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# National Security & Climate Instability

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## Introduction

The Earth's climate is a complex system. Greenland ice core evidence shows that when the climate system is left to itself and given the variability of natural forces, it tends to be wildly erratic. Looking from the perspective of the past several million years, climate change is the norm, and long-term stability is the exception. Moreover, major shifts in climate over large areas can be remarkably fast. Our sense of climate stability is comforting but it is illusory because the entire history of human civilization is so short.

It is probably no accident that agriculture, cities, and civilization itself arose during this extended time of climate quiescence. Because the entire human experience is associated with anomalous climate stability, we are inclined to continue to expect more of the same. Our National Security is intrinsically tied to trade systems, utility infrastructures, transportation networks, political alliances, energy policies, agricultural practices, supply chains, business investments, and military actions. All of these sectors make plans based on implicit assumptions that the climate will not be significantly different in a decade from what it is now.

Our success in using the Earth system to our advantage has depended, to a large extent, on its relative stability. Our approach is to think of the Earth's climate along with the factors that affect it as a system, which allows us to adopt language and concepts of systems engineering. We can think of a stable climate as being analogous to a properly-functioning engineered system while an abrupt climate change is analogous to the failure of an engineered system.

Those who have the capability to understand climate change, its cause, its mitigation, and its potential course will be those who will survive and prosper in the long run. On the other hand, those who continue to make the longstanding bet that climate will never return to its normal unstable behavior are probably naive. The purpose of this white paper is to suggest that, from a National Security standpoint, the only prudent course of action is to anticipate the possible end of climate stability and plan accordingly.

## Climate Instability

An example of an abrupt climate change is one that took place over the North Atlantic at the end of the last ice age. About half the warming associated with the end of the glacial period occurred within a decade, and the changes had global effects. A graph of the temperature of central Greenland over the past 100,000 years demonstrates that until about 11,000 years ago, such climate convulsions happened all the time. Since then, an extraordinarily stable condition has prevailed. Modern humans have been

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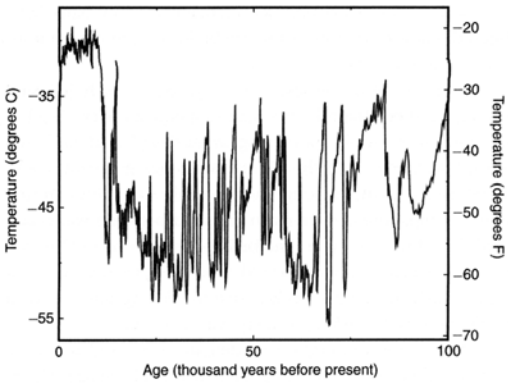
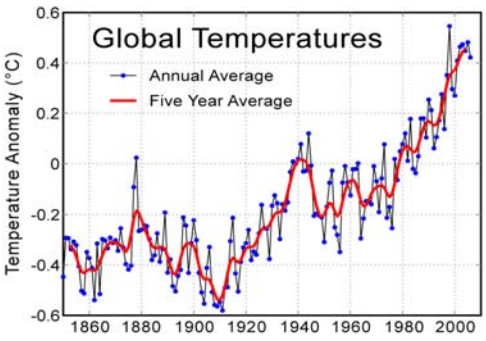
### Greenland Temperature




K.M. Cuffy and G.D. Clow. Temperature, accumulation, and ice sheet elevation in central greenland through the last deglacial transition. *J. Geophys. Res.*, 102:26,383–26,396, 1997.

*Until about11, 000 years ago, such climate convulsions happened all the time.*

### Global Warming 1850-2006




Global Warming Art rendering of instrumental data compiled by the Climatic Research Unit of the University of East Anglia
http://www.globalwarmingart.com/wiki/Image:Instrumental_Temperature_Record_png

blessed with 11,000 years of constant climate (relative to any equally-long period as indicated from a million years of Greenland ice core).

The term "climate instability" is still an incomplete description, but more accurately represents the history and expected future of the system. From the Earth's perspective, climate instability is not necessarily bad, wrong, or unnatural. From the human perspective—because of our civilization-long dependence on climate stability—climate instability can be considered a "failure" of the system. From the human perspective, an abrupt shift from stable to unstable climate has the potential to be calamitous.

There is no debate within the scientific community about the reality of climate change. A contentious political and social debate revolves mainly around issues of attribution, mitigation, adaptation, economics, statistics, policy, funding, and the scientific method, but the Earth is undoubtedly getting warmer as measured by global mean surface temperature. This sharp increase in global temperature since the beginning of the 20th century is the primary observational evidence for global warming.

It should be noted that while global mean surface temperature is a very convenient metric that can be used to determine whether or not climate is changing and to assess the rate of change, it does not provide a measure of the actual state of the Earth. Global mean surface temperature is only one of a multitude of variables that describe the climate. For example, global temperature does not tell us anything about Arctic sea ice, the mean pH of the oceans, the likelihood of severe heat waves in Europe, the desertification of the African Sahel, the rate of sea level rise, the average intensity of the South Asian monsoon, or the probability of a category 5 hurricane landfall on U.S territory. It does not tell use what will happen in the future, neither does it tell us whether the changes since the beginning of the 20th century are reversible.

Society and its institutions represent a second complex system, one that is tightly coupled to the Earth's climate. Systems engineers understand that the dynamics of one complex system can cascade into another, sometimes amplifying effects that initially appear to be innocuous, turning them into catastrophes. It goes without saying that as the climate becomes less stable the integrity of our national security will increasingly depend on our ability to identify potential cascading mechanisms.

Clearly, there is a need to use the tools of systems engineering along with models of climate change, supply chains, trade systems, political systems, etc. to develop the means to recognize possible unintended consequences of some policy or action and to identify potential solutions that would take advantage of the dynamics of these coupled complex systems.

## National Security Implications

There are many National Security implications associated with climate change. In general, conflicts tend to arise as societies seek to adapt to abrupt changes in their environment. These changes may be the result of economic shifts, migration, newly-accessible natural resources, disease spread, civil war, land use, or military actions. Climate changes may be either the cause or effect but in general, there are feedback mechanisms at work that will either amplify the perturbation or damp it out altogether. Some contemporary climate-related national security issues are:

- Conflicts resulting from the Northwest Passage becoming clear of ice

this summer for the first time since satellite records began 30 years ago. For example, a recent headline in the International Herald Tribune reads "Denmark dismisses attempts by Russia and Canada to claim Arctic." Resources such as oil, fish, and diamonds along with new trade routes will soon be accessible.

- In the African nations of Kenya, Sudan, Ethiopia, Somalia, and Chad, "You have climate change and reduced rainfall and shrinking areas of arable land; and then you add population growth and you have the elements of an explosion," says Francis Kornegay, a senior analyst at the Center for Policy Studies in Johannesburg.
- Glaciers provide water for about 1/3 of the world's population. For example, Peru, India, and western China are heavily dependant on glacial water. Shrinkage of these glaciers will lead to severe water shortages in the future.
- The risk of contracting Cholera, Lyme disease, and West Nile Virus, all associated with warm climates, is increasing. A study by the World Health Organization suggests that increased outbreaks of Malaria are associated with climate change.
- According to British charity Oxfam, the number of natural disasters per year has increased more than fourfold since the early 1980's. "This year we have seen floods in South Asia, across the breadth of Africa and Mexico that have affected more than 250 million people," according to Oxfam director Barbara Stocking.

It is clear that, due to globalization, the world's nations have become inexorably linked together to the degree that National Security is now, in fact, International Security. Thus, U.S. Security is directly affected by climate related calamities that occur anywhere in the world. Such calamities often lead to large economic losses, political instability, regional conflicts, and wide spread human suffering.

In order to better understand the dynamics of the complex interactions between climate and the nation's security issues, the National Security community is beginning to understand the need for employing science-based methods both to develop and validate decision support software. For example, such software might be used to provide the national security community with planning tools to examine mitigation strategies associated with climate induced conflict or to better understand requirements for military facilities in areas that are adversely affected by extreme weather.

## Science-Based Approach

The development of science-based decision support software aimed at allowing one to evaluate and understand the consequences associated with various intervention strategies is far from simple. A plethora of technological skills are required along with an understanding of the eventual user community and the challenges of interpretation of the results that are generated. In this vein, the importance of validation and uncertainty quantification along with its understanding by the user cannot be overstated.

### Ice Free Northwest Passage

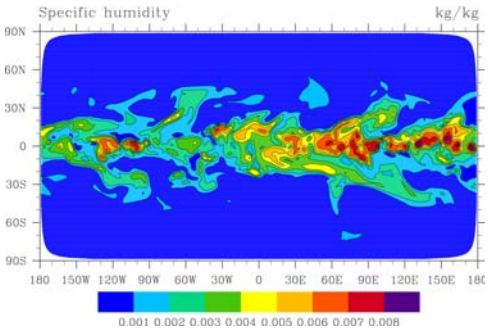
www.nasa.gov

*"Denmark dismisses attempts by Russia and Canada to claim Arctic"*

### Climate Induced Civil Unrest

Wikimedia.org
http://upload.wikimedia.org/wikipedia/commons/4/4b/African_Mission_in_Sudan.jpg

## New CCSM Dycore: SEAM




Mark Taylor, Sandia National Laboratories, 2007

*This is indeed a grand challenge and will require cooperation between a number of partners.*

## Collaboration is Key

Science-based software developed for studying the relationship between National Security & Climate Instability will require high-resolution climate modeling, climate and weather data (historical & real-time), and validated conflict modeling. This is indeed a grand challenge and will require cooperation between a number of partners.

- Regional climate change estimates using modeling and simulation will require the use of endogenous high-resolution models along with exogenous course resolution climate models. Advanced numerical methods will be required such as those related to adaptive mesh refinement, multi-scale physics, and scalability on massively parallel computers. An example of this is the new highly-scalable Spectral Element Atmospheric Model (SEAM) developed by Sandia for the Community Climate Simulation Model (CCSM) Dycore. Creative methods to interface computer intensive CCSM climate simulations with socio-economic conflict models will be required.
- Validating climate models and augmenting real-time decision making, requires a variety of historical and real-time sensor data. The creative use of satellite sensors can be used for obtaining data on ground moisture, aerosols, land use & agriculture, sea ice & snow pack, albedo & global dimming, deforestation (natural and man made), and the effects of natural disasters. New sensor technology and autonomous ground/air based systems can fill critical data gaps.
- Climate induced conflict modeling will entail expertise in disciplines such as systems dynamics and agent-based modeling, economics, behavioral modeling & social simulation with validation, country analysis, intelligence aggregation or data fusion, uncertainty quantification, decision support development environments, and infrastructure disruption modeling.

## Serving the Community

William Duggan who teaches strategy and leadership at Columbia Business School and who is a frequent guest lecturer at the U.S. Army War College discusses the ramifications of "Intuitive" versus "Analytical" decision making. He notes that for "complex or unfamiliar situations or competing courses of action" that "intuitive decision making does not work well." It is apparent that the present problem is complex, unfamiliar, and provides one with the possibility of taking numerous courses of action, many of which will lead to unintended consequences.

It is clear that an "analytical" or science-based approach to this important problem will yield long-term dividends to the national and international community. Sandia National Laboratories has a breadth of experience that includes climate modeling, innovative sensor technologies, earth system data collection, socio-economic modeling, validation methodologies, and modeling of networks (utilities, logistics, etc.). In conjunction with its partners such as NCAR, the DOE office of Science, BP, and others, Sandia is well positioned to provide service to the nation through the discovery of potential cascading events associated with climate and national security and through the development of integrated decision support software tools.