



Published on Science 2.0 (<http://www.science20.com>)

Climate Induced Migration and Conflict: historical evidence, and likely future outlook

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Created Sep 21 2009 - 4:38pm

Climate Induced Migration and Conflict: A study of evidence, historical cases and causes.

Contemporary civilization over the last five thousand years has enjoyed a period of relative climate stability. Prior to this period of climate stability, the historical record found in as shown in the fossil and ice core records drops off leaving only vague folklore and myths. Global climate events in prehistoric as well as events in more recent times have also led to general migrations and population pressures. While climate variability has created disaster or near-disaster situations such as drought, disease, as well as other extreme events, these relatively short-lived events have a much lower capacity for disruption than the possibility of a climate regime change. Climate stress has also been linked to political unrest that has placed further pressure on vulnerable populations, often also resulting in mass migration. This article will focus on the potential of climate change to cause disruptive migrations among vulnerable populations that have the potential to create instability in both the developed and developing world. First we will explore the physical impacts of climate change on resources such as water, food, and land, as well as the potential of climate change to increase disasters frequencies. The next section of the paper will explore the incentives and pressures populations face when they make their decision to migrate and analyze regions likely to face climate induced migration pressure. The paper will then analyze the prehistoric evidence in which climate change has caused past population to migrate, as well as discuss a few modern and contemporary cases in which climate stress may have been a cause of societal upheavals. The paper will conclude with a discussion of mitigation policies as well as their effectiveness under a climate regime shift scenario.

Climate Change Induced Migration Pressures:

Climate change will result in global changes in climate patterns which will have a net negative effect on populated regions of the world. In addition to mean increases in temperatures and sea levels, a more worrisome trend may be changes in extremes of temperatures, precipitation, and sea levels (IPCC 2007, 46), which overall are likely to cause increased climate migrations if past migrations caused by these events can be indicative of the future (OECD 2008). While a few degrees increase in the global mean temperature seems relatively mild, the extreme swings caused by this increase may cause significant climate changes in regions with a disproportionate number of vulnerable peoples already affected by floods and droughts (IPCC 2007, 25), as well as coastal areas where a majority of the global population resides (IPCC 2007, 11). Extreme heat waves as well as precipitation are likely to increase (IPCC 2006, 24). Abnormally hot weather has been linked to increased incidences of coronary heart disease, cerebral infarctions, and other sudden deaths in the elderly (Pan, Li and Tsai 1995). While sudden heat extremes may not necessarily affect migration decisions, as this population subset is relatively sedentary, extreme precipitation has been linked to diseases such as malaria, as well as cholera *salmonellosis*, and *giardiasis* (WHO 1998), which affect a wide swath of age groups who are capable of migrating. Increased precipitation predicted in a warmer future may result in increased abundance and changing geographic location of carriers such as mosquitoes. On the opposite precipitation extreme, it has been proposed that periods of extended disease outbreaks correlate to periods of low global precipitation (Huntington 1913). Increased heat may also result in droughts that lead to declines in crop productivity and famine. Famines not only increase the vulnerability of populations to infectious diseases (Khasnis and Nettleman 2005), but also push these populations to migrate towards regions of better prospects for food security, as had occurred in the steps of ancient China almost 3000 years ago (Huang et al. 2002).

Climate Change and Water Resources:

Of all the effects climate change is predicted to have, its effect on water resources is perhaps the most prescient with respect to climate migration pressures, whether climate change occurs in a slow, linear manner or an unpredictable abrupt manner. Climate change has the potential to disrupt current water supply, which in turn disruptions the amount and location of usable land resources as well as the security of the food supply. Under an abrupt regime shift scenario, the people would primarily struggle over food, energy and security (Schwartz and Randall 2003). Food production is underpinned by available water resources making water perhaps the dearest of resources that will be affected by a changing climate. While the rise in mean and extreme sea levels will not only contribute to the erosion of coastal lands, increasing the costs of keeping coastal physically settlements inhabitable, it will also cause the further salinization of freshwater aquifers (IPCC 27). However, climate change induced water stress will be coupled with water stress induced by human population growth, which is already on an unsustainable trajectory in many regions.

Under future predicted climate scenarios wherein extreme precipitation events such as flooding and drought become more frequent and unpredictable. While irrigation may provide a short term solution to the growing water shortage problem, if climate patterns change dramatically under a regime shift scenario, the massive investments made in irrigation and water transfer projects will most likely be wasted as old riverbeds dry out and new regions of high precipitation form. There is a strong relationship between average annual rainfall and population density. Furthermore, a shift from irrigated agriculture to greater rain fed agriculture may also be less feasible. When rainfall falls below the threshold of 900 mm, water stress increases to the point where populations will seek to migrate (Blanc and Perez 2007). Thus, the only remaining option for many in developing regions who are adversely affected by climate change with respect to their water resources who cannot afford technology or changes in lifestyle, may be migration. Global migration is estimated to be up to 98 million (OECD 2008).

Regional Winners and Losers:

Climate change will result in changes in precipitation patterns, which in turn will change the human population carrying capacity of the land. While some regions of the planet become drier, other regions become wetter, though overall it seems that the IPCC models project drier conditions. The link between climate change and social migrations is perhaps most affected by the precipitation vector, as it affects agricultural productivity as well as freshwater availability. When considering possible regions with climate induced migration pressure, it is critical to understand the absolute and relative growth rates of the regions, the Gross National Income (GNI) and GNI growth of the region, as well as the climate change precipitation and runoff model predictions. Areas with low growth rates require workers to fulfill the needs of the aging population, and thus may welcome migrants, though in modern examples, this has led to friction and conflict. Furthermore drier areas will have a lower population carrying capacity. Finally, regions with low GNI will suffer from a lack of technology implementation, as well as increased levels of climate induced social tension if GNI levels are flat or negative.

Precipitation directly affects the carrying capacity of a region. Urban density capacity has a strong correlation to the precipitation levels of a given region within a band of precipitation levels. In Africa, regions with below 400 mm of precipitation per year generally do not have any available runoff after rainfall, and thus population cannot be concentrated anywhere except near direct sources of water such as streams and lakes. Between 400 mm and 1000 mm of rainfall, runoff increases, allowing potential to channel the runoff to productive uses; the relationship between population density and rainfall follows a linear relationship between these levels of precipitation. Finally, above 900 mm, the linear relationship begins to fall off and a correlation between rainfall and population density is no longer strong (Blanc and Perez 2007). While this exact relationship may not hold for all regions, as different intra-annual patterns of rainfall will affect the amount of usable runoff available to the population, the general conclusion that, within limits, population density and rainfall are correlated makes intuitive sense. Figure 1 shows the Quartiles of Density distribution conditional on average rainfall in Sub-Sahara Africa. In general, the level of precipitation had a direct correlation to the urban density carrying capacity.

Figure 1: Quartile of
Density Distribution vs. Average Rainfall in Sub-Saharan Africa

Source: Blanc and Perez
2007

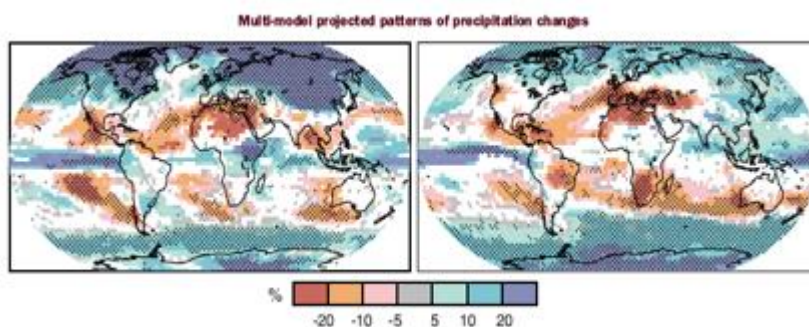
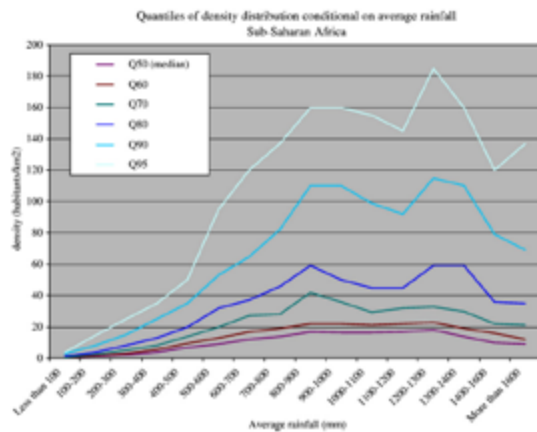


Figure 2 IPCC Multi-model projections of changes in
patterns of precipitation between 2090-2099 and 1990-1999 for December to
February (left) and June to August (right) Source:
(IPCC 2007).

From the assumption that decreased precipitation leads to decreased carrying capacity, some estimates may be made as to regions that will face migratory pressure due to decreased carrying

capacity of land as a result of reduced precipitation and runoff, as well as regions that may actually benefit from climate change. Many GCM forecasting models have been run which have created maps of potential changes in precipitation and changes in runoff. Net losers are proposed to be areas with lower precipitation. In regions where areas of low carrying capacity expand, pressure will bear on individuals to find finer pastures. In Figure 2 it is generally apparent that in the Western Hemisphere, the Caribbean countries, Central America, and Brazil will be net losers in both the summer months and the winter months. This may place further migration pressure on Central America, with the logical receiving regions being the United States and Canada, where the change in precipitation is generally positive in Canada during the winter months, and neutral during the summer months for the United States and Canada. This migration may exacerbate existing resentments of the native population. Furthermore, Brazil will also face migration pressure that may cause its population, which is already heavily concentrated along the coasts, to migrate towards the wetter Western and Southern regions of South America.

A particularly worrying trend is the extreme loss of precipitation in North Africa and the Middle East, as well as Central Asia during the winter and summer months. Raleigh and Urdal (2007) found a population growth coupled with water shortages produce a significant increase in conflict outbreaks, where water shortage increased likelihood of conflict by only 6% without population growth versus 30% with high rates of growth. The Middle East is already a volatile area that possesses a population with a high growth rate, high rate of economic inequality, and negative projected change in precipitation. Western Europe is already a major receiver of immigrants from this region, with significant resentment building against the migrants in this region. However, Western Europe also faces a dilemma in that its population growth has fallen to replacement levels (World Bank 2007). Thus, the existing population depends on economic migrants to support its aging population. This is a significant contrast to the United States which has a higher birthrate than Europe. Further migration pressure from the middle eastern countries, which do not share a similar culture, but do share a history of enmity, as well as the falling predicted precipitation levels in Western Europe may make this a particularly threatening flashpoint in the future.

The changes in runoff shown in Figure 3 are generally correlated to figure one. An interesting observation that may be drawn from the two figures are that two regions which face significant water stress, Western Africa and Northeast China, which possess the lowest per capita arable land in the world (Reuveny 2007), may actually benefit from the changes in climate, though this is not certain as increased precipitation must also be moderately spaced rather than extreme in concentration to be useful to the existing population. Despite the increases in potential carrying capacity in Western Africa, its proximity to the Middle-east may make it an attractive region for migrants from that region, putting further pressure on the existing population. On a positive note, North East China, which faces severe water shortages may actually enjoy aquifer replenishment with increases in available rainfall and runoff alleviating the problems that region faces. Furthermore, Northeast Asia is not near another region that faces significant declines in precipitation or runoff near the end of the 21st century, and thus may actually benefit from the changing climate without facing significant immigration pressures from the immediate surrounding regions.

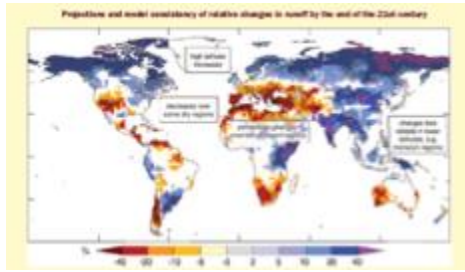


Figure 3: Projections of relative changes in runoff by the end of the 21st Century and Figure 4: Projection of World Population to 2030.

Source: IPCC 2007 and OECD Environmental Outlook to 2030

Conflicts caused by Climate Change Induced Migrations:

Historians and policy researchers have speculated that past and current migrations have been induced by changes in climate. Migration incentives may be divided into two types: push and pull. On the one hand, pull factors include improved quality of life, as well as access to existing immigrant social networks within a country, and are more likely to induce middle-income migration which currently makes up a large proportion of migration to developed countries. On the other hand, push factors are the primary factors that involve climate induced migrations. These migrants typically leave their homes because of the threat of starvation (World Bank 2007). Because of their increased mobility, middle income migrants who are also pushed to leave their lands by climate change may doubly damage the prospects of the source country. Those best equipped to implement mitigation strategies are also the best fit to emigrate. Climate stress induced migrations have been theorized to result in violent conflict as migrants from less developed cultures have invaded more developed settled cultures, though whether the actual cause of migration and conflict are related to climate factors or more the result of political factors is in dispute. Contemporary research supports the idea that environmental degradation causes more internal conflict than international conflict (Raleigh and Urdal 2007). Slow onset climate change tends to produce migrants while rapid onset events produce refugees (Meze-Hausken 2000). Thus, in contemporary history, it is difficult to find cases of true climate change induced migrations, though cases of climate variability induced migrations may serve as good analogues for predicting migrations due to climate change. Even in ancient history, only one real climate change event, which occurred approximately 3100 years ago which might be properly considered a climate change event rather than multi-decadal or multi-century

variability, while the rest of the migrations in which climate played a role are properly classified as climate variability induced. Migration leads to conflict because of competition between native populations and migrant populations; furthermore, populations that lack shared values or have historical enmity may face ethnic tensions as well as distrust. Conflict may also arise out of socio-economic lines as poorer migrants overwhelm an existing social structure (Reuveny 2007). A study by Raleigh and Urdal (2007) using geospatial statistics found that the direct impact of climate change, such as land degradation and increased water scarcity had a far lower impact than political and economic stress. However, climate may have both a direct and indirect influence in encouraging migrations in which lowered crop yields drove migration directly, while outbreaks of civil and international war also led to migrations, though the outbreak of wars cannot be directly correlated to climate change.

Prehistoric Examples of Climate Migration:

Civilizations depend on periods of relatively stable climate conditions to develop and prosper. In the past, highly developed and settled civilizations have been undermined by invading peoples who were very likely migrating in search of more productive lands after their native regions suffered from changes that decreased its carrying capacity. This section will discuss the cases of China and Rome, the Mongol Invasion of Europe, as well as a few prehistoric cases based on circumstantial evidence. Figure 4 provides an interesting proxy for precipitation levels based on tree ring records in California derived from 450 *sequoia gigantea* and derived precipitation data from Asia based on written records from 1300 BC to 1800 AD, which are less scientific, but appear to have some correlation to the tree ring records (Huntington 1913). It should be noted that in general, the absolute value of precipitation is not as important as the first derivative of precipitation levels. This may be due to dynamics in which settled populations grow used to a particular carrying capacity when the climate is stable and maximize this carrying capacity. However, when climate takes a change for the worse, the region where a developed civilization resides is already supersaturated and has to cope with a falling carrying capacity. For a highly developed and adaptable civilization, degrading environmental conditions may result in innovation. However, for less developed cultures, the pressures placed by a poor climate on crops may result in immigration. With climate change synchronized throughout large regions, internal and external pressures would lead to migrations as well as conflict and potential collapse of settled civilizations (Huntington 1913). Perhaps the most interesting and apparent period of climate stability is the period from 100 BC to 100 AD. This period was the height of the Roman Republic as well as the beginning of the transition of the Roman government into its imperial form. The wars fought by Rome during this period were typically offensive in nature and were not in defense against invading barbarians, as were later wars, but rather against settled peoples (Huntington 1913). The steady decline of the Roman empire in the west also seems to coincide with the steady fall in precipitation from 200 – 400 AD, with the final sack of Rome by the Vandals that most historians consider the fall of the Western Roman empire occurring in 455 AD following the first sack of Rome by another Germanic tribe in 410 AD.

Other examples of cultures that could not cope with climate change include the Mayan Civilization and the Akkadian civilization. Interestingly, the height of the Mayan civilization began during the classical period when Rome was at its height. The Mayans developed one of the most accurate calendars known to man, and built pyramids which rivaled those of ancient Egypt. However, by the middle of the 1st millennium, the Mayan's were facing multi-year droughts which correspond to the low period in the tree-rings from Figure 4 which may have ultimately contributed to its demise (Haug et al). There is evidence of sand dunes overwhelming irrigation channels during the middle of the 1st millennium in Mesoamerica showing the link between increased aridity and the decline of civilizations (deMenocal 2001). Similarly, the decline of the Akkadian civilization in Mesopotamia approximately 4100 years before present (BP) also paralleled a strong decline in the North Atlantic sea surface temperature, as well as an increase in the aridity in the region (deMenocal 2001).

In China's history, there are two interesting examples of possible climate induced migrations overturning the dominant culture and ruling dynasty. The Shang dynasty is considered by historians to be the first Chinese dynasty that united China and one of the first cultures in the Chinese region. The Shang dynasty lasted for about 500 years from 1600 BC to 1100 BC. However, the Shang were overthrown by an invading Zhou culture who originated from the Loess Steps of central china. Circa 1100 BC, there was a major drought in China, shown by high resolution soil sediment data. This led to famine which ultimately led to a southward migration of the Zhou people, as well as internal disorder within the Shang Dynasty (Huang et al.). It may be noted by referring to Figure 4 that the period of Shang dominance also coincided with a period of relatively high precipitation and only ended with an abrupt drop in precipitation as measured by the Californian tree ring samples. Later, China's Han dynasty, from which the ethnic majority of modern-day China derive their name, lasted from 206 BC to 260 AD, also enjoyed its classical period during the same period as the Augustan Era and collapsed during the same a period of declining precipitation as Rome. Its collapse also occurred as a result of invading barbarians from the north (Huang et al.). In 1000-1200 AD there is also an apparent downturn in precipitation. It may be recalled that during this period the Mongol invasions began, which resulted in the conquest of most of the known world at the time from China to Germany. During this period, the Asian steppes from which the Mongols originated were particularly dry (Huntington 1913). That the invasions began to cease in 1200 seems to be another coincidence in dates that is too strong to ignore, as the degradation in precipitation levels begins to settle around the same period.

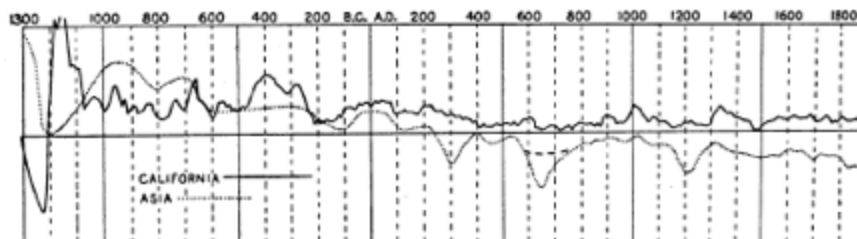


Figure 4: Tree Ring Thickness in California and derived rainfall data in Asia. Source: Huntington 1913

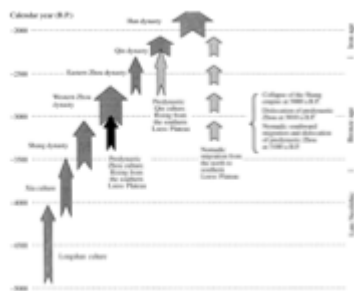


Figure 4. The historical chronology of the western Loess Plateau of China and the major social events happened at ca. 1000 A.D.

Figure 5: Historical Chronology of Chinese Dynastic periods and invasion threats that ultimately lead to the overthrow of the ruling dynasty.

Source: (Huang et al.)

While these circumstantial connections do seem to have some logical bearing, Huntington's theories have also been criticized and even said to be "discredited" (Lamb and Ingram) or highly controversial, though influential none-the-less (Glantz 1990). In order to establish a firmer basis of inquiry, it may be useful to conduct statistical studies based on defined historical events to determine their correlation with climate. A model could be written as a time series regression test with a dummy variable for significant historical events, further categorized as stabilizing or destabilizing events, tested against the rate of change of precipitation levels. Again the categorizations could be somewhat arbitrary, but a survey of historians may allow for some basis for classification.

More recent examples of climate induced migrations as well as resulting conflicts are many. While not all of the cases led to wars, they did put pressures on the surrounding regions. In Reuveny's study, thirty-six out of thirty-eight conflicts occurred in less developed countries while only two of the cases of climate induced conflict occurred in developed countries. Of these, "nineteen cases involved interstate conflict, 6 cases involved intrastate conflicts, and thirteen involved both." (Reuveny 2007, 662). In South Asia, climate migration induced conflicts occurred in India and Bangladesh due to droughts, floods, erosion and scarcity. These migrations resulted in ethnic conflicts within the community as well as religious conflicts. In the 1970s and 1980s, worldwide drought caused a number of migrations and conflicts to occur. Ethiopia faced a case of conflicts arising from water scarcity, land degradation and drought that led to internal nomad and farmer conflicts over land (Reuveny 2007). The total land degradation reached 30 million tons of top soil (Keller 1992). Estimates of total migrants in Ethiopia due to the climatic event range from 116000 to 1.32 million of the total Tigrinian population of 2.4 million. Internal migration within Ethiopia during the early 1980s also numbered 3.2 million people. It is interesting to note that there were no statistically significant relationships between vulnerability of the population and the months until migration though the underlying conditions of Ethiopia made it such that when droughts occurred, the ability to absorb this shock was low for the population in general (Meze-Hausken 2000). However, it is also not clear that environmental degradation caused migrations and deepening vulnerability, as the region had already been wracked with civil wars as well as inter-state wars, which degraded the ability of the government to mitigate climate risks (Keller 1992). Thus, Ethiopia seems like a case where the interaction between climate and society created a non-linear impact of climate variability on the vulnerable population. In El Salvador a border war between El Salvador and Honduras broke out due to famine and migrants, which brought conflicting social classes to arms in each country (Glantz 1990). Finally, a very clear case of environmental degradation related migration pressures is the evaporation of the Aral sea has led to almost 100,000 migrants annually, though intrastate migration in general led to less severe conflicts than interstate migration (Reuveny 2007). Water tension has also contributed to the Israeli-Arab conflict, though migration was not a factor in this tension (Amery 2002).

Abrupt Climate Change Events in Prehistory:

The most threatening scenario is abrupt climate change in which a sudden shift in climate due to a change from one steady climate state to a new radically different state. In the past there have been incidences of this scenario. It has been demonstrated that abrupt climate change in high latitudes also corresponded to abrupt climate change in low latitudes through a demonstrated correlation between high latitude ice cores and low latitude sea sediments. Abrupt climate shift has been attributed in 850 BC by Geel et al (2004). There is evidence that abrupt climate change events occurred over a period of 200 years (Kemp) rather than much longer timescales, implying an exponential phase in rate of Climate change. During the Jurassic Cretaceous time within the

Mesozoic period there is significant evidence within sea sediment samples that rapid climate shifts occurred. While the timescale of these shifts are in the tens of thousands and hundreds of thousands of years, cold snaps are hypothesized to be the result of changes in ocean circulation or rapid release of methyl-hydrates (Jenkyns 2003). For example, the climate may reverse if the Thermohaline Circulation collapsed (Hulme 2003), as was postulated to have happened 8000 years ago when the ice of the great lakes melted into the Atlantic ocean. Northern Europe had a little ice age. The coastline of California also changed dramatically between 10000 to 3000 years ago forcing human settlements to shift rapidly. However, because population density was relatively low in these regions, the impact on human settlements were not devastating (Kennet et al). Figure 4 correlates well with figure 6 showing severe climate instability circa 3000 BP, where the surface air temperature as derived from models of thermohaline collapse due to ice melt over Greenland rises abruptly and precipitation levels seem erratic.

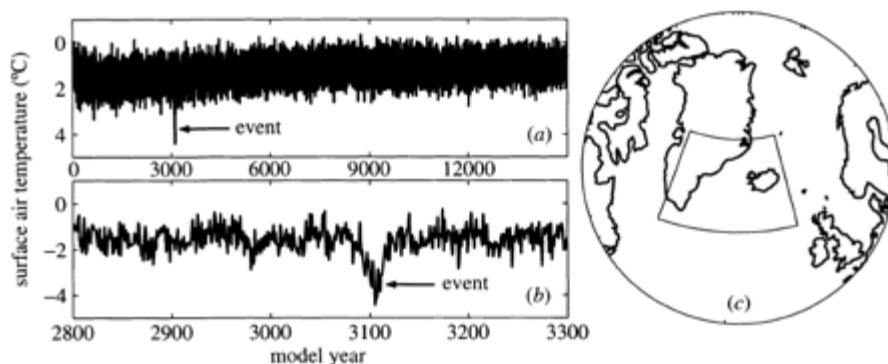


Figure 6. In 3100 BC there was a climate event focused around Greenland caused surface temperatures to increase dramatically.

Source: (Hulme 2003).

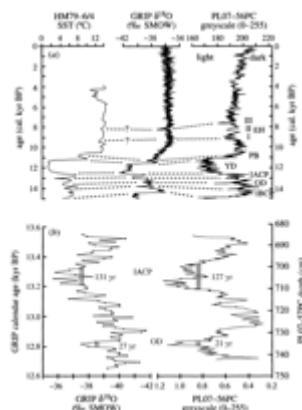


Figure 7 shows an event that occurs about 8000 years ago, Furthermore, there were also more frequent shifts prior to this period approximately 10,000 years ago, and 1200 years, with erratic changes prior. This data is interesting because it correlates to the erratic behavior of the early part of the climate record presented by Huntington (1913).

Figure 7. Sea Sediments: 10000 and 13000 years ago there was an abrupt climate change.

Climate change will place pressure on existing stocks of natural resources upon which local populations survive. Of the natural resources that are affected by climate change, perhaps the most important is the availability of freshwater. Based on maps of population growth and predicted precipitation change, projections of regions with potential migration pressure may be made. Migration can be both international and internal. While in ancient history, periods of high aridity correlated to periods of large migrations as well as the collapse of civilizations, further study must be conducted to understand the relevance of history to modern conditions. Statistical analysis conducted on available quantitative data has produced results that show small but significant relationships between resource degradation and conflict, though the relationship is much stronger for internal, civil conflicts than for international conflicts. However, because the data available is relatively short compared to the events recorded in the historical record, the previous conclusion can only be held tentatively. An abrupt climate shift would be potentially devastating, not only nullifying existing mitigation strategies and technologies, but possibly causing mass migrations on an unprecedented scale. Thus, it is this paper's tentative conclusion that the majority of climate change mitigation resources should be channeled into geoengineering projects and carbon capture technologies that can prevent the onset of non-linear climate change, which have occurred time and time again throughout history. Given the dynamics of natural systems, it seems unlikely that climate will change in a linear or even exponential rate. Instead, given the historical record of surface temperature, sea ice cover, glacier cover, and carbon dioxide levels, a regime shift seems to be the likely outcome of further anthropogenic forcing.

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