Environmental security, abrupt climate change and strategic intelligence

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This paper assesses the current policy efforts to define and confront environmental security challenges. National and international organizations (e.g., ENVSEC, NATO, US DOE, OSCE) have made renewed attempts in recent years to address environmental links to security, and since 2002 have been forced to redefine and reassess efforts in light of new data, emerging political pressures, and accelerating environmental conditions. While ‘classically’ defined environmental security problems remain yet unresolved, institutions are attempting to adapt to new expectations and responsibilities, including a broadening of geographical responsibility into regions such as the Arctic, where previously no involvement was thought necessary. This research focuses on the opportunities of such efforts, the likely challenges they face in the future, and recommendations for how to link environmental security research to intelligence needs and strategic policies. The case of abrupt climate change risks as a security issue in the Arctic will highlight these concerns.
Introduction

The past two decades have witnessed increasing concern over new security threats and risks, from environmental issues to terrorism and economic instability. The traditional definitions of national or international security, based upon narrowly defined and easily measured metrics of violent interstate conflict, have proven inadequate for describing the spectrum of risks that the international community now face. The shifts in security discourse and policy since the end of the Cold War have affected academic, policy and intelligence communities, while increasingly engaging certain scientific communities that had previously little contact with or interest in issues of international security. Policy interest in environmental security since 1989 has rested upon both a need to define new operational missions for existing security forces, and growing realization that environmental changes may bring overwhelming pressures to bear upon critical systems and vulnerable regions.

The need to define environmental security and methods for identifying insecurity contain similarities with previous security concerns, while other attributes of environmental issues necessitate new tools and approaches. Environmental concerns are transnational and often non-deliberate, rife with uncertainty and requiring new communities of expertise. In practical terms, however, abrupt and severe environmental change is little different from Cold War conceptions of security as elucidated by Bernard Brodie. To Brodie, whose experiences with German V-2 attacks on London during the Second World War led him to conclude that security defenses were imperfect, the consequences of allowing conflict to erupt were unacceptable in the nuclear age. The most effective strategy, argued Brodie, was to deter conflict and ensure that the worst consequences did not come to pass. Even if the probability of a nuclear exchange between the US and USSR was low, the potential impacts were so severe that strategies needed to be adopted to prepare and prevent that eventuality.

The concern for precaution may have shifted from Brodie’s age, that in facing the risks and dangers of abrupt climate change, security policies must deal with systems rather than individuals, unintended rather than deliberate actions, and time scales that require action far in advance of emerging threats. Security policies must be based upon strategic foresight, of knowing where vulnerable systems and regions exist before catastrophic changes occur in the environment, and how to mitigate or avoid the worst consequences. This study reviews the need for new security definitions in regard to environmental security, specifically the role of vulnerability and risk in anticipating critical environmental changes. In assessing the potential role of new, global intelligence systems, the potential risks and impacts of abrupt climate change in the Arctic are examined as illustrative. In contrast to many past approaches to climate change as an external force acting upon state security, we emphasize that greater integration of energy, environmental, economic, social and political systems are necessary. Rather than attempting to falsify or substantiate causal relationships between climate change and one measure of insecurity (e.g., violent conflict), risk assessment techniques can be employed to help estimate potential areas of insecurity in terms of plausible risk and severity of consequences. It is this vulnerability foresight that may prove of use to policymakers concerned about abrupt climate change and security issues.

The need for greater foresight and warning involves not only development of analytic systems to provide relevant data, but we also need more robust understanding of critical system-level vulnerabilities, and how these vulnerabilities can be understood as security concerns. Where are the weak spots or key factors that connect together two apparently disconnected systems? Are there ‘latent’ systems whose existence only becomes manifest if current systems break or are perturbed beyond safe and assumed operating limits? How do these systems span across boundaries of geography, of governance, of jurisdiction, of discipline? What forms of governance and adaptation may need to evolve in order to deal with these? Not all of these questions can be answered in such a report, but a good starting point is consideration of the nature of environmental security, and its relationship to intelligence and forecasting.
Intelligence services and operations have existed for centuries, becoming more professionalized in the 20th century in response to greater needs for technical expertise, and in recognition of severe consequences of inaction or surprise. The combination of events during the Second World War (notably, the 1941 attack on Pearl Harbor), combined with the advent of nuclear weapons largely shaped current institutions in the United States, while other countries have either relied upon allied intelligence or had their own institutions shaped in other ways by the Cold War. Simply put, however, intelligence analysis has been overwhelmingly concerned with actions of foreign countries and risks of violent (often military or terrorist) action. Yet viewed from the perspective of intelligence as a general activity of analysis, the Central Intelligence Agency’s (CIA) definition can be interpreted more broadly:

*Reduced to its simplest terms, intelligence is knowledge and foreknowledge of the world around us - the prelude to decision and action by US policy makers.*

*(As quoted in: Warner 2009: 4)*

Despite the preponderance of effort spent on operational and tactical intelligence in government, the knowledge that is often most needed are long-term trends and ideas concerning what the ‘world around us’ will look like in the future. Environmental conditions are paramount among such concerns, yet have been lacking in most analyses. Even when strategic analyses have included environmental factors, they have applied political or economic models that may be inappropriate for complex, ecological issues, and have relied upon identification of what seems ‘most probable’ from the perspective of widely accepted information.

The true value of strategic intelligence, however, is not to provide information on what is generally considered most probable. Such information is often already available, and does not provide warning capabilities that allow for effective preparation of potentially disastrous events. Rather, what is most useful may be identification of black swans, sometimes statistically referred to as ‘fat tails’ or ‘long tails’. These are the high-impact, low-probability events that create enormous disruptions when they do occur. The impacts and dislocations that such events create are disproportionate in large part precisely because we are not expecting them to occur, and people underestimate their likelihood because they have no past experience with such conditions. Yet things that have never happened before happen all the time. Whether one refers to the attacks on September 11, 2001, or the sudden collapse of the North Atlantic fisheries, events occur that people insist should have been anticipated, yet are irreversible once they take place. Had certain scenarios but considered plausible, the anticipatory actions may have reduced related risks, and the non-linear shift in conditions may not have taken place. Enormous difficulties lay in identifying potential risks, assessing the system complexities and tipping points, and being able to communicate these threats effectively to policy makers.

To use the terminology from security studies of a ‘surprise attack’, the three primary ingredients can apply to abrupt climate change impacts if one removes the deliberate action and existence of an aggressor. According to Kam (1988) and reviewed by Parker and Stern (2002), the three components are: the event is contrary to expectations of future events, that there is a failure of advance warning, and that the event exposes a lack of preparedness for the given situation. Admittedly, removing the aggressor and the action make early warning and advance preparation difficult from a cognitive perspective, as past security issues have almost always contained primary actors. Environmental conditions, by contrast, tend to be unintentional outcomes of collective action, and are therefore perhaps less visible. Strategic surprises, like emergent environmental problems, have generally occurred when ample information is available to respond to the situation, yet the risk was not recognized or acted upon by policy makers. The obstacles to effective foresight in environmental security consist of several major factors: organizational ‘stovepipes’ preventing communication, scientific expectations for strong causality and methodological conservatism, and cognitive risk perception biases of past experience and underestimation of rare events.

The organizational obstacles for abrupt climate change warning exist both at the scientific community and within the larger policy communities, and are not limited to specific countries. The problems
relate to a mismatch between rules for uncertainty in scientific and policy communities, and organizational flows that prevent data sharing between concerned parties. As to the first issue of uncertainty, scientific enterprises rely upon methodologies that are inherently conservative in making judgments according to available evidence. The internal logic of scientific research posits that when uncertainty exists in describing causal relationships, it is better to commit the possible error of false negatives in drawing conclusions, and that overwhelming evidence in the field is generally necessary before conclusions can be reached. In other words, in any given study, scientists are professionally obliged to claim “more research is needed” rather than risk claiming a causal relationship that might be untrue. By this process, which is strictly regulated by peer review, scientists try to ensure that the scientific literature does not contain significant false claims that, for example, chemical A at levels of 5 parts per billion in drinking water will cause adverse health effects.

The practical implication of such methodological rules is that research into environmental and health fields can seem painfully slow at times. Epidemiological rules of evidence and causality, which are very strict in preventing false claims, are often insufficient for providing advance warning of public health risks. Likewise, climate science, dependent upon modeling of complex and chaotic systems where prediction is extremely uncertain, will as a field be reluctant to claim causal relationships. When combined with IPCC rules on consensus among all scientists and brokering by political actors, the evidence presented in the IPCC reports is often somewhat dated, and only mention the most probable outcomes and most widely accepted models. The IPCC is therefore criticized both for the inaccuracy of its predictions (it has been consistent in under-predicting the rate of climate change), while at the same time its admission of scientific uncertainty is amplified by climate change skepticism as supposed evidence that the research isn’t actually scientific, a gross misunderstanding or portrayal of the process.

Such scientific rules for uncertainty are made more complicated by the organizational challenges of coordinating research and communicating information. Understanding the risks and impacts of abrupt climate change requires interdisciplinary cooperation among researchers, which is often hampered by disciplinary boundaries and organizational fragmentation at universities and research centers. Security impacts of abrupt climate change are even more difficult to coordinate, owing to a nascent field of environmental security (which does not even possess its own research journals), and historic lack of cooperation between environmental scientists and those specializing in traditional security fields. Among policy makers and the intelligence community the issue becomes one of historical security ‘firewalls’, meant to prevent unauthorized access to sensitive or classified information. Lack of information sharing among and within agencies is problematic even for traditional security concerns, but it is especially ill-fitting for environmental science issues that rely upon free flow of data, and where expertise exists not in the government agencies, but among international communities of researchers.

Even when information is available, however, there can be cognitive barriers to effective recognition of potential risks. If one treats foresight as an exercise in risk assessment, the bias of past experience must be taken into account. This bias, which applies both to risk perception and to construction of methodological tools, results in underestimation of future risk probabilities. Probability estimations are based upon past experience and familiarity, and in general people do not expect nor plan for those events with which they have had little experience. The bias can be made structural by the manner in which assessments are constructed, where only certain measurements and observations are considered, while others are largely ignored. The existence of the ozone hole over the Antarctic, the basis for the landmark Montreal Protocol on CFCs, was contained within NASA data but not actually ‘seen’ until much later. Simply put, few people thought to look for it. Likewise with climate change issues, abrupt change was not even considered a possibility until paleo-climatological studies in the 1990s demonstrated the historical record of rapidly shifting temperatures. Until that had been established, the common perception of climate change was that it shifted over much longer, often geological, time periods.

Even within statistical analyses, people largely underestimate infrequent events or the interactions between increased probability in complex systems. For example, Freudenberg (1988) demonstrated that in a system with dependent components, we underestimate those areas more vulnerable when the risk is reduced to numerical probabilities. If part of the
time (10%) a system has a one-in-a-billion chance of failure (10^-9), most often (80%) has a one in a million chance (10^-6), and for only a short period has a one in a thousand chance of failing (10^-3), people would often assume that the more fragile and more resilient time periods would balance each other out. In terms of actual probabilities, however, the chance of system failure over the entire period would be approximately one in ten thousand (10^-4). People underestimate the effects of changing conditions on total risk, and also will often focus on probabilities and ignore the enormous magnitudes of some events. Even if unlikely, the total risk is a function of hazard and probability, so that those hazards with extremely high impacts are taken seriously even when rare.

The final obstacle to assessing environmental risks to security has been the difficulty in translating environmental risks to security concerns. People typically understand risks in terms of preconceived categories of thought, and when applied to security such categories involved Cold War models of state-level analysis and explanations for violent conflict. The challenge for understanding abrupt climate change and security is not only to understand tipping points for climatic and ecological systems, but deeper understanding of how such changes are both caused by and impact groups and regions are varying levels. (Halden 2007; Paskal 2007)

Recent events have shifted perception of potential impacts from climate change. Yet despite popular intuition that climate change issues affect national and international security, it remains difficult to conceptualize what these connections may be, particularly for a global process so rife with uncertainty. Without a useable framework for analysis, policy action and discussion will remain difficult and a form of policy paralysis may result. (Barnett 2001) The following sections explain briefly the contradictions that climate change possesses with regard to traditional security, before reviewing alternative definitions of vulnerability and risk assessment.

### Security and climate change

Connections between environment and security began with medical concerns over nuclear weapons tests in the early 1960s, but the debate over environmental determinants for security concerns dates to 1989. Dominant among the earlier 1990s studies were those postulating that increased resource scarcities would lead directly to violent conflict between states, often as a result of population increases in less developed countries. Such scarcity-conflict models relied upon traditional models of security as interstate conflict, and largely assumed linear relationships in terms of both causality and decision-making. Academic criticisms highlighted that scarcity does not necessarily result in conflict, that such causal relationships were nearly impossible to substantiate even post-facto, and that a focus on the state level misleadingly ignored interstate economic relationships that exploited natural resources from afar. (Gleditsch 1998; Hauge & Ellingsen 1998)

From a policy perspective, the scarcity-conflict theses could result in a form of paralysis, as conflicts were blamed on natural conditions and population levels in foreign countries, with little if any direct connection to wealthier, western states. (Kaplan 1994) Although general development may help in the long-term, the logical response to scarcity-conflict explanations was to bolster border defenses and justify the issue as an external problem. Even those concerned with cross-border environmental issues in environmental security tended to downplay the potential role of climate change. (Homer-Dixon 1991)

### Environmental security contradictions

Conceptions of national security often used by both political science and popular understanding contain a number of artefactual assumptions, ways of thinking that must be addressed before we can understand the difficulties inherent in climate change and security connections. Daniel Deudney first explained many such contradictions at the end of the Cold War (1991), at least in reference to traditional security definitions. It is arguable that potential obstacles have expanded since that time. In brief, these potential problem areas are:

1. Complexity of variables and non-linear nature of relationships.
2. Irreversible nature of environmental systems.

3. Vision of environmental issues as external to political, economic, and social systems.

4. Focus on state level analyses imposes false divisions between relevant factors.

5. Visions of environmental systems as ‘natural’ and root causes of issues.

These issues have been present in many of the attempts to address climate change and security in recent years, with abrupt climate change first appearing as a security issue in the 2003 Global Business Network (GBN) report commissioned by the US Department of Defense (Schwartz and Randall 2003). Since that time, similar reports have been released by the Center for Naval Analysis (CNA 2007), Directorate for National Intelligence (NIC 2008), Global Business Network (GBN 2008), US Climate Change Science Program (CCSP 2008), German Federal Ministry for Economic Cooperation & Development (2002), German Advisory Council on Global Change (WGBU 2008), Swedish Development Agency (SIDA 2008), European Commission (2008), and others. These reports have been valuable in raising awareness of climate risks, and some (particularly the CNA report) have lent considerable credence to climate change scenarios in audiences that formerly had not readily accepted such possibilities. Most of the reports however, with the notable exception of the 2008 Swedish contribution, were hampered by several shortcomings in analysis which are detailed below and which led to potentially conflicting policy prescriptions. An over-reliance on IPCC data and projections, continued use of violent conflict as the measure of insecurity, and use of the state as the unit and level of analysis, narrow our understanding of the risks of abrupt climate change in several crucial ways.

To take one example, the 2007 GBN report is a good start on vulnerability, but in some ways the authors employ terminology like systems theory and nonlinear effects without really changing views of things. Climate and the environment are still seen as external factors, not integrated within systems themselves. They also mention ‘threshold’ effects without really mentioning feedback mechanisms, which thus remains a (bifurcated) linear relationship. They do not define what is meant by vulnerability, and imply fragility without using the term or explaining it. The notion given is one of either a working or collapsed system, not the ecological understanding of multiple stability points that more accurately describes nonlinear shifts. And underlying many of their explanations of resource changes are assumptions of scarcity-conflict, little different from the 1990s linear-causal models (Homer-Dixon 1991, 1994).

Popular perceptions of environmental issues are based upon notions that environmental conditions are largely static, that they remain more or less the same over time save for outside interference by human actions or some other overwhelming interference. Ideas of a stable environment even influence ecological sciences by the earlier adoption of ‘climax ecosystem’ models, positing that disrupted environments return to one ‘optimum’ level once human interference is removed. Such ideas are further reinforced by the widespread use of ‘stock measures’ as a metric for environmental health, where measurable amounts of forested land, open grassland and similar items are considered comparable and meaningful (Lomborg). Such approaches, however, limit understanding of non-linear and complex environmental systems.

**Systems Theory**

In contrast, ecological systems (including the global climate) are better understood as complex emergent systems. The units of environmental systems, however defined, are not nearly as important as the relationships and networks between a system’s components. Properties of the system cannot be determined simply by reference to its components, nor can the future state of a system be understood in reductionist terms. Change can occur while maintaining the integrity of the system, but the system may shift to multiple points of stability. Such shifts, as with eutrophication of lakes, may occur quite suddenly and with little indication that conditions may suddenly ‘worsen’. Likewise, paleo-climatological studies have indicated that atmospheric temperatures can shift very suddenly, perhaps as much as 10-20 degrees Celsius within a few years. Similar, sudden temperature shifts occurred 12,000 years ago at the
What are less well understood are the ‘tipping points’ in such systems, technically known as catastrophe sets. How far can a system be pushed before it shifts to a new level of stability? What are the most relevant relationships? In climate terms, the most pressing questions concern what amount of greenhouse gases (GHGs) can the ecosystem absorb before a large-scale shift in climate stability occurs? Atmospheric temperatures may rise gradually over the years, as per the standard IPCC projections, but then suddenly rise (or fall) precipitously. The National Research Council’s 2002 report on abrupt climate change described several qualities of the system that creates ‘abruptness’. First, the system is nonlinear, and shifts from one condition (often measured as temperature) to another rapidly, perhaps within a number of years. Second, this change is irreversible as measured by human time scales, a condition made even more likely by the long-term forcing of GHG emissions and atmospheric CO2 lifetimes. Third, the changes may occur due to second-order effects of the global system, as positive feedback loops originally unrelated to the more obvious forcing (e.g., Arctic methane gas release caused by melting permafrost). Finally, abrupt changes are often categorized as such due to the inability of related systems to adapt, leading to the possible description ‘dangerous’ climate change. The danger does not necessarily stem from threats of violent conflict between people. Climate change is very unlikely to lead directly to conflict, but may adversely affect social, political and economic systems at varying levels, and these overlapping systems may contain feedback loops that accelerate the stability shifts.

Most issues concerning resources and conflict stem not from changes in the environment as a root cause, but rather, the failure of political and economic systems to provide adequate resources or adaptation measures. At times such failure can be deliberate, as with resilience and livelihood targeting during violent conflicts. (Briggs et al 2009; Brown 2004) At other times these failures can be second or third-order effects, such as the breakdown in food and health security currently being experienced in Zimbabwe. The effects of climate change in such
situations have been conceptualized as ‘threat multipliers’, conditions that exacerbate risks and make adaptation more difficult, but not conditions which could be understood as the root causes of conflict. The concept of abrupt climate change is both quantitatively and qualitatively distinct, in that such sudden shifts in environmental conditions will not merely emphasize existing inequalities and conflicts. Vulnerable systems, be they ecological, political or economic, may ‘fail’ completely should environmental conditions shift much more quickly than adaptation allows. (Gallopin 2007) Failures of systems need not be understood in simple, binary terms often used to describe failed state in political science. Rather, unstable systems will find a new, often lower, level of stability and operation, often resulting in severely negative consequences for certain components or populations.

Environmental issues are not necessarily more complex than the socio-political conditions that give rise to violent conflict, but it is far more difficult to attribute intentions or divination of rational thought to how conditions change. Global environmental conditions are also inextricably linked to social, political, and economic systems, which can further compound uncertainty when analysts would prefer to study systems as discrete collections of isolated variables. Thus climate change is not merely the interaction of a few variables, where a simple, linear relationship exists between levels of atmospheric greenhouse gases and average atmospheric temperatures. Rather, the global climate is a complex system, exhibiting emergent properties and influenced by numerous feedback effects, none of which can easily be predicted in advance. Just as with ecological systems, the climate may rest upon multiple points of stability, but these stable levels may be unsuitable for both existing human and environmental adaptation.

The concept of ‘abrupt’ therefore applies not only to the sudden shifts in average air temperature, but also adaptive capacity and our ability to anticipate such changes. The ability of people to respond to environmental change depends, at least in part, on the congruence between the rate of expected change and the actual physical changes that affect a particular group. Ecosystem resilience does not depend upon perception of the problem, but is very much tied to both rate and extent of change. Overall, there are four primary components to the concept of vulnerability, and to understanding what makes a particular system more or less able to adapt to changing circumstances. Responses to environmental changes can be both positive or negative, and the ability of a system to react positively or adequately does not merely depend upon the most visible characteristic of the system in question. Resilient ecosystems may have high or low numbers of species, economic systems may be more vulnerable as wealth increases, and adaptation to climate change may depend upon factors not yet well understood.

**Vulnerability: risk, sensitivity, resilience and fragility**

Policymakers and analysts perhaps assume that regions like Africa are more vulnerable to climate changes, and recent reports have focused on lesser-developed regions to create risk scenarios for climate change and security. (Brown et al 2007) That estimation of vulnerability is true to an extent, but only by one aspect of the components of vulnerability. As security implications are based upon notions of vulnerability to climate change, it is notable that often a full definition of vulnerability is omitted from analyses, and what is meant by these terms makes little reference to previous work in risk and ecology. Vulnerability in disaster studies (Wisner et al 2005) and livelihood models (Lantze & Raven-Roberts 2006) can provide a guide to framing risks from abrupt climate change. Vulnerability is a general term for risk from environmental change, but is constituted from risk/hazard, sensitivity, resilience, and fragility measures. (See also Brooks 2003; DeFur 2007; Gallopin 2006)

The first component of vulnerability is risk, or the probabilistic measure of adverse outcomes to which a particular group is exposed. Often the most traditional measure of vulnerability, the extent of risk is a function of probability of hazard and the exposure level \( R = [H, E] \). In some iterations, this function is modified by the level of ‘vulnerability’, meaning the extent to which the effects of hazards can be miti-
Health studies have demonstrated that those groups with the largest stocks of social capital are most likely to recover from outbreaks of illness, while recurring illnesses leave neighborhoods and cities vulnerable to any number of additional stresses, often creating a downward spiral of vulnerability.

The last factor in vulnerability is fragility, a measure that represents the variable nature of the factors above. Rather than conceive of resilience as a ‘stock’ that merely exists and is drawn down over time, fragility represents the extent to which a group can be stressed before its underlying resilience and support networks are permanently weakened. Resilience is an emergent property of social networks and interaction, a society’s ability to respond from taxing events may be permanently damaged if pushed beyond a particular limit state. Once this limit state is exceeded, the ability of groups to respond and adapt is undermined in crucial ways, possibly resulting in the society falling to a lower level of stability. Fragility is not a matter, as some political analyses would suggest, of a binary stable/unstable categorization, but rather describes how vulnerable a group is to a stability shift (catastrophe set) to an entirely different set of relationships and adaptive capacity. When combined, these factors of vulnerability help to describe those system components or conditions that need to be assessed if we are to understand potential security risks of abrupt climate change. One can begin by considering the geographic region where the climate system is most sensitive and potentially fragile, the Arctic.

Abrupt climate change risks in the Arctic

The Arctic may provide a useful illustration of how foresight of environmental conditions and knowledge of non-linear effects can contribute to a greater understanding of potential impacts. Rather than examine global models of average climate change, a number of potential tipping points exist in Arctic ecosystems that can trigger abrupt climate changes worldwide.
Greenland and Arctic ice melting

The geopolitical implications of loss of Arctic summer sea ice are potentially profound, but are beyond the scope of this assessment. From an ecological perspective, loss of sea ice will affect global albedo measures and wildlife, but would not have any effect on either sea level or freshwater intrusion into deep ocean currents. The more problematic issue for Arctic-climate systems is the stability of the Greenland ice sheet (GIS), a frozen reservoir of fresh water locked into 2.85 million km³ of ice that has existed since the late Pliocene period over 100,000 years ago. Should the entire ice sheet melt, the resulting meltwater would raise global sea levels by approximately 7 meters (23 feet), while significant melting may affect the salinity and stability of the thermohaline circulation (THC) that drives the warm waters of the Gulf Stream. (Alley et al 2003)

Original estimates of global climate change assumed the long-term stability of the Greenland ice sheet, indicating that any significant melting of the ice sheet would take hundreds of years, if not millennia. (IPCC 2001) More recent observations of ice melt indicated that the rate of net runoff was far higher than expected, and that loss of GIS was accelerating rapidly. The melt rate exceeded possible scenarios from ice sheet models, and scientists soon discovered that water intrusion to the glacial bases through moulins resulted in lower friction between the glacial and underlying rock. Other nonlinear dynamics were also at work, such as force imbalances between calving sections of the glacier

![Greenland Ice Sheet Melt 1992 to 2002](image)

**Figure 2:** Acceleration of the Greenland ice sheet melt. Source: Environment Canada
and inland sheets. The resulting changes in conditions, combined with higher summer temperatures in Greenland of some 2 degrees Celsius, have resulted in significant reductions in glacial cover and thickness in some regions (especially coastal areas, where summer average temperatures average close to freezing). More recent estimates of GIS stability indicate that it may largely disappear by the end of the century, an abrupt shift that is matched by past climatological records.

The potential impacts of GIS melting are twofold. The first and more obvious concern is rising sea level, a risk that has been downplayed in standard IPCC projections at least until the end of the 21st century. In the potential abrupt climate change scenarios of sudden warming, accelerated ice melt from Greenland could raise sea levels by anywhere from 1-4 meters in the short term or decadal measure, and up to seven meters in a worst case scenario. Historical climate records indicate that abrupt rises in sea level are possible, and would cause obvious and severe dislocation in coastal areas globally. The areas at most risk of coastal flooding or inundation are fairly easily mapped, although the cascading effects of large-scale dislocation must be assessed and measured according to regional social, economic and political systems.

The second impact of GIS melt is the possible interaction between a sudden influx of freshwater into the north Atlantic, and the stability of the thermohaline circulation of ocean currents. Climate researchers have hypothesized that the sudden cooling recorded at the end of the Younger Dryas Period 11,400 years ago, a drop of 10 degrees centigrade over a decade, was caused by the sudden release of meltwater from the Saint Lawrence in North America. The fresh water released into the north Atlantic decreased the density and salinity of the waters at the northern edge of the warm Gulf Stream, preventing the water from sinking. This action effectively shut down the global THC, and may have the cause of the sudden, global cooling of the period. Recent scientific reports have indicated that the northern extent of the Gulf Stream has been shortening, with regional impacts of more severe winters in the British isles and Scandinavia, although it is difficult to discern long-term trends from natural variation. The risk of global warming turning to sudden global cooling is a plausible risk, considering past and geologically recent climatological records, and the global impacts could be quite severe in terms of food security and shocks to fragile ecosystems.

Terrestrial and oceanic methane releases

Much of the focus on global GHG emissions remains on carbon dioxide, but increasing attention is being paid to methane (CH4) concentrations in the atmosphere. Methane is released in greater quantities in the northern latitudes than elsewhere, and the rate of release has been increasing over the past decade (see Figure 3). Explanations for the increase in methane releases initially rested on terrestrial release from melting lakes and permafrost. As warming trends increase more rapidly in the Arctic than elsewhere, ground-cover and lakes begin to melt, thereby releasing methane as a by-product of biotic decomposition. As methane cannot be released while these sources remain frozen, any warming can create a positive feedback effect of increasing methane release increasing warming effects, which then cycle back into increasing warming. This so-called Clathrate Gun Hypothesis is thought to have contributed to or triggered the warming periods of the late Quaternary period. (Kennett et al 2002)

The Arctic areas of Siberia and North America contain large carbon deposits in the form of peat bogs and decomposed organic matter, and scientists estimate that thawing of the region may significantly increase Arctic methane contributions to the global carbon balance. As methane is over 20 times more effective than carbon dioxide as a greenhouse gas, releases have a potentially disproportionate impact on climate change risks. Estimates of natural contributions from only a few years ago have already been revised upwards by approximately 50%, and researchers warn that new 'surprises' in methane sources and feedbacks are likely in the years to come. (Walter et al 2006, 2007)

1 Over a 100-year period, while over twenty years the effectiveness rises to over 70 times.
One such surprise has come from the Arctic oceans, particularly the shallow seas over the continental shelves (e.g., the Barents Sea). The Arctic seas contain large amounts of methane hydrate deposits, also known as methane clathrate or methane ice, a form of frozen water containing large amounts of methane within a crystal structure. This form of methane deposit is created by the decomposition of organic matter in low-oxygen marine environments, where a combination of low temperatures and high pressure creates the hydrates. The Arctic deposits alone contain up to 400 gigatons of carbon, compared with the 700 gigatons of carbon present in the atmosphere. These deposits were formerly believed to be highly stable, and the 2007 IPCC report only made passing mention of their existence. Recent research in 2008, however, has indicated that continental marine deposits may be highly sensitive to changes in water temperature, and that high levels of methane are now being released from areas such as the Barents Sea and Arctic Ocean north of Russia (Rigby et al. 2008; Schiermeier 2008; Shakhova et al. 2008a, 2008b).

Should even a relatively small proportion of the Arctic methane hydrate deposits be disturbed, this process may create a powerful, positive feedback effect that would have substantial effects on climate change globally. Moreover, release of marine hydrate deposits would accelerate release of CH4 from northern permafrost, amplifying a process that, by itself, would be unlikely to trigger abrupt climate change. One outstanding problem is that the research into carbon releases in the Arctic is fairly new, and it will likely take years for conclusive research to establish the thresholds for methane hydrates. Whether such thresholds may have already been crossed by the time that the research becomes conclusive is another question, and one which must be posed to policymakers. As a cautionary tale, these influences in the Arctic are useful, for none of the above-mentioned forces (Greenland melting, Arctic sea ice, methane releases) were included in the 2007 IPCC report as potentially significant influences. (IPCC 2007: 372)

As a result, they are also missing from more recent security reports on climate change, as they rely almost entirely on IPCC data to substantiate potential risks and to estimate future conditions.

Tipping points, cascading effects and forward assessments

Once the initial tipping points in certain systems is better understood, and certain abrupt change scenarios can be played out in terms of possible events, we can assess the potential impacts on various related systems globally. The cascading effects enter where change in one system (e.g., the Greenland ice sheet) results in conditions (rapid rise in sea levels) that have varying impacts elsewhere depending upon the vulnerability of geographic region (e.g., sensitivity to flooding from low-lying coastal land), social systems (resilience to forced migration), economic systems (fragility of infrastructure), all applied at scalable levels and according to analytical needs. Disruptions in those systems then have their own cascading effects on related, complex systems.

Projects and initiatives are underway to provide stra-
Strategic environmental assessments to policymakers, and to link the research community more effectively with interested parties in government, non-profit work, and business. The Environment and Security Initiative (ENCSEC) provides assessments for the OSCE region of Europe and Central Asia, the United Nations Environment Program (UNEP) conducts post-conflict and post-disaster environmental assessments, and individual governments provide scenario and impact assessments according to national needs. The larger need for environmental security is of an open-source, international effort to provide research space for the growing environmental security community. Certain research centers already exist (at the Woodrow Wilson Center and Institute for Environmental Security) and provide international fora, but resource constraints and organization prevent such centers from drawing upon the larger academic, business and government communities of analysts in a systemic way. It may be argued that the best way to approach a complex set of systems with emergent order is to create a strategic intelligence system with similar attributes. Interdisciplinary ‘black swan’ research is more likely to be successful if it can bypass organizational barriers, national parochialism, and instead perhaps create the sort of epistemic community that was successful in solving other transnational environmental issues. (Litfin 1999)

**Conclusion**

Definitions for security (both energy and environmental) and climate change need to be constructed in such a way that policymakers have incentives to pursue mitigation and adaptation, not merely to focus on GHG emissions as the only suitable goal and outcome of the current Copenhagen process. They must also allow integration of energy and environment as key concepts, both as contributing to forcing of environmental systems, and as the possible solutions for cooperation. Such concepts will be inherently complex, involving large amounts of uncertainty and illustrating scenarios that contain multiple feedback effects and cascading perturbations (‘ripple effects’). Simple models and a continued view that environmental systems lay outside of human activity impose artificial barriers on both understanding and solutions.

The point of this exercise is not to provide immediate and concrete answers. It is unlikely that this is even possible, owing to the large amount of uncertainty inherent in the discussion. Rather, we need to provide workable definitions and frameworks for approaching policy, ones that break from past cold war era definitions that assume state security, deliberate action, and violent conflict. Should these definitions be used, we will be looking at the wrong places and at the wrong times.

**References**


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