will occur slowly over the next decades–centuries must be made with appropriate caution. That is, the experiments and the interpretations made from them must consider how populations might acclimatize, adapt, and evolve to climate change, including OA (e.g. Donelson et al., 2011; Hoffmann and Sgrò, 2011; Sunday et al., 2013; Harvey et al., 2014). Recent studies indicate that even the effects of OA that are considered most worrisome—various behavioural impairments resulting from short-term exposure to high CO2 (see Nagelkerken and Munday, 2016)—might be reduced or overcome through adaptation and evolution (Regan et al., 2016). More knowledge of the mechanisms of direct action of OA-related drivers—higher concentrations of CO2, hydrogen ions (=lower pH), and/or carbonate chemistry (less carbonate ions)—and of indirect drivers such as the effects of OA on food quality, are essential to understand what degree of adaption is possible. Readers should be duly sceptical of studies that completely ignore the possibility of adaptation when presenting their inferences about OA, particularly scenario modelling of socio-economic impacts.¶ We must also do better to incorporate analogous work in other fields, for example, rapid evolution of tolerance to envirotoxins (e.g. Whitehead et al., 2012) and environmental change (e.g. Collins et al., 2014; Stoks et al., 2015; Thibodeau et al., 2015) via a combination of genetic and epigenetic mechanisms (Yona et al., 2015).¶ Publication bias¶ Negative results—those that do not support a research hypothesis (e.g. OA will have detrimental effects on marine organisms)—can provide more balance for a subject area for which most published research reports positive results. Negative results can indicate that a subject area is not mature or clearly enough defined, or that our current methods and approaches are insufficient to produce a definitive result. Gould (1993) asserted that positive results tell more interesting stories than negative results and are, therefore, easier to write about and more interesting to read. He calls this a privileging of the positive. This privileging leads to a bias that acts against the propagation of negative results in the scholarly literature (see also Browman, 1999). Further, it is also important to recognize that studies showing no effect of OA are less equivocal than those that do, for all of the reasons noted above. Following from this, it is essential that authors writing about possible effects of OA present and discuss research that is inconsistent with their results and/or their interpretations—openly, honestly, and rigorously. Readers should be duly sceptical of articles that do not do this.

#### Ozone hole healing now.

National Geographic, 6/30/2016. “Remember the Ozone Hole? Now There's Proof It's Healing,” <http://news.nationalgeographic.com/2016/06/antarctic-ozone-hole-healing-fingerprints/>.

After three decades of observation, scientists have finally found the first fingerprints of healing in the notorious Southern Hemisphere ozone hole.

In 1974, Mario Molina and Sherwood Rowland, two chemists at the University of California, Irvine, published an article in Nature detailing the threats to the ozone layer from chlorofluorocarbon (CFC) gases. At the time, CFCs were commonly used in spray bottles and as coolants in many refrigerators, and they were rapidly accumulating in the atmosphere.

The groundbreaking research—for which they were awarded the 1995 Nobel Prize in chemistry—concluded that the atmosphere only had a “finite capacity for absorbing chlorine” atoms in the stratosphere.

After being widely attacked by the chemical industry, Molina and Rowland’s work was vindicated 11 years later, in 1985, when a team of English scientists realized the dire implications of their findings: the CFCs in the atmosphere had created a hole in the ozone layer. The loss of the protective ozone can lead to increased rates of skin cancer in humans and animals.

The Emergence of Healing

The research team, led by Susan Solomon, a professor of atmospheric chemistry and climate science at MIT, found multiple lines of evidence for the healing. The findings were published Thursday in Science.

The ozone hole forms every year over Antarctica, beginning in August and generally peaking in October. Solomon's team compared September ozone measurements, collected from balloon data and satellites, with statistical simulations that predict ozone.

Solomon’s team found that, in recent years, the hole is not eclipsing the 12-million-square-kilometer threshold until later in the southern spring, which indicates that the September hole is shrinking. In fact, the researchers believe the ozone hole has shrunk by more than 4 million square kilometers. Furthermore, the hole is not as deep as it used to be.

“The fact that the ozone hole is opening later is really the key here,” says Solomon. “It is opening later, it is smaller, and its depth is depleted. All of the measurements are independent, and when they all point to this [healing], it is hard to imagine any other explanation.”

The researchers also found that the observations matched model predictions, and that more than half the shrinkage could be traced to the reduction in atmospheric chlorine.

According to Donald Blake, a professor of chemistry at the University of California, Irvine, the research represents the most complete study of polar ozone to date.

Tackling the Problem

In the 1980s, ozone in the atmosphere dropped like a rock at the initial onset of the affliction. The implementation of the 1987 Montreal Protocol—widely considered a triumph of international cooperation—quickly phased out industrial CFCs, and the ozone layer stabilized, though it was still at a depleted level.

The size of the ozone hole varies from year to year, influenced by changes in meteorology and volcanism, which can make it difficult to identify a healing trend. Scientists believe it has remained relatively stable since the turn of the century, but the October 2015 hole was the largest on record.

Scientists have long thought the ozone layer was recovering slowly, but Solomon and her team—comprising researchers from MIT, the National Center for Atmospheric Research, and the University of Leeds—are the first to rigorously uncover evidence of the healing.

Though the size of the 2015 hole was unusual, Solomon attributes it largely to the April 2015 eruption of the Calbuco volcano in Chile. Though volcanoes do not spew chlorine molecules into the atmosphere, their contribution of small particles increases the number of polar stratospheric clouds that react with human-made chlorine.

Future Implications

These findings suggest that ozone healing is right on pace with the expected timeline. As Blake explained, this shows that the gases that affect ozone are decreasing in the atmosphere.

#### No impact to ozone depletion and it isn't anthropogenic - reject their evidence

Singer 10 Siegfried Fred Singer is an Austrian-born American physicist and emeritus professor of environmental science at the University of Virginia. " The Ozone-CFC Debacle: Hasty Action, Shaky Science," The Heartland Institute, Nov 30, http://heartland.org/policy-documents/ozone-cfc-debacle-hasty-action-shaky-science

Yet in spite of the hardships caused by the hasty phaseout of CFCs and other suspected ozone-depleting halocarbons, the EPA has never questioned the adequacy of the science that forms the basis for its phaseout policy. The facts are that the scientific underpinnings are quite shaky: the data are suspect; the statistical analyses are faulty; and the theory has not been validated (3,4). The science simply does not support this premature and abrupt removal of widely used chemicals -- at great cost to the economy. This fact seems finally to have been recognized by legislators; in early 1995, Republican Congressman from Texas, Tom Delay, introduced a bill, H.R. 475, to repeal the provisions in Title VI of the 1990 Clean Air Act regulating the production and use of CFCs.¶ If one examines the history of governmental CFC policy, one finds that it is based mainly on panicky reactions to press releases from EPA, National Aeronautics and Space Administration (NASA), and National Oceanographic and Atmospheric Administration (NOAA) about skin cancer and possible Arctic ozone holes -¬ stimulated and amplified by environmental pressure groups and the media ¬- rather than on published work that has withstood the scrutiny of scientific peers. Credence has been given to EPA "estimates" of millions of extra skin cancer deaths, to lurid stories about ozone depletion leading to blind sheep, to the travails of whales in the Antarctic, and to the worldwide disappearance of frogs and toads. It is perhaps characteristic of this topic that so many of the scary announcements have led off with some statement like: "The depletion of ozone is worse than expected" -¬ starting with the March 1988 press conference by the Ozone Trends Panel (5). Yet since "expectation" must be based on theory, the discrepancy with observations means, logically, that either the theory is wrong or the data are wrong, or both are wrong!¶ For the general public, and even for the trained scientist, these scientific controversies are difficult to sort out. It is indeed a multi-faceted problem, a chain with many links connecting the release of CFCs into the atmosphere with the occurrence of skin cancer. Briefly, the steps are postulated as follows (6):¶ 1. CFCs with lifetimes of decades and longer become well-mixed in the atmosphere, percolate into the stratosphere, and there release chlorine. ¶ 2. Chlorine, in its active form, can destroy ozone catalytically and thereby lower its total amount in the stratosphere. ¶ 3. A reduced level of ozone results in an increased level of solar ultraviolet radiation reaching the surface of the earth. ¶ 4. Exposure to increased UV leads to increases in skin cancer.¶ Each of these four steps is controversial, has not been sufficiently substantiated, and may even be incorrect (7,8). One can reasonably conclude that policy is rushing far ahead of the science.¶ Scientific Uncertainties and Controversies¶ It is generally agreed that natural sources of tropospheric chlorine (volcanoes, ocean spray, etc.) are four to five orders of magnitude larger than man-made sources (9). But it is what gets into the stratosphere that counts. The debate has degenerated into arguing about how much chlorine is rained out in the lower atmosphere (10) rather than measuring whether stratospheric chlorine is actually increasing. ¶ Contrary to the claims of some skeptics, CFCs do indeed reach the stratosphere; the secular increase of fluorine, in the form of HF, as reported by Belgian researcher R. Zander, may be sufficient proof (11,12). But as late as 1987, Zander found no long-term increase in HCl, suggesting that stratospheric chlorine comes mostly from natural sources, which are not expected to increase over time. The situation changed in 1991, however, when NASA scientist C. Rinsland published data showing HCl increasing at about half the rate of HF, suggesting both natural and man-made sources (13). Yet the Montreal Protocol to freeze CFC production and roll it back to lower levels was signed in 1987, at a time when published work still indicated little, if any, contribution from CFCs.¶ (Earlier aircraft-based observations of HCl increases between 1978 and 1982 by NCAR researchers Mankin and Coffey (14) were used to justify a CFC phaseout, even as late as 1993 (15,16), in spite of the fact that their data series was judged to be of poor quality and too short; according to MIT Professor Prinn, their published rate of increase of stratospheric chlorine could well be close to zero, in agreement with Zander's 1987 result (17). In any case, Mankin and Coffey themselves ascribe their observed 1982 increase to the volcano E1 Chichon (18) rather than to CFCs).¶ The question of global ozone depletion has been bedeviled by doubts about the quality of the data. Readings from Dobson ground observatories can be contaminated by long-term trends in SO2 pollution of the lower atmosphere. DeMuer and DeBacker have demonstrated that the Dobson ozone meter can misinterpret the downward trend of SO2 pollution, giving rise to a "fictitious" ozone trend (19). (Their finding was confirmed by a task group, chaired by Robert T. Watson, in a Joint Workshop of the IPCC and the International Ozone Assessment Panel in May 1993).¶ Another, quite separate problem is produced by the extreme noisiness of the ozone record. To establish the existence of a small, long-term trend it is necessary to eliminate the large natural variations, especially also those correlated with the 11-yr sunspot cycle. This is an impossible task given the shortness of the record and the virtual absence of data on long-term variations of the solar far-UV radiation that produces ozone in the upper atmosphere. The analysis fails a simple test: The "trend" is found to depend strongly on the choice of time interval (20). An additional problem in identifying a man-made trend arises from long-term trends in sunspot number, and therefore long-term ozone trends of natural origin (21).¶ Thus, the issue of whether the global ozone layer shows a steadily depleting trend is still controversial. Satellite data on global ozone content are not subject to interference from low-altitude pollution, but long-term calibration drift presents a problem; the TOMS data from satellites appear to have a calibration drift due to nonlinearities in the photomultiplier (22). In any case, the shortness of the record, 1979 to present, makes the solar-cycle correction problematic (23).¶ The Antarctic ozone "hole", an annual short-lived thinning of the layer first identified in 1985, is a genuine phenomenon whose intensity has increased markedly since about 1978. Its proximate cause is unquestionably stratospheric chlorine, but its fate may be controlled more by climate factors and the presence of particulates than by the concentration of chlorine itself (24); the hole may persist even if the chlorine level were to drop below the 1978 value. In any case, no theoretical predictions exist that can be tested by future observations.¶ Nor is the CFC-ozone theory itself in good shape. Over the years, its predictions for long-term, global ozone depletion have varied widely; during the early eighties the National Academy of Sciences published values that gradually decreased from 18% down to 3%. Since the discovery of the ozone hole, there have been no further quantitative predictions published because it was recognized that the existing theory could not cope with the heterogeneous destruction processes that depended more on particulate surface area than on the level of chlorine (25,26).¶ The theory could not describe ozone variations caused by the (heterogeneous) reactions on particulates (volcanic debris, aerosols, etc.) in the lower stratosphere and therefore was not able to predict the Antarctic ozone hole.. In the upper stratosphere, where only gas-phase (homogeneous) reactions take place, the theory predicts larger changes than are actually observed (27).¶ There is marked disagreement also among the satellite ozone data (28): In the upper stratosphere, trends seen by the SBUV instrument are negative, while SAGE I and II data show slightly positive trend values; in the lower stratosphere SAGE shows much larger decreases than SBW¬up to 3%-6%/yr in the equatorial region, a result that is difficult to explain from CFC theory.¶ In the lower stratosphere, recent model calculations and observations indicate that chlorine-based ozone destruction may be rate-limited by the amounts of OH and HO2 radicals (29,30). If borne out, then increasing stratospheric water vapor -¬ as a result of rising tropospheric methane from human activities, such as cattle raising and rice growing ¬- could play a significant role in ozone chemistry (31).¶ Concerns About Skin Cancer¶ The major public concern about a possible depletion of ozone comes from the fear that solar UV-B (280-320 nm) radiation reaching the surface will increase, typically by 10%. Yet UV-B intensity increases naturally by about 5000% between pole and equator; there is less ozone traversed when the sun is closer to the zenith (32). Hence a 10% increase at mid-latitudes translates into moving 60 miles (100 km) to the south, hardly a source for health concerns. ¶ There has been, of course, a determined search for a secular increase in UV-B to match the presumed depletion of ozone. But no such trends had been observed (33) until publication in November 1993 of a startling increasing trend, between 1989 and 1993, over Toronto, Canada (34). Close examination, however, revealed that this "smoking gun" was mostly smoke. The authors confused a short-lived increase at the end of their record with a long-term trend (35).¶ The driving force behind the policy to phase out CFCs has always been the fear of skin cancer, particularly malignant melanoma. The EPA has predicted 3 million additional skin cancer deaths by the year 2075 as a result of ozone depletion (36,37). But unlike basal and squamous cell skin cancers, which are easily cured growths caused by long-term exposure to UV-B, melanoma does not show the same characteristic increase towards lower latitudes (38) (Surprisingly, European data on melanoma incidence show a reverse latitude effect).¶ It is clear therefore that the rising incidence of melanoma over the past 50 yr cannot be due to any changes in the ozone layer. Non-melanoma (basal cell and squamous cell) skin cancers are clearly linked to chronic exposures to UV-B, as judged from the increasing incidence towards lower latitudes; melanoma exhibits a different epidemiology and often occurs on areas of the body not chronically exposed to the sun. Yet the clear link to solar exposure suggests that changes in lifestyle leading to greater exposure to the sun may be the main cause of melanoma.¶ A breakthrough in our understanding of the mechanism of melanoma induction came with the experiments of Dr. Richard Setlow and colleagues at the Brookhaven National Laboratory. To measure the action spectrum of UV radiation for melanoma induction, they exposed hybrids of the fish genus Xiphophorus to specific wavelengths in the UV-A and UV-B range. The animals had been back-cross bred to have only one tumor-suppressor gene; inactivation of this gene in a melanoblast or melanocyte then permits the melanoma to develop (39).. The experimenters found that the action spectrum (sensitivity per quantum) was reasonably flat across the UV-B and UV-A regions. Because of the much greater number of UV-A photons, they conclude that 90%-95% of melanomas are caused by UV-A (40).¶ But UV-A is not absorbed by ozone at all, and therefore melanoma rates would not be affected by changes in stratospheric ozone. This important finding undercuts one of the main reasons for the Montreal Protocol and all subsequent regulations (41).

#### Grid resilient

Douglas Birch 12, former foreign correspondent for the Associated Press and the Baltimore Sun who has written extensively on technology and public policy, "Forget Revolution," October 1, Foreign Policy, www.foreignpolicy.com/articles/2012/10/01/forget\_revolution?page=full

But are cyber attacks really a clear and present danger to society's critical life support systems, capable of inflicting thousands of casualties? Or has fear of full-blown cybergeddon at the hands of America's enemies become just another feverish national obsession -- another of the long, dark shadows of the 9/11 attacks? Worries about a large-scale, devastating cyber attack on the United States date back several decades, but escalated following attacks on Estonian government and media websites during a diplomatic conflict with Russia in 2007. That digital ambush was followed by a cyber attack on Georgian websites a year later in the run-up to the brief shooting war between Tbilisi and Moscow, as well as allegations of a colossal, ongoing cyber espionage campaign against the United States by hackers linked to the Chinese army. Much of the concern has focused on potential attacks on the U.S. electrical grid. "If I were an attacker and I wanted to do strategic damage to the United States...I probably would sack electric power on the U.S. East Coast, maybe the West Coast, and attempt to cause a cascading effect," retired Admiral Mike McConnell said in a 2010 interview with CBS's 60 Minutes. But the scenarios sketched out above are not solely the realm of fantasy. This summer, the United States and India were hit by two massive electrical outages -- caused not by ninja cyber assault teams but by force majeure. And, for most people anyway, the results were less terrifying than imagined. First, the freak "derecho" storm that barreled across a heavily-populated swath of the eastern United States on the afternoon of June 29 knocked down trees that crushed cars, bashed holes in roofs, blocked roads, and sliced through power lines. According to an August report by the U.S. Department of Energy, 4.2 million homes and businesses lost power as a result of the storm, with the blackout stretching across 11 states and the District of Columbia. More than 1 million customers were still without power five days later, and in some areas power wasn't restored for 10 days. Reuters put the death toll at 23 people as of July 5, all killed by storms or heat stroke. The second incident occurred in late July, when 670 million people in northern India, or about 10 percent of the world's population, lost power in the largest blackout in history. The failure of this huge chunk of India's electric grid was attributed to higher-than-normal demand due to late monsoon rains, which led farmers to use more electricity in order to draw water from wells. Indian officials told the media there were no reports of deaths directly linked to the blackouts. But this cataclysmic event didn't cause widespread chaos in India -- indeed, for some, it didn't even interrupt their daily routine. "[M]any people in major cities barely noticed the disruption because localized blackouts are so common that many businesses, hospitals, offices and middle-class homes have backup diesel generators," the New York Times reported. The most important thing about both events is what didn't happen. Planes didn't fall out of the sky. Governments didn't collapse. Thousands of people weren't killed. Despite disruption and delay, harried public officials, emergency workers, and beleaguered publics mostly muddled through. The summer's blackouts strongly suggest that a cyber weapon that took down an electric grid even for several days could turn out to be little more than a weapon of mass inconvenience. "Reasonable people would have expected a lot of bad things to happen" in the storm's aftermath, said Neal A. Pollard, a terrorism expert who teaches at Georgetown University and has served on the United Nation's Expert Working Group on the use of the Internet for terrorist purposes. However, he said, emergency services, hospitals, and air traffic control towers have backup systems to handle short-term disruptions in power supplies. After the derecho, Pollard noted, a generator truck even showed up in the parking lot of his supermarket. The response wasn't perfect, judging by the heat-related deaths and lengthy delays in the United States in restoring power. But nor were the people without power as helpless or clueless as is sometimes assumed. That doesn't mean the United States can relax. James Lewis, director of the technology program at the Center for Strategic and International Studies, believes that hackers threaten the security of U.S. utilities and industries, and recently penned an op-ed for the New York Times calling the United States "defenseless" to a cyber-assault. But he told Foreign Policy the recent derecho showed that even a large-scale blackout would not necessarily have catastrophic consequences. "That's a good example of what some kind of attacks would be like," he said. "You don't want to overestimate the risks. You don't want somebody to be able to do this whenever they felt like it, which is the situation now. But this is not the end of the world."

#### Grid collapse wouldn’t cause meltdowns.

Arthur T. Bradley 16, Ph.D in electrical engineering, works at NASA, Prepper’s Instruction Manual: 50 Steps to Prepare for any Disaster Would a Long-Term Blackout Mean Nuclear Meltdown? <http://thesurvivalmom.com/long-term-blackout-nuclear-meltdown/>

Worst-case power-loss scenario With backup systems to the backup systems, it would seem that there’s nothing to worry about, right? Under all but the direst of circumstances, I think that assessment is correct. However, one could imagine a scenario in which the grid was lost and the diesel generators ran out of fuel. Speaking of fuel, how much is actually stored onsite? It depends on the plant, but at the Watts Bar Nuclear Plant, for example, there is enough fuel to run the emergency diesel generators for at least 42 days. I say at least because it would depend on exactly what was being powered. Once the reactor was cooled down, a much smaller system, known as the Residual Heat Removal System, would be all that was required to keep the fuel assemblies cool, both in the reactor and the spent fuel rods pool. The generators and onsite fuel supply could power that smaller cooling system for significantly longer than if they were powering the larger reactor cooling system. Even if we assumed a worst case of 42 days, it’s hard to imagine a scenario in which that would not be enough time to bring in additional fuel either by land, water, or air. Nonetheless, let’s push the question a little further. What would happen in the unlikely event that the diesel fuel was exhausted? Even with the reactor having been successfully cooled, the biggest risk would continue to be overheating of the fuel rod assemblies, both in the reactor and the spent fuel rods pool. Without circulation, the heat from the fuel rod assemblies could boil the surrounding water, resulting in steam. In turn, the water levels would drop, ultimately exposing the fuel rods to air. Once exposed to air, their temperatures would rise but not to the levels that would melt the zirconium cladding. Thankfully, that means that meltdown would not occur. The steam might well carry radioactive contaminants into the air, but there would be no release of hydrogen and, thus, no subsequent explosions. The situation would certainly be dangerous to surrounding communities, but it wouldn’t be the nuclear Armageddon that many people worry about.

#### Extinction inevitable independent of nukes—accidental and deliberate misuse of nanotech, AI and superintelligence, genetically engineered diseases, future tech development

Bruce **Sterling**, 6-1-20**18**, "When Nick Bostrom says “Bang”," WIRED, https://www.wired.com/beyond-the-beyond/2018/06/nick-bostrom-says-bang/

This is the most obvious kind of existential risk. It is conceptually easy to understand. Below are some possible ways for the world to end in a bang.[8] I have tried to rank them roughly in order of how probable they are, in my estimation, to cause the extinction of Earth-originating intelligent life; but my intention with the ordering is more to provide a basis for further discussion than to make any firm assertions. 4.1 Deliberate misuse of nanotechnology In a mature form, molecular nanotechnology will enable the construction of bacterium-scale self-replicating mechanical robots that can feed on dirt or other organic matter [22-25]. Such replicators could eat up the biosphere or destroy it by other means such as by poisoning it, burning it, or blocking out sunlight. A person of malicious intent in possession of this technology might cause the extinction of intelligent life on Earth by releasing such nanobots into the environment.[9] The technology to produce a destructive nanobot seems considerably easier to develop than the technology to create an effective defense against such an attack (a global nanotech immune system, an “active shield” [23]). It is therefore likely that there will be a period of vulnerability during which this technology must be prevented from coming into the wrong hands. Yet the technology could prove hard to regulate, since it doesn’t require rare radioactive isotopes or large, easily identifiable manufacturing plants, as does production of nuclear weapons [23]. Even if effective defenses against a limited nanotech attack are developed before dangerous replicators are designed and acquired by suicidal regimes or terrorists, there will still be the danger of an arms race between states possessing nanotechnology. It has been argued [26] that molecular manufacturing would lead to both arms race instability and crisis instability, to a higher degree than was the case with nuclear weapons. Arms race instability means that there would be dominant incentives for each competitor to escalate its armaments, leading to a runaway arms race. Crisis instability means that there would be dominant incentives for striking first. Two roughly balanced rivals acquiring nanotechnology would, on this view, begin a massive buildup of armaments and weapons development programs that would continue until a crisis occurs and war breaks out, potentially causing global terminal destruction. That the arms race could have been predicted is no guarantee that an international security system will be created ahead of time to prevent this disaster from happening. The nuclear arms race between the US and the USSR was predicted but occurred nevertheless. 4.2 Nuclear holocaust The US and Russia still have huge stockpiles of nuclear weapons. But would an all-out nuclear war really exterminate humankind? Note that: (i) For there to be an existential risk it suffices that we can’t be sure that it wouldn’t. (ii) The climatic effects of a large nuclear war are not well known (there is the possibility of a nuclear winter). (iii) Future arms races between other nations cannot be ruled out and these could lead to even greater arsenals than those present at the height of the Cold War. The world’s supply of plutonium has been increasing steadily to about two thousand tons, some ten times as much as remains tied up in warheads ([9], p. 26). (iv) Even if some humans survive the short-term effects of a nuclear war, it could lead to the collapse of civilization. A human race living under stone-age conditions may or may not be more resilient to extinction than other animal species. 4.3 We’re living in a simulation and it gets shut down A case can be made that the hypothesis that we are living in a computer simulation should be given a significant probability [27]. The basic idea behind this so-called “Simulation argument” is that vast amounts of computing power may become available in the future (see e.g. [28,29]), and that it could be used, among other things, to run large numbers of fine-grained simulations of past human civilizations. Under some not-too-implausible assumptions, the result can be that almost all minds like ours are simulated minds, and that we should therefore assign a significant probability to being such computer-emulated minds rather than the (subjectively indistinguishable) minds of originally evolved creatures. And if we are, we suffer the risk that the simulation may be shut down at any time. A decision to terminate our simulation may be prompted by our actions or by exogenous factors. While to some it may seem frivolous to list such a radical or “philosophical” hypothesis next the concrete threat of nuclear holocaust, we must seek to base these evaluations on reasons rather than untutored intuition. Until a refutation appears of the argument presented in [27], it would intellectually dishonest to neglect to mention simulation-shutdown as a potential extinction mode. 4.4 Badly programmed superintelligence When we create the first superintelligent entity [28-34], we might make a mistake and give it goals that lead it to annihilate humankind, assuming its enormous intellectual advantage gives it the power to do so. For example, we could mistakenly elevate a subgoal to the status of a supergoal. We tell it to solve a mathematical problem, and it complies by turning all the matter in the solar system into a giant calculating device, in the process killing the person who asked the question. (For further analysis of this, see [35].) 4.5 Genetically engineered biological agent With the fabulous advances in genetic technology currently taking place, it may become possible for a tyrant, terrorist, or lunatic to create a doomsday virus, an organism that combines long latency with high virulence and mortality [36]. Dangerous viruses can even be spawned unintentionally, as Australian researchers recently demonstrated when they created a modified mousepox virus with 100% mortality while trying to design a contraceptive virus for mice for use in pest control [37]. While this particular virus doesn’t affect humans, it is suspected that an analogous alteration would increase the mortality of the human smallpox virus. What underscores the future hazard here is that the research was quickly published in the open scientific literature [38]. It is hard to see how information generated in open biotech research programs could be contained no matter how grave the potential danger that it poses; and the same holds for research in nanotechnology. Genetic medicine will also lead to better cures and vaccines, but there is no guarantee that defense will always keep pace with offense. (Even the accidentally created mousepox virus had a 50% mortality rate on vaccinated mice.) Eventually, worry about biological weapons may be put to rest through the development of nanomedicine, but while nanotechnology has enormous long-term potential for medicine [39] it carries its own hazards. 4.6 Accidental misuse of nanotechnology (“gray goo”) The possibility of accidents can never be completely ruled out. However, there are many ways of making sure, through responsible engineering practices, that species-destroying accidents do not occur. One could avoid using self-replication; one could make nanobots dependent on some rare feedstock chemical that doesn’t exist in the wild; one could confine them to sealed environments; one could design them in such a way that any mutation was overwhelmingly likely to cause a nanobot to completely cease to function [40]. Accidental misuse is therefore a smaller concern than malicious misuse [23,25,41]. However, the distinction between the accidental and the deliberate can become blurred. While “in principle” it seems possible to make terminal nanotechnological accidents extremely improbable, the actual circumstances may not permit this ideal level of security to be realized. Compare nanotechnology with nuclear technology. From an engineering perspective, it is of course perfectly possible to use nuclear technology only for peaceful purposes such as nuclear reactors, which have a zero chance of destroying the whole planet. Yet in practice it may be very hard to avoid nuclear technology also being used to build nuclear weapons, leading to an arms race. With large nuclear arsenals on hair-trigger alert, there is inevitably a significant risk of accidental war. The same can happen with nanotechnology: it may be pressed into serving military objectives in a way that carries unavoidable risks of serious accidents. In some situations it can even be strategically advantageous to deliberately make one’s technology or control systems risky, for example in order to make a “threat that leaves something to chance” [42]. 4.7 Something unforeseen We need a catch-all category. It would be foolish to be confident that we have already imagined and anticipated all significant risks. Future technological or scientific developments may very well reveal novel ways of destroying the world. Some foreseen hazards (hence not members of the current category) which have been excluded from the list of bangs on grounds that they seem too unlikely to cause a global terminal disaster are: solar flares, supernovae, black hole explosions or mergers, gamma-ray bursts, galactic center outbursts, supervolcanos, loss of biodiversity, buildup of air pollution, gradual loss of human fertility, and various religious doomsday scenarios. The hypothesis that we will one day become “illuminated” and commit collective suicide or stop reproducing, as supporters of VHEMT (The Voluntary Human Extinction Movement) hope [43], appears unlikely. If it really were better not to exist (as Silenus told king Midas in the Greek myth, and as Arthur Schopenhauer argued [44] although for reasons specific to his philosophical system he didn’t advocate suicide), then we should not count this scenario as an existential disaster. The assumption that it is not worse to be alive should be regarded as an implicit assumption in the definition of Bangs. Erroneous collective suicide is an existential risk albeit one whose probability seems extremely slight. (For more on the ethics of human extinction, see chapter 4 of [9].) 4.8 Physics disasters The Manhattan Project bomb-builders’ concern about an A-bomb-derived atmospheric conflagration has contemporary analogues. There have been speculations that future high-energy particle accelerator experiments may cause a breakdown of a metastable vacuum state that our part of the cosmos might be in, converting it into a “true” vacuum of lower energy density [45]. This would result in an expanding bubble of total destruction that would sweep through the galaxy and beyond at the speed of light, tearing all matter apart as it proceeds. Another conceivability is that accelerator experiments might produce negatively charged stable “strangelets” (a hypothetical form of nuclear matter) or create a mini black hole that would sink to the center of the Earth and start accreting the rest of the planet [46]. These outcomes seem to be impossible given our best current physical theories. But the reason we do the experiments is precisely that we don’t really know what will happen. A more reassuring argument is that the energy densities attained in present day accelerators are far lower than those that occur naturally in collisions between cosmic rays [46,47]. It’s possible, however, that factors other than energy density are relevant for these hypothetical processes, and that those factors will be brought together in novel ways in future experiments. The main reason for concern in the “physics disasters” category is the meta-level observation that discoveries of all sorts of weird physical phenomena are made all the time, so even if right now all the particular physics disasters we have conceived of were absurdly improbable or impossible, there could be other more realistic failure-modes waiting to be uncovered. The ones listed here are merely illustrations of the general case.

#### Nuclear war won’t lead to extinction, but it will provide a smooth transition to a low tech society---that solves our impacts AND is the only way to transition to a degrowth society – otherwise warming inevitably causes extinction

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We’ve tied ourselves in a perfect Gordian knot. The global economy is a vast machine, operating beyond the control of even the most powerful individuals, and it has a will of its own to consume and pollute. It’s hard to believe that this massive metal beast will be peacefully undone by the people who survive by it, and we all survive by it in some way, often against our wills; it bribes and entraps us all in ways large and small. But a wrench could clog the gears, and maybe only a wrench can stop it. One wrench that could slow climate disruption may be a large-scale conflict that halts the global economy, destroys fossil fuel infrastructure, and throws particulates in the air. At this point, with insane people like Trump, Putin, Xi, May, and Macron leading the world’s biggest nuclear powers, large-scale conflagration between them would probably lead to a nuclear exchange. Nobody wants nuclear war. Rather, nobody sane and prosocial wants nuclear war. It is an absolute horror that would burn and maim millions of living beings, despoil millions of hectares, and scar the skin of the earth and dome of the sky for centuries, maybe millennia. With proxy conflict brewing between the US and Russia in the Middle East and the Thucydides trap ready to ensnare us with an ascendant China, nuclear war looks like a more realistic possibility than it has since the 1980s. A devastating fact of climate collapse is that there may be a silver lining to the mushroom cloud. First, it should be noted that a nuclear exchange does not inevitably result in apocalyptic loss of life. Nuclear winter—the idea that firestorms would make the earth uninhabitable—is based on shaky science. There’s no reliable model that can determine how many megatons would decimate agriculture or make humans extinct. Nations have already detonated 2,476 nuclear devices. An exchange that shuts down the global economy but stops short of human extinction may be the only blade realistically likely to cut the carbon knot we’re trapped within. It would decimate existing infrastructures, providing an opportunity to build new energy infrastructure and intervene in the current investments and subsidies keeping fossil fuels alive. In the near term, emissions would almost certainly rise as militaries are some of the world’s largest emitters. Given what we know of human history, though, conflict may be the only way to build the mass social cohesion necessary for undertaking the kind of huge, collective action needed for global sequestration and energy transition. Like the 20th century’s world wars, a nuclear exchange could serve as an economic leveler. It could provide justification for nationalizing energy industries with the interest of shuttering fossil fuel plants and transitioning to renewables and, uh, nuclear energy. It could shock us into reimagining a less suicidal civilization, one that dethrones the death-cult zealots who are currently in power. And it may toss particulates into the atmosphere sufficient to block out some of the solar heat helping to drive global warming. Or it may have the opposite effects. Who knows? What we do know is that humans can survive and recover from war, probably even a nuclear one. Humans cannot recover from runaway climate change. Nuclear war is not an inevitable extinction event; six degrees of warming is. Given that mostly violent, psychopathic individuals manage the governments and industries of the world, it may only be possible for anti-social collective action—that is, war—to halt, or at least slow, our inexorable march toward oblivion. A courageous, benevolent ruler might compel vast numbers of people to collective action. But we have too few of those, and the legal, political, and military barriers preventing them from rising are immense. Our current crop of villainous presidents, prime ministers, and CEOs, whether lusting for chaos or pursuing their own petty ends, may inadvertently conspire to break the machine now preventing our future. When so bereft of heroes, we may need to rely on humanity’s antagonists and their petty incompetence to accidentally save the day. It is a stark reflection of how homicidal our economy is—and our collective adherence to its whims—that nuclear war could be a rational course of action.

#### Proponents of nuclear winter fail in applying their theory to modern atmospheric catastrophes – Most particles stay below the stratosphere and rainout checks any anomalies

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In the 1980s, the concept of nuclear winter shocked the world. By that time, the Socialist bloc and the West were on the brink of a military conflict, with U.S. Pershing missiles deployed in Europe, able to reach Moscow in 8-10 minutes. News of a possible nuclear winter added to the global sense of fear. This led to changes. In 1985, Mikhail Gorbachev and Ronald Reagan stated after their first summit in Geneva: “a nuclear war cannot be won and must never be fought.'' In less than a decade, the Cold War was over and the possibility of a nuclear war between Russia and the U.S. became far less likely. But since that time the question remains – was the nuclear winter concept accurate? Several scientists heavily criticized the research conducted by Sagan, Golitsyn and Moiseyev as faulty and questionable. “The computer models were so **simplified**, and the data on smoke and other aerosols were so poor that **scientists could not say anything for certain,”** the American Institute of Physics noted in 2011. Furthermore, the consequences of the First Gulf War (1990-1991) weakened Sagan’s position in the U.S. He predicted that the raging fires from the oil wells would result in an effect similar to nuclear winter, with global temperatures decreasing by several degrees, probably causing a “year without summer,” like the infamous one in 1816. **None of this happened, however**. “I always considered ‘nuclear winter’ to be **a hoax and scientifically incorrect**,” said Dr. S. Fred Singer, Sagan’s chief opponent, after those events in the early 1990s. In Russia, the nuclear winter hypothesis is also disputed. For instance, Sergey Utyuzhnikov from the Moscow Institute of Physics and Technology, in his 2001 article, Simulation of Pollution Spread over Conflagrations in the Atmosphere, stated that **most soot and dust will stay in the lower atmosphere** without reaching the stratosphere. “**The impurities are washed away by rains without having any serious impact on the climate**,” Utyuzhnikov says, denouncing the nuclear winter hypothesis.

#### Nuke war won’t cause extinction---BUT, it’ll solve all future wars – that avoids all our impacts

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Although nuclear war is the oldest of these technogenic threats to civilization and human survival, and although important steps to restraint, particularly at the end of the Cold War, have been achieved, the nuclear world is increasingly changing in major ways, and in almost entirely dangerous directions. The third “bombs away” phase of the great debate on the nuclear-political question is more consequentially divided than in the first two phases. Even more ominously, most of the momentum lies with the forces that are pulling states toward nuclear-use, and with the radical actors bent on inflicting catastrophic damage on the leading states in the international system, particularly the United States. In contrast, the arms control project, although intellectually vibrant, is largely in retreat on the world political stage. The arms control settlement of the Cold War is unraveling, and the world public is more divided and distracted than ever. With the recent election of President Donald Trump, the United States, which has played such a dominant role in nuclear politics since its scientists invented these fiendish engines, now has an impulsive and uninformed leader, boding ill for nuclear restraint and effective crisis management. Given current trends, it is prudent to assume that sooner or later, and probably sooner, nuclear weapons will again be the used in war. But this bad news may contain a “silver lining” of good news. Unlike a general nuclear war that might have occurred during the Cold War, such a nuclear event now would probably not mark the end of civilization (or of humanity), due to the great reductions in nuclear forces achieved at the end of the Cold War. Furthermore, politics on “the day after” could have immense potential for positive change. The survivors would not be likely to envy the dead, but would surely have a greatly renewed resolution for “never again.” Such an event, completely unpredictable in its particulars, would unambiguously put the nuclear-political question back at the top of the world political agenda. It would unmistakeably remind leading states of their vulnerability It might also trigger more robust efforts to achieve the global regulation of nuclear capability. Like the bombings of Hiroshima and Nagasaki that did so much to catalyze the elevated concern for nuclear security in the early Cold War, and like the experience “at the brink” in the Cuban Missile Crisis of 1962, the now bubbling nuclear caldron holds the possibility of inaugurating a major period of institutional innovation and adjustment toward a fully “bombs away” future.

#### Isolated island populations repopulate Earth after radiation and nuclear winter – Bunkers and submarines expand the likelihood of survival

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Different types of possible catastrophes suggest different scenarios for how survival could happen on an island. What is important is that the island should have properties which protect against the specific dangers of particular global catastrophic risks. Specifically, different islands will provide protection against different risks, and their natural diversity will contribute to a higher total level of protection: **Quarantined island survives pandemic**. An island could impose effective quarantine if it is sufficiently remote and simultaneously able to protect itself, possibly using military ships and air defense. **Far northern aboriginal people survive an ice age**. Many far northern people have adapted to survive in extremely cold and dangerous environments, and under the right circumstances could potentially survive the return of an ice age. However, their cultures are endangered by globalization. If these people become dependent on the products of modern civilization, such as rifles and motor boats, and lose their native survival skills, then their likelihood of surviving the collapse of the outside world would decrease. Therefore, preservation of their survival skills may be important as a defense against the risks connected with **extreme cooling**. Remote polar island with high mountains survives brief global warming of median surface temperatures, up to 50˚C. There is a theory that the climates of planets similar to the Earth could have several semi-stable temperature levels (Popp et al., 2016). If so, because of climate change, the Earth could transition to a second semi-stable state with a median global temperature of around 330 K, about 60˚C, or about 45˚C above current global mean temperatures. But even in this climate, **some regions of Earth could still be survivable for humans**, such as the Himalayan plateau at elevations above 4,000 m, but below 6,000 (where oxygen deficiency becomes a problem), or on polar islands with mountains (however, global warming affects polar regions more than equatorial regions, and northern island will experience more effects of climate change, including thawing permafrost and possible landslides because of wetter weather). In the tropics, the combination of increased humidity and temperature may increase the wet bulb temperature above 36˚C, especially on islands, where sea moisture is readily available. In such conditions, proper human perspiration becomes impossible (Sherwood and Huber, 2010), and there will likely be increased mortality and morbidity because of tropical diseases. If temperatures later returned to normal – either naturally or through climate engineering – **the rest of the Earth could be repopulated**. ‘‘Swiss Family Robinsons’’ survive on a tropical island, unnoticed by a military robot ‘‘mutiny’’. Most AI researchers ignore medium-term AI risks, which are neither near-term risks, like unemployment, nor remote risks, like AI superintelligence. But a large drone army – if one were produced – could receive a wrong command or be infected by a computer virus, leading it to attack people indiscriminately. Remote islands without robots could provide protection in this case, allowing survival until such a drone army ran out of batteries, fuel, ammunition or other supplies: Primitive tribe survives civilizational collapse. The inhabitants of **North Sentinel Island**, near the Andaman Islands in the Indian Ocean, are hostile and uncontacted. **The Sentinelese survived the 2004 Indian Ocean tsunami apparently unaffected** (Voanews, 2009), and if the rest of humanity disappear, **they might well continue their existence without change.** Tropical Island survives extreme global nuclear winter and glaciation event. Were a **nuclear**, bolide impactor or volcanic “**winter**” scenario to unfold, these islands would remain surrounded by Warm Ocean, and local volcanism or other energy sources might provide heat, energy and food. Such island refuges may have helped life on Earth survive during the **“Snowball Earth”** event in Earth’s distant past (Hoffman et al., 1998). Remote island base for project “Yellow submarine”. Some catastrophic risks such as a gamma ray burst, a global nuclear war with high radiological contamination or multiple pandemics might be best survived **underwater in nuclear submarines** (Turchin and Green, 2017). However, after a catastrophe, the submarine with survivors would eventually need a place to dock, and an island with some prepared amenities would be a reasonable starting point for rebuilding civilization. Bunker on remote island. For risks which include multiple or complex catastrophes, such as a bolide impact, extreme volcanism, tsunamis, multiple pandemics and nuclear war with radiological contamination, **island refuges could be strengthened with bunkers**. Richard Branson survived hurricane Irma on his own island in 2017 by seeking refuge in his concrete wine cellar (Clifford, 2017). Bunkers on islands would have higher survivability compared to those close to population centers, as they will be neither a military target nor as accessible to looters or unintentionally dangerous (e.g. infected) refugees. These bunkers could potentially be connected to water sources by underwater pipes, and passages could provide cooling, access and even oxygen and food sources.

#### Hydrophilic black carbon would adhere to atmospheric precipitation – Results in a rainout effect that quickly reverses nuclear cooling

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\*BC = Black Carbon

The no-rubble simulation produces a significantly more intense fire, with more fire spread, and consequently a significantly stronger plume with larger amounts of BC reaching into the upper atmosphere than the simulation with rubble, illustrated in Figure 5. While the no-rubble simulation **represents the worst-case scenario** involving vigorous fire activity, **only a relatively small amount of carbon makes its way into the stratosphere** during the course of the simulation. But while small compared to the surface BC mass, stratospheric BC amounts from the current simulations are significantly higher than what would be expected from burning vegetation such as trees (Heilman et al., 2014), e.g., the higher energy density of the building fuels and the initial fluence from the weapon produce an intense response within HIGRAD with initial updrafts of order 100 m/s in the lower troposphere. Or, in comparison to a mass fire, wildfires will burn only a small amount of fuel in the corresponding time period (roughly 10 minutes) that a nuclear weapon fluence can effectively ignite a large area of fuel producing an impressive atmospheric response. Figure 6 shows vertical profiles of BC multiplied by 100 (number of cities involved in the exchange) from the two simulations. The total amount of BC produced is in line with previous estimates (about 3.69 Tg from no-rubble simulation); however, the majority of BC resides **below the stratosphere** (3.46 Tg below 12 km) and can be **readily impacted by scavenging from precipitation** either via pyro-cumulonimbus produced by the fire itself (not modeled) or other synoptic weather systems. While the impact on climate of these more realistic profiles will be explored in the next section, it should be mentioned that **these estimates are** still **at the high end**, considering the inherent simplifications in the combustion model that lead to **overestimating BC production**. 3.3 Climate Results Long-term climatic effects critically depend on the initial injection height of the soot, with larger quantities reaching the upper troposphere/lower stratosphere inducing a greater cooling impact because of longer residence times (Robock et al., 2007a). Absorption of solar radiation by the BC aerosol and its subsequent radiative cooling tends to heat the surrounding air, driving an initial upward diffusion of the soot plumes, an effect that depends on the initial aerosol concentrations. **Mixing and sedimentation** tend to **reduce this process**, and low altitude emissions are also significantly impacted by precipitation if aging of the BC aerosol occurs on sufficiently rapid timescales. But once at stratospheric altitudes, aerosol dilution via coagulation is hindered by low particulate concentrations (e.g., Robock et al., 2007a) and lofting to much higher altitudes is inhibited by gravitational settling in the low-density air (Stenke et al., 2013), resulting in more stable BC concentrations over long times. Of the initial BC mass released in the atmosphere, most of which is emitted below 9 km, **70% rains out within the first month** and 78%, or about 2.9 Tg, is removed within the first two months (Figure 7, solid line), with the remainder (about 0.8 Tg, dashed line) being transported above about 12 km (200 hPa) within the first week. This outcome differs from the findings of, e.g., Stenke et al. (2013, their high BC-load cases) and Mills et al. (2014), who found that most of the BC mass (between 60 and 70%) is lifted in the stratosphere within the first couple of weeks. This can also be seen in Figure 8 (red lines) and in Figure 9, which include results from our calculation with the initial BC distribution from Mills et al. (2014). In that case, only 30% of the initial BC mass rains out in the troposphere during the first two weeks after the exchange, with the remainder rising to the stratosphere. In the study of Mills et al. (2008) this percentage is somewhat smaller, about 20%, and smaller still in the experiments of Robock et al. (2007a) in which the soot is initially emitted in the upper troposphere or higher. In Figure 7, the e-folding timescale for the removal of tropospheric soot, here interpreted as the time required for an initial drop of a factor e, is about one week. This result compares favorably with the “LT” experiment of Robock et al. (2007a), considering 5 Tg of BC released in the lower troposphere, in which 50% of the aerosols are removed within two weeks. By contrast, the initial e-folding timescale for the removal of stratospheric soot in Figure 8 is about 4.2 years (blue solid line), compared to about 8.4 years for the calculation using Mills et al. (2014) initial BC emission (red solid line). The removal timescale from our forced ensemble simulations is close to those obtained by Mills et al. (2008) in their 1 Tg experiment, by Robock et al. (2007a) in their experiment “UT 1 Tg”, and © 2018 American Geophysical Union. All rights reserved. by Stenke et al. (2013) in their experiment “Exp1”, in all of which 1 Tg of soot was emitted in the atmosphere in the aftermath of the exchange. Notably, the e-folding timescale for the decline of the BC mass in Figure 8 (blue solid line) is also close to the value of about 4 years quoted by Pausata et al. (2016) for their long-term “intermediate” scenario. In that scenario, which is also based on 5 Tg of soot initially distributed as in Mills et al. (2014), the factor-of2 shorter residence time of the aerosols is caused by particle growth via coagulation of BC with organic carbon. Figure 9 shows the BC mass-mixing ratio, horizontally averaged over the globe, as a function of atmospheric pressure (height) and time. The BC distributions used in our simulations imply that the upward transport of particles is substantially less efficient compared to the case in which 5 Tg of BC is directly injected into the upper troposphere. The semiannual cycle of lofting and sinking of the aerosols is associated with atmospheric heating and cooling during the solstice in each hemisphere (Robock et al., 2007a). During the first year, the oscillation amplitude in our forced ensemble simulations is particularly large during the summer solstice, compared to that during the winter solstice (see bottom panel of Figure 9), because of the higher soot concentrations in the Northern Hemisphere, as can be seen in Figure 11 (see also left panel of Figure 12). Comparing the top and bottom panels of Figure 9, the BC reaches the highest altitudes during the first year in both cases, but the concentrations at 0.1 hPa in the top panel can be 200 times as large. Qualitatively, the difference can be understood in terms of the air temperature increase caused by BC radiation emission, which is several tens of kelvin degrees in the simulations of Robock et al. (2007a, see their Figure 4), Mills et al. (2008, see their Figure 5), Stenke et al. (2013, see high-load cases in their Figure 4), Mills et al. (2014, see their Figure 7), and Pausata et al. (2016, see one-day emission cases in their Figure 1), due to high BC concentrations, but it amounts to only about 10 K in our forced ensemble simulations, as illustrated in Figure 10. Results similar to those presented in Figure 10 were obtained from the experiment “Exp1” performed by Stenke et al. (2013, see their Figure 4). **In that scenario as well, somewhat less that 1 Tg of BC remained in the atmosphere after the initial rainout**. As mentioned before, the BC aerosol that remains in the atmosphere, lifted to stratospheric heights by the rising soot plumes, undergoes sedimentation over a timescale of several years (Figures 8 and 9). This mass represents the effective amount of BC that can force climatic changes over multi-year timescales. In the forced ensemble simulations, it is about 0.8 Tg after the initial rainout, whereas it is about 3.4 Tg in the simulation with an initial soot distribution as in Mills et al. (2014). Our more realistic source simulation involves the worstcase assumption of no-rubble (along with other assumptions) and hence serves as an upper bound for the impact on climate. As mentioned above and further discussed below, our scenario induces perturbations on the climate system similar to those found in previous studies in which the climatic response was driven by roughly 1 Tg of soot rising to stratospheric heights following the exchange. Figure 11 illustrates the vertically integrated mass-mixing ratio of BC over the globe, at various times after the exchange for the simulation using the initial BC distribution of Mills et al. (2014, upper panels) and as an average from the forced ensemble members (lower panels). All simulations predict enhanced concentrations at high latitudes during the first year after the exchange. In the cases shown in the top panels, however, these high concentrations persist for several years (see also Figure 1 of Mills et al., 2014), whereas the forced ensemble simulations indicate that the BC concentration starts to decline after the first year. In fact, in the simulation represented in the top panels, mass-mixing ratios larger than about 1 kg of BC © 2018 American Geophysical Union. All rights reserved. per Tg of air persist for well over 10 years after the exchange, whereas they only last for 3 years in our forced simulations (compare top and middle panels of Figure 9). After the first year, values drop below 3 kg BC/Tg air, whereas it takes about 8 years to reach these values in the simulation in the top panels (see also Robock et al., 2007a). Over crop-producing, midlatitude regions in the Northern Hemisphere, the BC loading is reduced from more than 0.8 kg BC/Tg air in the simulation in the top panels to 0.2-0.4 kg BC/Tg air in our forced simulations (see middle and right panels). The more rapid clearing of the atmosphere in the forced ensemble is also signaled by the soot optical depth in the visible radiation spectrum, which drops below values of 0.03 toward the second half of the first year at mid latitudes in the Northern Hemisphere, and everywhere on the globe after about 2.5 years (without never attaining this value in the Southern Hemisphere). In contrast, the soot optical depth in the calculation shown in the top panels of Figure 11 becomes smaller than 0.03 everywhere only after about 10 years. The two cases show a similar tendency, in that the BC optical depth is typically lower between latitudes 30º S-30º N than it is at other latitudes. This behavior is associated to the persistence of stratospheric soot toward high-latitudes and the Arctic/Antarctic regions, as illustrated by the zonally-averaged, column-integrated mass-mixing ratio of the BC in Figure 12 for both the forced ensemble simulations (left panel) and the simulation with an initial 5 Tg BC emission in the upper troposphere (right panel). The spread in the globally averaged (near) surface temperature of the atmosphere, from the control (left panel) and forced (right panel) ensembles, is displayed in Figure 13. For each month, the plots show the largest variations (i.e., maximum and minimum values), within each ensemble of values obtained for that month, relative to the mean value of that month. The plot also shows yearly-averaged data (thinner lines). The spread is comparable in the control and forced ensembles, with average values calculated over the 33-years run length of 0.4-0.5 K. This spread is also similar to the internal variability of the globally averaged surface temperature quoted for the NCAR Large Ensemble Community Project (Kay et al., 2015). These results imply that surface air temperature differences, between forced and control simulations, which lie within the spread may not be distinguished from effects due to internal variability of the two simulation ensembles. Figure 14 shows the difference in the globally averaged surface temperature of the atmosphere (top panel), net solar radiation flux at surface (middle panel), and precipitation rate (bottom panel), computed as the (forced minus control) difference in ensemble mean values. The sum of standard deviations from each ensemble is shaded. Differences are qualitatively significant over the first few years, when the anomalies lie near or outside the total standard deviation. Inside the shaded region, differences may not be distinguished from those arising from the internal variability of one or both ensembles. The surface solar flux (middle panel) is the quantity that appears most affected by the BC emission, with qualitatively significant differences persisting for about 5 years. The precipitation rate (bottom panel) is instead affected only at the very beginning of the simulations. The red lines in all panels show the results from the simulation applying the initial BC distribution of Mills et al. (2014), where the period of significant impact is much longer owing to the higher altitude of the initial soot distribution that results in longer residence times of the BC aerosol in the atmosphere. When yearly averages of the same quantities are performed over the IndiaPakistan region, the differences in ensemble mean values lie within the total standard deviations of the two ensembles. The results in Figure 14 can also be compared to the outcomes of other previous studies. In their experiment “UT 1 Tg”, Robock et al. (2007a) found that, when only 1 Tg of soot © 2018 American Geophysical Union. All rights reserved. remains in the atmosphere after the initial rainout, temperature and precipitation anomalies are about 20% of those obtained from their standard 5 Tg BC emission case. Therefore, the largest differences they observed, during the first few years after the exchange, were about - 0.3 K and -0.06 mm/day, respectively, comparable to the anomalies in the top and bottom panels of Figure 14. Their standard 5 Tg emission case resulted in a solar radiation flux anomaly at surface of -12 W/m2 after the second year (see their Figure 3), between 5 and 6 time as large as the corresponding anomalies from our ensembles shown in the middle panel. In their experiment “Exp1”, Stenke et al. (2013) reported global mean surface temperature anomalies not exceeding about 0.3 K in magnitude and precipitation anomalies hovering around -0.07 mm/day during the first few years, again consistent with the results of Figure 14. In a recent study, Pausata et al. (2016) considered the effects of an admixture of BC and organic carbon aerosols, both of which would be emitted in the atmosphere in the aftermath of a nuclear exchange. In particular, they concentrated on the effects of coagulation of these aerosol species and examined their climatic impacts. The initial BC distribution was as in Mills et al. (2014), although the soot burden was released in the atmosphere over time periods of various lengths. Most relevant to our and other previous work are their one-day emission scenarios. They found that, during the first year, the largest values of the atmospheric surface temperature anomalies ranged between about -0.5 and -1.3 K, those of the sea surface temperature anomalies ranged between -0.2 and -0.55 K, and those of the precipitation anomalies varied between -0.15 and -0.2 mm/day. All these ranges are compatible with our results shown in Figure 14 as red lines and with those of Mills et al. (2014, see their Figures 3 and 6). As already mentioned in Section 2.3, the net solar flux anomalies at surface are also consistent. This overall agreement suggests that the **inclusion of organic carbon aerosols, and** ensuing **coagulation** with BC, **should not dramatically alter the climatic effects** resulting from our forced ensemble simulations. Moreover, aerosol growth would likely **shorten the residence time of the BC particulate in the atmosphere** (Pausata et al., 2016), possibly **reducing the duration of these**