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An Environmental Security Analysis of Abrupt Climate Change Scenarios

Keywords

Abrupt climate change, environmental security, military geography, thermohaline circulation, global cooling.

Abstract

Changes in global climate have been gradual and the environmental security effects have been manageable. However, the long-term climate record indicates that significant change is usually abrupt with major implications for regional and global security. Economic and ecological impacts of such events could exceed the management capacity of most states. Climate models indicate that a potential abrupt change can result in harsher winter conditions, severe drought, and more intense winds. These conditions can induce food and water shortages, persistent epidemics, and disputed access to energy. This scenario could destabilize the geo-political environment leading to violent conflict. This paper will examine an abrupt climate change scenario from an environmental security perspective, and present a regional framework to demonstrate the spatial pattern of potential threats.

1 Introduction

There is evidence indicating that the contemporary late Holocene warming trend will continue well into the 21st Century. Changes in global climate since 1850 have been gradual (figure 1) and the environmental security effects of global warming are expected to be manageable for most states (NRC 2002). However, it is important to note that in the context of the Holocene climate record, the contemporary warming trend has been gradual and rather unremarkable in speed and magnitude (F. PEARCE, 2007). More importantly, there is a growing body of evidence indicating that the warming trend could trigger a slowing of the ocean's Thermohaline Conveyor, potentially initiating an adjustment in global climate patterns. This could lead to harsher winters and major drought in the world's principal food producing regions (URL1; URL3; URL9). This potential shift is problematical because it can be manifested as a pervasive global cooling and drying trend that persists for many decades, and occurs at magnitudes that defy human adaptation (URL8; URL10).

It is conceivable that anthropogenic influences may increase the likelihood of an abrupt cooling event (URL4). This is important because the economic and ecological impacts of such events could be catastrophic. A number of models have been developed that indicate that an abrupt change in climate can result in rapid and substantial cooling − perhaps by as much as 9 − 18 °C in a decade (USGS, 2009). These conditions can induce acute food and water shortages, epidemics, mass migrations, and disputed access to energy supplies; and potentially lead to violent conflict. Climate change is a persistent

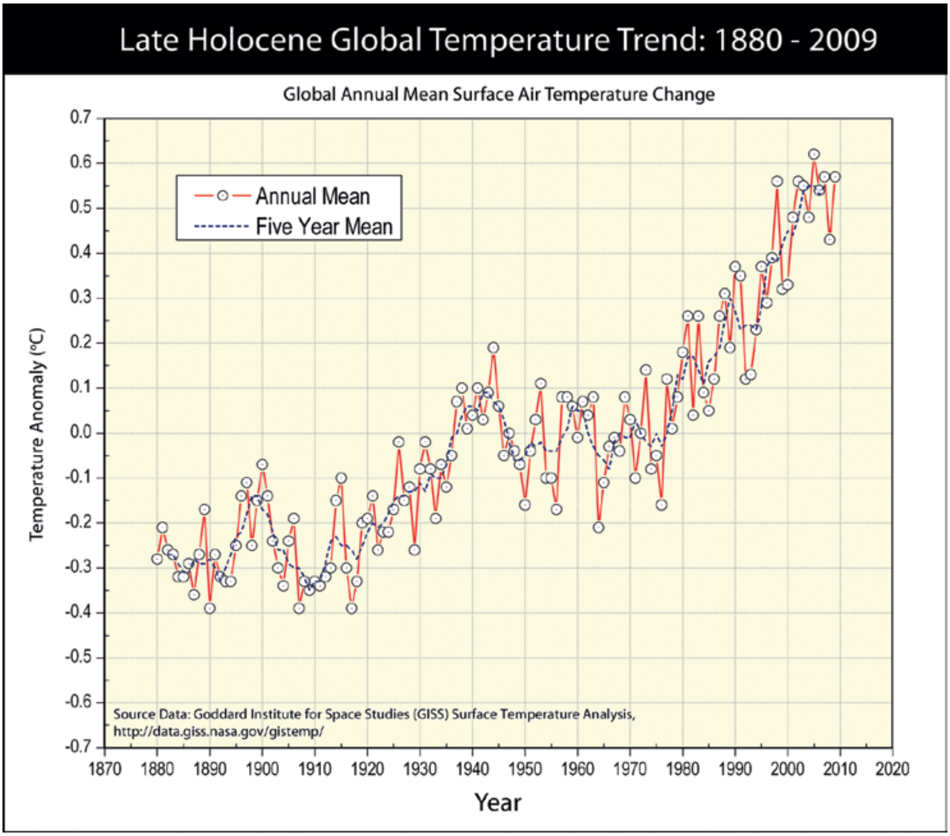

Figure 1: The contemporary warming trend following the Little Ice Age (i.e. "global warming"). The rate of change since 1850 has been +0.23 °C per decade (NRC 2002).

reality, and is significant because many conflicts are enabled by environmentally triggered instability. Historical records indicate that abrupt climate change has occurred in the past at regional scales and may be linked to violent conflict (J. DIAMOND, 2005). Hence, military geography offers an especially valuable vantage point from which to conduct an analysis of conflict and environmental security. This paper will examine an abrupt climate change scenario, patterned after the so-called 8.2k climate event and develop a regional framework to demonstrate the spatial pattern of potential threats.

2 Abrupt Climate Change: A Historical Context

Environmental instability is not a new security concept, and history suggests that ancient cultures experienced violent conflict and collapse triggered by abrupt climate change. One such example is the Anasazi culture of the American Southwest, which flourished between 900 and 1 100 AD, and then suddenly collapsed, coincident with a rapid drying trend (L. W. MAYS, 2007). Another compelling example is the demise of the ancient Akkadian Empire 4 000 years ago. This civilization developed in Mesopotamia in what is now Iraq (A. GIBBONS, 1993). The Akkadian Empire prospered as an agrarian society between 2 300 - 2 200 B.C., and archeological evidence suggests that it came to a sudden halt in 2 200 B.C. H. WEISS and R. S. BRADLEY (2001) suggest that Akkadian society literally dried up from an abrupt climate event. This shift caused a severe drought, which advanced from north to south along the Fertile Crescent. As a result, tens of thousands of northerners migrated to southern cities, overtaxing precarious water and food supplies. Archeological evidence suggests that urban chaos ensued and southerners made war on their unwanted northern cousins. Weiss indicates, *"... for the first time, we've indentified abrupt climate change directly linked to the collapse of a thriving civilization"* (H. WEISS and R. S. BRADLEY, 2001, p. 611).

This is an excellent illustration of environmental security. It demonstrates how environmental degradation diminishes a state's ability to assure the most essential aspects of security because environmental change undermines natural support systems on which humans depend. Environmental degradation has the potential to erode the resource base and make it impossible for a regime to provide for the population.

2.1 Defining Abrupt Climate Change

Quaternary climatologists have long been familiar with the variable nature of Earth's climate record. However, the dominant perspective of climate change is that Earth's climate system changed gradually, notwithstanding significant geologic evidence to the contrary. Geologic and fossil records clearly demonstrate that Earth's climate actually undergoes large magnitude changes sometimes with astonishing speed, and although the Holocene climate record has been the most stable in recent geologic history, abrupt changes in climate appear to be the norm (URL1).

Several definitions of abrupt climate change have been offered in the literature. The National Research Council (NRC 2002) defines it as fluctuations in climate that take place when the global climate system is forced across a threshold, thus causing a transition to a new climate state at a rate faster than the initial cause. The U.S. Climate Change Science Program (USGS 2009) defines it as a change that occurs over a few decades, endures for several decades, and causes substantial disruptions in human and natural systems. Thus, abrupt climate changes are oscillations in climate, typically by 9 - 18 °C, which occur over geologically short time spans, and three such changes are given in figure 2 (URL7).

Rapid changes in climate take place because Earth's climate system is non-linear: inputs and outputs are not proportional and once the system crosses a threshold, change is characteristically abrupt, rather than slow and gradual; hence, the system exhibits multiple equilibria (URL8). The concept of equilibrium is the seminal issue in understanding climate change.

The inherent problem is that climate is assumed to be at some equilibrium and thus, the recent warming trend is fundamentally anomalous, thus implying that climate has persisted in an unchanging condition (URL1).

In fact, variability is the norm, and the meaning of equilibrium is dependent on the time scales being considered. There are different types of equilibrium, and indeed, different forms of equilibrium are related to specific intervals of time. An abrupt change occurs when climate is pushed beyond a threshold, precipitating change from one equilibrium state to another (URL3).

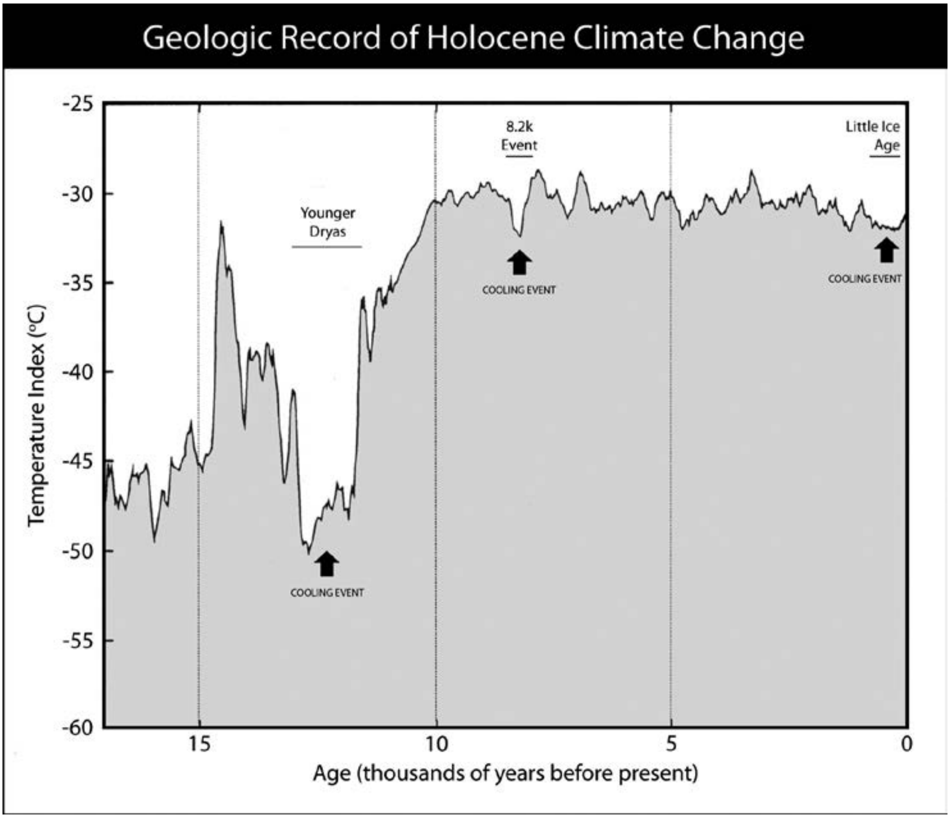

Figure 2: The Holocene warming trend manifests the variability of climate conditions and three so-called abrupt events since 12 000 years B.P. (USGS 2009).

Given that multiple equilibria exist, the climate record is necessarily highly variable with cyclical events occurring at different scales and magnitudes. The concept of static equilibrium explains conditions in the climate system that persists over short or steady time intervals of years and decades. An example of static equilibrium is the periodic warm and cool periods that persist for a decade, such as the warm period of the 1930s and cool period of the 1940s. A number of static equilibria are linked to compose steady state equilibrium – also known as graded time – with periodic fluctuations above and below an average condition typically measured in centuries to millennia. Finally, a series of intervals of graded time are joined in a dynamic equilibrium measured over thousands to millions of years.

2.2 Abrupt Holocene Climate Events

While the details of a potential abrupt climate change cannot be predicted accurately, the geologic record provides useful guidelines. The objective of this paper is to illustrate a reasonable scenario, similar to one that has already occurred, for which there is plausible data to theorize that it may happen again, so that we may examine potential environmental security implications. Figure 2 illustrates the Holocene climate record following the Wisconsin glaciation and it suggests that three abrupt cooling events that took place during the last 15 000 years. Each event is presumed to be associated with a collapse in the Thermohaline Conveyor. This premise is certainly true for the first two events, but less certain for the Little Ice Age, which may be related to other causal factors (B. FAGAN, 2000).

2.2.1 The Younger Dryas

The first abrupt climate event was the Younger Dryas, which took place about 12 700 years ago. Paleoclimate data indicates that this cooling event, which lasted 1 300 years, was characterized by a rapid drop in temperatures in Greenland, and substantial changes throughout the North Atlantic region (URL6). The striking feature of the Younger Dryas was that it happened in a series of decadal drops of around 9 °C each, and then the cold, dry conditions persisted for a millennia. While this event had an enormous effect throughout the North Atlantic region, its impact would be more severe today in our densely populated society. In fact, it would be fair to say that such an event today would be a civilization changing event (F. PEARCE, 2007). However, an event of this magnitude is less likely because similar physical conditions – that being massive amounts of glacial melt water – are not present today.

2.2.2 The 8.2K Climate Event

The climate change scenario outlined in this paper is modeled after the so-called 8.2k climate event, which was a century-long episode. The paleoclimate record suggests that this scenario is perhaps the most plausible of abrupt events. This event followed an extended period of warming – much like the period we appear to be in today – followed by a sudden cooling (URL5). In this scenario, Greenland's average annual temperatures dropped by roughly 9 °C, and similar temperature decreases are likely to have occurred throughout the North Atlantic region. During this climate event severe winters in Europe and other regions adjacent to the North Atlantic caused glaciers to advance, rivers to freeze, and agricultural lands to be far less productive. Paleoclimatic evidence suggests that this event was associated with a collapse of the Thermohaline Conveyor (URL5).

2.2.3 Modeling an 8.2k Event

The climate scenario given in this paper suggests that once global temperatures rise above some threshold, cold climate conditions could develop abruptly, with persistent changes in atmospheric circulation causing drops in some regions of 9 - 18 °C in a single decade (URL8). Paleoclimatic evidence suggests that altered climatic patterns could last for as long as a century, much as it did 8 200 years ago (F. PEARCE, 2007). This abrupt change scenario is characterized by a clear set of conditions (Figure 3):

- A drop in temperatures by approximately 9 °C in North America and Asia and about 12 °C in northern Europe.
- An increase in temperatures by 7 °C in Australia, South America, and southern Africa.
- Pervasive drought in agricultural regions and major population centers.
- An intensification of winter storms and arid conditions.

This scenario suggests that such an abrupt climate change could potentially de-stabilize the geo-political environment, leading to violent conflict resulting from resource constraints such as severe food and water shortages. These climate-related events would also have a substantial effect on society. For example, the 1998 U.S. drought cost it $40 billion in lost revenue. The drought that persisted in the Horn of Africa from 1984 - 1985 is estimated to have led to the death of 750 000 people (URL10).

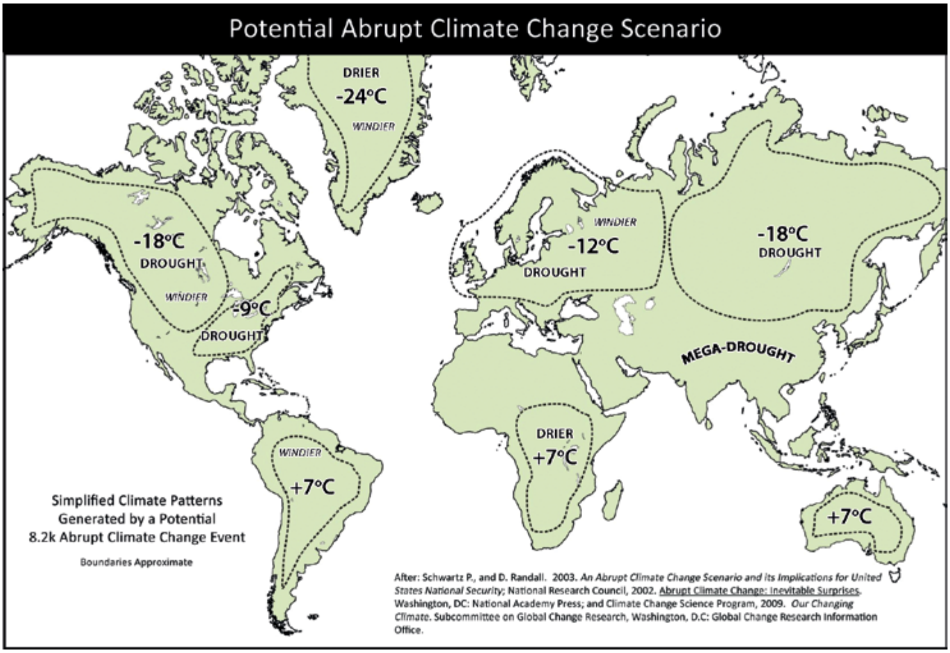

Figure 3: An abrupt climate change scenario modeled after a potential 8.2k event (URL8).

The 8.2k scenario presented in this paper will certainly be much longer with larger scale implications, however. For example, these climate conditions may reduce rainfall leading to a possible 15 percent decline in grass productivity, causing reductions in cattle weight by as much as 12 percent, thus reducing protein supplies.

Furthermore, given these conditions, milk production is expected to decrease by some 25 - 30 percent, and new pests are likely to spread in agricultural regions, further reducing food production. These conditions could beset the world's primary food-producing regions at once, thus challenging the idea that society and governments can adapt (URL8).

This climate scenario will result in significantly reduced carrying capacity, and mounting tensions could lead to environmentally triggered warfare. Given that more than 400 million people live in drier, over-populated and economically poor regions; this scenario and its resultant effects pose a severe risk to political, economic, and social stability (F. PEARCE, 2007). In the developing world, where states lack the resources required to adapt to such severe conditions, the problem is likely to be exacerbated. States with adequate resources may resort to enforced isolation to preserve resources.

Less fortunate states may instigate warfare to secure access to food, water, or energy. Thus, national defence priorities could shift with a new goal of securing resources for survival (URL8).

2.2.4 The Little Ice Age

Beginning in the 14th century, the North Atlantic region experienced a dramatic cooling period that lasted until about 1850. This event may have been caused by a slowing of the ocean conveyor, although it is more generally thought that reduced solar output and/or volcanic eruptions may have prompted this cooling trend (B. FAGAN, 2000). This so-called Little Ice Age brought severe winters and profound agricultural, economic, and political impacts to Europe. The period was marked by persistent crop failures, famine, disease, and population migration (J. DIAMOND, 2005). While climate crises like the Little Ice Age are not solely responsible for the death of civilizations, it is undeniable that they have a large impact on society (M. HULME, 2003).

3 Role of the Thermohaline Conveyor

One important question then, is what mechanism could possibly drive such a large-scale abrupt change in climate? So far, scientists have recognized only one viable process-response mechanism: a rapid restructuring of global ocean currents. These currents, collectively known as the Thermohaline Conveyor, distribute immense volumes of heat around our planet, and therefore play an essential role in regulating the climate system (URL2). A simplified explanation of the basic ocean-atmosphere dynamics that are regulated by the Thermohaline Conveyor is useful to explain this process-response mechanism (figure 4).

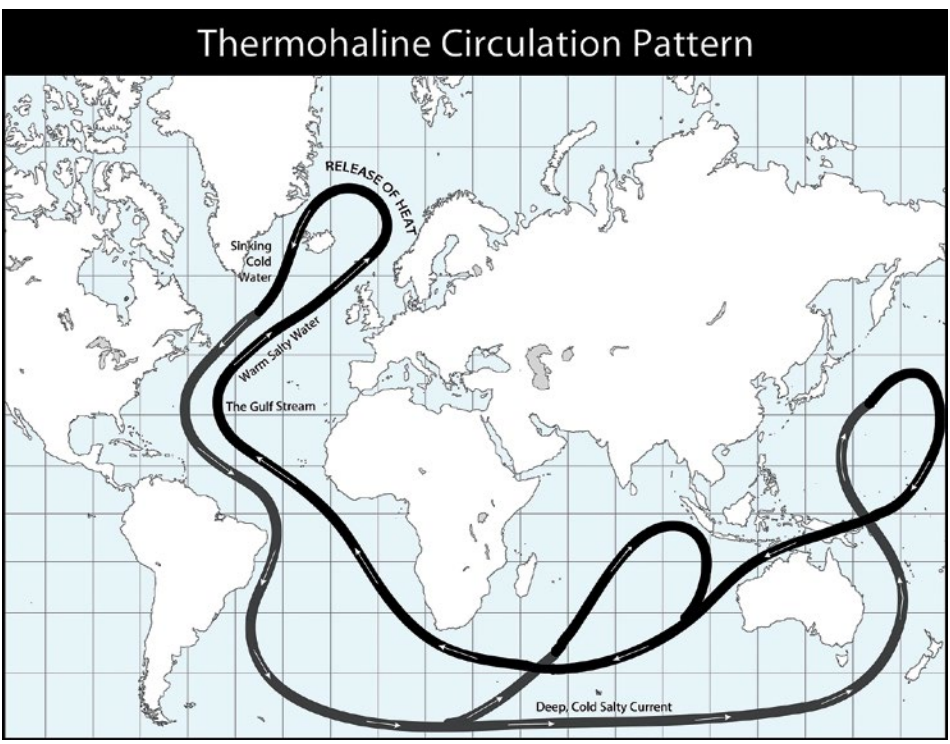

Figure 4: The ocean's Thermohaline Conveyor delivers warm, salty water to the North Atlantic region. Heat is released, thus moderating Europe's climate, especially in winter (USGS 2009).

Equatorial ocean waters are warmed by solar radiation, which creates a surplus of heat, and enhances evaporation in the tropics; thus leaving tropical ocean water saltier. The Gulf Stream, an extension of the Thermohaline Conveyor, carries an enormous volume of warm, salty water to the North Atlantic region. This oceanic heat pump is an important mechanism for balancing the global energy budget and moderating climate in the North Atlantic region. At northern latitudes, the ocean releases heat to the atmosphere – especially in winter – hence, it warms North Atlantic regions by as much as 5 - 7 °C and significantly moderates average winter temperatures (USGS 2009).

However, records of past climates, from sources such as deep-sea sediments and ice-sheet cores, suggest that the Thermohaline Conveyor has shut down several times in the recent geologic past (URL1). This shutdown limited heat delivery to the North Atlantic, triggering a substantial cooling trend throughout the region. The crucial component of the Thermohaline Conveyor is water saltiness.

For an assortment of reasons, North Atlantic waters are relatively salty. This system functions because salty water is denser than fresh water; and cold water is denser than warm. Consequently, when the warm, salty waters of the North Atlantic release heat to the atmosphere, they become colder and sink. Once this happens, a massive volume

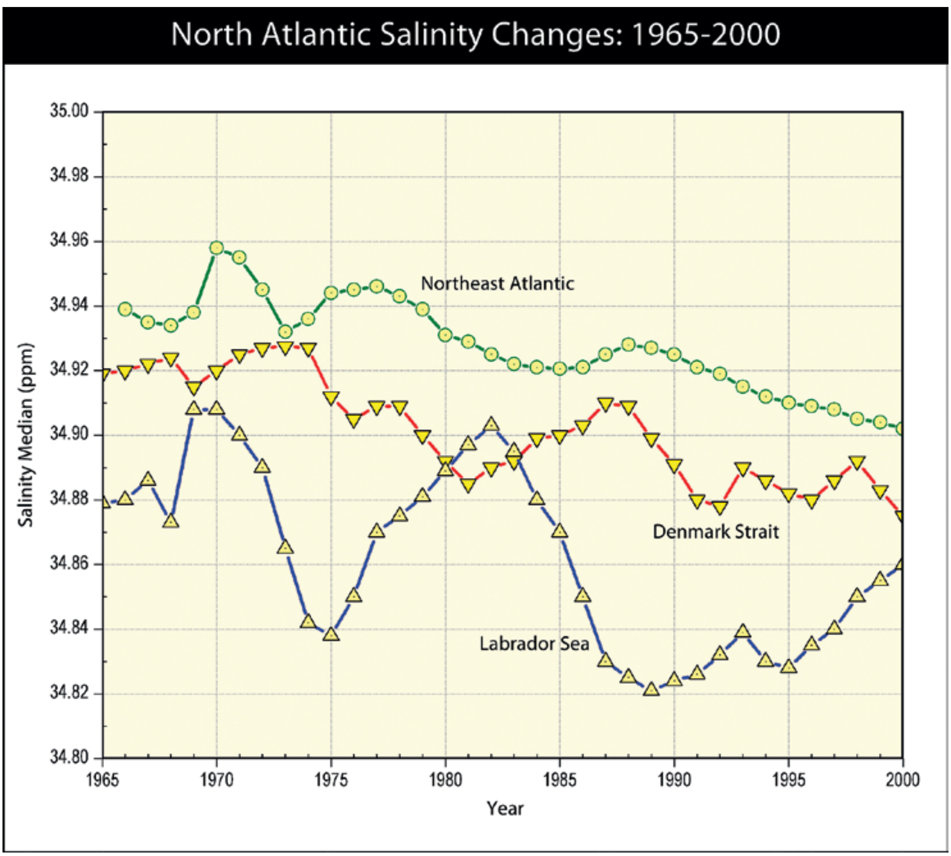

Figure 5: Data indicating that the surface waters of the North Atlantic are becoming fresher and perhaps establishing conditions for a disruption of the Thermohaline conveyor (after DICKSON et al. 2002).

of cold, salty water sinks to the abyss. This water flows at great depths throughout the world's oceans (URL2).

However, this process can be dislocated if the North Atlantic's cold, salty waters do not sink. If that happens, the principal process driving global ocean circulation could taper off and potentially cease altogether (NRC, 2002). The resulting restructuring of the ocean's currents could modify global climate patterns. This can happen if an influx of fresh water into the North Atlantic could create a cap of buoyant fresh water over the denser, saltier water. This fresh water would in effect insulate the surface, inhibiting the transfer of heat to the atmosphere. At the same time, the influx of fresh water could dilute the North Atlantic's salinity. Thus, at a critical but unknown threshold, when North Atlantic waters are no longer sufficiently salty and dense, they may stop sinking (USGS, 2009).

DICKSON et al. (2002) presented data that tend to support this model. These oceanographers, monitoring conditions in the North Atlantic, concluded that it has been steadily freshening for the past 40 years but especially during the past decade. These data (figure 5) suggests that since the mid-1960s, North Atlantic waters have steadily and noticeably become less salty. Therefore the crucial question is at what threshold will the conveyor cease to operate? The short answer is we just do not know, and furthermore, scientists have not convincingly determined the relative contributions of sources that may be adding fresh water to the North Atlantic. Among suspected sources are melting glaciers, increased precipitation, or rivers that discharge into the Arctic Ocean (DICKSON et al. 2002).

4 Environmental Security

Environmental stress will play a pervasive role in future conflicts because the economic well-being of about half of the world's population is tied directly to the land. This is important because nearly 2 billion people do not have access to clean water, and almost 75 percent of the world's most impoverished inhabitants are subsistence farmers (T. F. HOMER-DIXON, 1999).

Drought, desertification, deforestation, and soil exhaustion are major problems in these regions. This scenario is a concern because anticipated population growth, especially in the developing world, will result in higher per capita consumption rates. Consequently, we should anticipate that environmental stress would make an increasingly significant contribution to three modes of conflict: 1) ethnic/racial warfare enabled by environmental stress and population pressure; 2) civil warfare instigated by economic collapse; and 3) limited-scale interstate wars.

Environmental security is a process involving, environmental risk analysis based on natural processes that destabilize the environment and contribute to instability or conflict. The fundamental components of environmental security include environmental processes that undermine governments, promote instability, and trigger violent conflict. Since 1990, violent conflicts have occurred in many places and it would be too simplistic, and probably incorrect, to assert that environmental stress instigated each of these conflicts, and too difficult to disaggregate their human and environmental components (T. F. HOMER-DIXON, 1999).

The relationships between food, population, climate, resources, and environmental stress are evident in many developing states; and this Malthusian paradigm generates much disagreement among scholars. However, all factions have to agree on an undeniable outcome that has been evident in places like Darfur and Rwanda: population growth and environmental stress, superimposed over latent ethic and political divisions in the end, will be solved one-way or another (J. DIAMOND, 2005). Detractors of the environmental security perspective argue that wars result solely from politico-military factors, and are minimally influenced by environmental stress at best, and perhaps allude to environmental determinism.

However, environmental stress results from the combined influence of anthropogenic effects on the environment in conjunction with the vulnerability of the ecosystem. Scarcity and stress contribute to conflict only under certain circumstances, but there is no deterministic link. Clearly, not all violent episodes are alike and the influence of environmental stress on conflict will vary in magnitude from example to example (T. F. HOMER-DIXON, 1999).

5 Abrupt Climate Change Scenario for the Future

Examples of abrupt climate change that have occurred in the past suggest that it is prudent to envisage such a scenario for the future as reasonable, especially because data indicate that we could be on the cusp of such an event. This scenario makes reasonable assumptions about which regions are likely to be colder, drier, and windier. Nevertheless, there is no way to confirm its assumptions because the most complex climate models cannot estimate in detail how climate change will unfold, how discrete regions will be affected, and how governments might respond (URL8).

This scenario estimates that average annual rainfall will decline by nearly 30 percent and winds will become about 15 percent stronger. These persistently colder and arid conditions are assumed to be more severe in continental interiors. The effects on populations would be devastating as persistent drought in the world's most populated regions lingers for decades. Given that we expect to experience a considerable reduction in precipitation, water supplies will quickly be over-taxed and reserves will be depleted to the extent that shortages will overwhelm conservation options (URL8).

The fundamental problem presented by this scenario is that cooling will be more pronounced during the winter season and will persist throughout the year. Furthermore, winters are expected to become increasingly intense and less predictable, thus making growing seasons shorter. Added to the problem of intensive cooling and summer dryness, it is projected that wind patterns and velocities will become more zonal: i.e., winds flow more frequently from the pole to the equator.

This altered pattern implies that wind speeds will accelerate as the atmosphere tries to adjust dynamically to a stronger pole-to-equator temperature gradient. Consequently, cold air blowing across Europe, North America, and Asia could potentially generate harsh conditions for agriculture, and the combination of wind and dryness will cause widespread dust storms and soil loss. Given these conditions and the data in the geologic record, we can expect that by the end of the first decade of this event, Europe's climate will approximate Siberia's (URL8).

6 Summary and Conclusions

The potential abrupt climate change described in this paper will profoundly affect agriculture, biomes, water supplies, and energy in most of the world's major population centers. Crop yields, affected by frigid temperature and water stress, as well as the length of growing season are expected fall by 10 - 25 percent. They will be less predictable as key regions shift from a warming to a cooling trend. This scenario also means that affected regions will experience more frequent epidemics from vectors and blowing dust, and arid conditions will introduce new varieties of agricultural pests. Developing states and states with limited resources may not have the wherewithal to adapt to these new conditions. One concern is that this scenario will induce mass migrations, such as those suggested in the Akkadian example leading to acute civil and ethnic violence.

The spread of human civilization flourished with the stabilization and warming of Earth's climate after the last glacial period. A warmer stable climate meant that humans could develop agriculture and permanent settlements. With the end of the Younger Dryas and the warming and stabilization that followed, human civilization benefited from an extended period of relatively stable climate.

Modern civilization has never experienced weather conditions as persistently disruptive as the ones outlined in this scenario. Thus, the implications for national security outlined in this paper are only hypothetical. The tangible effects would of course vary greatly depending on the subtleties and abruptness of climate conditions, the ability of societies to adapt, and decisions by policymakers. Nonetheless, violence and disruption triggered by abrupt climate change pose a different type of threat to national security than we are accustomed to today. Military confrontation may be triggered by a need for natural resources and the shifting motivation for confrontation would alter which countries are most vulnerable.

Glossary

Abrupt Climate Change:
A change in climate that occurs over a few decades, endures for several decades, and causes substantial disruptions in human and natural systems: oscillations in climate, typically by 9 to 18 °C, which occur over geologically short time spans.

Environmental Security:
The process involving, environmental risk analysis based on multifaceted linkages between anthropogenic and natural processes that destabilize the environment and contribute to instability or conflict.

Holocene:
The current geological epoch, this began approximately 11 700 years ago – or upon the termination of the last ice age.

Little Ice Age:
The Little Ice Age was a time of cooler climate in most parts of the world, which began about 1250 A.D. and lasted until about 1850.

Pleistocene:
The epoch from approximately 2 million to 12 000 years BP covering the world´s recent period of repeated glaciations.

Thermohaline Conveyor:
The term refers to the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes.
Younger Dryas:
This period is named after the alpine/tundra wildflower Dryas octopetala, and also referred to as the Big Freeze, was a geologically brief (approximately 1 300 years) cold climate period at the end of the Pleistocene between approximately 12 800 to 11 500 years ago.
8.2k Climate Event:
A period of abrupt cooling period − triggered by a disruption of the Thermohaline Conveyor − that began approximately 8.2 k years ago and lasted for nearly a century.

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