# Sun, climate, hunger, and mass migration

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**Abstract** Paleoclimatic studies indicate four epochs of global cooling during the last 4 000 years, i.e. during the few centuries before and after 2000 BC, 800 BC, 400 AD, and 1 600 AD; the quasiperiodicity corresponds to cyclic variation of solar activity. Global temperature changes influenced regional precipitation patterns: Northern Europe was wetter while the middle- and low-latitude lands were more arid during colder epochs. Both sets of cold climatical conditions were unfavorable for agricultural production. Historical records show that large demographic movements in history took place because of crop failures and mass starvation, rather than escaping from war zones. The "wandering" of the Germanic tribes during the first two or three centuries of the Christian Era is one example.

Whereas the accelerated release of carbon dioxide from the burning of fossil fuels is ultimately to cause global warming, historical evidence indicates, however, that global warming has been on the whole a blessing to mankind. Global cooling, on the other hand, has curtailed agricultural production and has led to famines and mass migrations of people. Perhaps the most important task at the present is not so much computer-modelling of greenhouse effect on global climate, but water-management and agricultural researches to insure food-supply for an everincreasing world population.

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There has been considerable ballyhoo in the press medium about the impending catastrophe of global warming. The warming is seen as an inevitable consequence of the greenhouse effect of the industrially produced carbon dioxide. The elder statesmen at the International Council of Scientific Unions have been sufficiently alarmed that they initiated a project to study global changes as the first priority of their International Geosphere and Biosphere Program. Socioeconomic scientists held their international congress and they came up with a resolution that the world's consumption of fossil fuels should be reduced by 25% toward the end of this century. Politicians gathered in Brazil and drafted a Rio de Janeiro Charter to combat the warming to be caused by the burning of fossil. European parliaments are discussing the imposition on consumers of fossil fuels a new "carbon-dioxide tax".

In the middle of all the excitements, the scientific community itself has not reached a consensus on this issue. There are two schools of thought. The press-medium propagated the orthodox of a "greenhouse-warming", a conclusion arrived at mainly on the basis of computer-models relating the burning of fossil fuels to global temperatures. Their opponents pointed out, however, the more important role of evaporation and precipitation; they suggested that a temperature-rise initiated by the greenhouse would lead to increased cloud cover globally and to more snowfall in polar regions, resulting thus ultimately in a global cooling (Ramanathan and others, 1989).

There is a correlation of the global temperature with the atmospheric carbon dioxide in the 4 billion years of earth history. The long-term effect of greenhouse gases has been to produce global warming[1]. The temperature record of the last 150 years indicates also a warming trend, when

the atmospheric carbon-dioxide content has been increasing because of the burning of fossil (ref. IPCC the 1st and 2nd Assessment Reports of Climate Change). The trend was, however, interrupted three times by decades of cooling, the last of which happened during the late 1960s and early 1970s, even though atmospheric carbon dioxide has been progressively increasing. The temperature record thus does not correlate to the atmospheric greenhouse; Friss-Christensen and Lassen[2] found instead an almost certain correlation between the average temperature and the variations in solar activity.

That there has been a global-warming trend since the last century is a fact, but global warming did take place even when there was no burning of fossil fuels. There were four little ice ages during the last four millennia, and we have just come out of the last. Global warming is a natural phenomenon, when clusters of warmer years follow the cluster of cold years. What I would like to explore is thus not whether global warming is or is not going to take place; it is going to happen anyway, whether we are to burn more or less fossil fuel. What I have done is to look into the historical records to examine the consequence of past epochs of warm climate. Has global warming been a catastrophe, or has global cooling brought even greater disasters to mankind?

My colleagues and I in the Limnogeological Laboratory of the Swiss Federal Institute of Technology have been engaged in paleoclimatical studies during the last three decades. We have acquired a global view through co-operative research with colleagues in Europe, Asia, North and South Americas. Our data indicate that there have been alternate epochs of global warming and cooling since the last deglaciation some 10 000 years ago. Global temperature changes have predictable influence on regional precipitation patterns. During warmer epochs, the low/middle-latitude temperature lands, such as the Mediterranean countries, are wetter, whereas high-latitude countries, such as northern Europe, are drier. During colder epochs, the low/middle-latitude lands are more arid, whereas the high-latitude countries are wetter.

Global warming has brought ages of prosperity to Europe, Aasia, and North America in the history of civilizations, and those ages alternated with times of famines and epidemics at times of global chill. In what can be described as little ice ages in history, the cold and/or arid climate caused bad harvests[3,4], leading in turn to the large demographic movements in history[5]. The cyclic changes of climate have a quasi-periodicity of about 1 200 years, and I shall present evidence to show that those cycles are correlative to the solar activity.

The purpose of the present paper is to pose some questions in order to help orientate the current research on global changes: What is the record of climatic changes and of their impact on the civilizations of the Old World? What is the primary cause of the climatic changes? What kind of research should we emphasize if we wish to mitigate short-term natural disasters that might be inevitable?

After three years of library research, I find a pattern relating the rise and fall of civilizations to climatic changes, from the Neolithic to the Little Ice Age s.s., in the thousands of years when the economy of human society was dependent upon agricultural production. A theory of climate is formulated. The theory could serve as a working hypothesis for historians studying climatic records. I am encouraged to learn that the Ministry of Science and Technology of China has not only studied the document, but Chinese scientist is making a recommendation that a project be initiated to study systematically the climatic changes recorded by the Chinese history[6].

## 1 The postglacial climate

The earth underwent numerous episodes of continental glaciation during the last two million years. Half of North America, all of Scandinavia, and large parts of Europe were covered by continental ice sheets during the last Ice Age. The ice caps started their retreat rapidly after they reached their greatest extent at about 18 000 BP. The postglacial time began some 16 000 or 15 000 years ago. Shortly after that, Denmark was liberated from the ice cover, and an alpine flower *Octopella dryas* appeared on the tundras in the periphery of retreating glaciers. This small white flower is still found growing in the tundras and high meadows of the Alps. Its occurrences in Denmark suggest that the climate of northern Europe at that time was similar to that of the present-day Swiss Alps at 2 000—3 000 m elevation. Scientists called this first epoch of the postglacial climate the Old Dryas Stage.

Climate got warmer during the next few thousand years. Tundras were replaced by coniferous forests, and then deciduous trees to form the "mixed forests" in Europe. The global climate became as mild as, or even milder than, that of today. Then suddenly, about 11 000 years ago (varve date[7]), the glaciers returned. This relatively brief cold interlude, when the alpine flower *O. dryas* came back to Denmark, is called the Younger Dryas Stage. In several hundred years, however, the chill disappeared as quickly as it appeared. A wholly new epoch, called the Holocene, had its beginning some 10 500 years ago (varve date), and the global climate has been, on the whole, warm since then. The global climate was warmer during the Early Holocene, and that interval has thus been characterized as the time of Climatic Optimum or the Megathermal stage[8]. The second half of the Holocene was colder.

The global climate during the last several millenia has been considered stable. The press-medium has perpetuated the impression that global temperatures have not changed very greatly until the recent global warming, allegedly caused by the greenhouse effect of industrially burnt fossil fuel. Indeed variations during the historical times of an average global temperature of about 1℃ do not seem significant. The average masks, however, the significant regional variations. A cold spring in northern Europe may not have made much of difference in the annual average of the temperature record, but the late planting season because of the cold spring could make a difference if there is to be a harvest in the autumn or not. A decrease of one or two degrees of the average annual temperature in China seems insignificant, but a long drought because of a change of the precipitation pattern is to have dire consequence on agricultural production. The alternating cold and and warm eras did not leave an impressive imprint on the records of natural history, even though there seems to be quasi-periodicity during the last several thousand years. The slight temperature change has had, however, a great impact on the fortunes of the human civilizations. I have, therefore, first identified little ice ages and little climatic optimums on the basis of the historical records, found then a verification in the paleoclimatical records, and finally sought an answer as to the origin of the cyclicity in the astronomical records.

## 2 The desiccation of the Sahara and the return of mountain glaciers

Was the first important global change in the history of civilization a severe cooling taking us from the Climatic Optimum to Late Holocene? The manifestations of the cooling came early in northern realms around 5 200 years BP[9]. The most significant change occurred later simultane-

ously, at about 4 000 years BP, in Europe, North Africa, Near East, Far East, and in the Americas. The change marks the end of the Climatic Optimum and the start of the Late Holocene. Since then, the climate was never so warm, and there were three periodic alternations of global cooling and warming during the last four millenia[5].

The Alps had few glaciers during the Climatic Optimum. The first coming of the Alpine glaciers at about 5 300 BP buried the "Man in Ice" of the Tirolian Alps[10], but mountain glaciers expanded greatly only during the next little ice age at about 4 000 BP. The beginning of the Late Holocene is manifested by a start of the varve-sedimentation in Alpine lakes (A. Lehmann ETH dissertation, 1993).

Global climate during the last 4 000 years has never been as warm as the Neolithic. There has not been a steady cooling either: the trend has been repeatedly interrupted[5]. There have been clusters of cold years for some 600 years, which may be conveniently called Little Ice Ages (LIA). And there have been clusters of warm years for another 600 years, and those are the little climatic optimums (LCO). The natural clustering of apparently random events is called Joseph's Effect, referring to the biblical seven years of good and seven years of bad harvests during Joseph's sojourn to Egypt[11]. The last little ice age, i.e. the Little Ice Age, *sensu stricto* (LIA b), refers to the numerous clusters of colder years during the period of 1280—1820. The recent global warming is but a manifestation that we have entered an age of a little climiatic optimum (LCO a).

Prior to the coming of glaciers to the Alps at the beginning of the Late Holocene, the climate was not only warmer but also wetter in the low/middle latitudes of North Africa, Middle East and Asia. Great freshwater lakes existed in Mali and surrounding countries during a humid phase between 9 500—4 000 BP, although there were also intervals of colder and more arid climate. Precipitations were abundant in the Saharas during the warm epochs to feed the freshwater lakes. Fish faunas migrated in from the Niger River and from the coast of Senegal. The Cro-Magnon people came down to the Malian Sahara during the Early Holocene, when Sahara was a continuous, viable landscape between North Africa and the Topical Africa. Their rock-paintings, which have been dated to range mostly from 8 000 to 7 000 BP, depicted scenes of hunters chasing elephants, rhinoceros, buffaloes, hippopotamus, antelopes, giraffes, etc. That was the time when the postglacial climate was warmer than today, and when the sea-level rose rapidly from a low glacial stand to that of today (Ters, 1989)[12]. Ancient Neolithic artefacts are more abundant and better represented than the more recent ones, indicating more inhabitants and better ecological conditions there during the earlier time.

The global temperature changes had a drastic influence on regional precipitation patterns. An early clustering of cold centuries around 5 200 BP cuased an expansion of the deserts, and the deterioration of environments drove the hunters and grazers to the alluvial plains of Egypt where an agricultural civilization had its beginning[13]. The last of the freshwater lakes dried up 4 000 BP[14], ending the Saharan civilization at about the same time as the glaciers advanced in the Alps. The clusters of cold years during the few hundred of years before and after 4 000 BP constituted the first little ice age (LCO b) during the Late Holocene.

Mild and wet climate prevailed also during the Early Holocene in the Near East. I visited the Canaanite City Arad on the edge of the Negev Desert: it was a populous settlement of several thousand inhabitants during the Early Bronze Age[15]. Suddenly the city was abandoned. The de-

serted dwellings showed no signs of destruction by war, and the exodus has been attributed to a shortage of water supply as a consequence of increasing aridity. The abandonment of Arad is but one example of the collapse of agrarian societies in the Middle East toward the end of the Third Millenium BC. Weiss et al.[16] defined recently the origin, growth, and collapse of Mesopotamian civilizations. After several centuries of urban life, the catastrophe came: at 2200 BC, a marked increase in aridity induced a considerable degradation of land-use conditions. The cold and arid climate caused the abandonments of settlements in the north, and the collapse of the Akkadian Empire in southern Mesopotamia. Synchronous collapases in adjacent regions, such as Hindus Valley and Egypt, suggest that the impact of the climatic change was extensive.

The Little Ice Age of 2000 BC (LIA h) left a different kind of record in central Europe. The chill brought not aridity, but increased precipitation, and the cold and wet climate caused the advance of the Alpine glaciers. During the Middle Bronze Age prior to that time, the Lake Dwellers in the region of Prealpine lakes had enjoyed warm and dry weather, and they had built villages on lake shores. The sudden arrival of the cold and wet climate caused the Lake Dwellers to abandon their flooded settlements, flooded because of a rise of the lake-level. Villages on the shores of Lake Zurich, for example, were abandoned at about 2400 BC, and they remained uninhabited for about 800 years until 1600 BC[17].

The global cooling around 2000 BC brought cold and wet summers to northern Europe. Prior to that time, cattle-farming had brought prosperity to the megalithic kingdoms of the north[18]. Then the cold weather hit, and it became eventually too cold and too wet to make hay for their cattle. Deprived of their subsistence, the Indo-Europeans of northern Germany and southern Scandinavia had to move. Carrying with them their corded-ware pottery and battle axes, they went to southern Russia, from there to southeastern Europe, to Anatolia, to Persia and India and to northwestern China[19,20].

Paleoclimatic studies have also indicated that the transition in the Far East from the Early Holocene optimum to the Late Holocene temperature climate also took place toward the end of the Third Millenium BC. A global cooling caused increasing aridity in the regions of the middle latitudes[21]. The first chill came thus to northern and central China at about the same time when the Saharan lakes dried up, when the Akkadian Empire collapsed, when the first glaciers advanced in the Alps, when the first Lake-Dweller's settlements were flooded, and when the Indo-Europeans first left their northern German homes. The climatic impact was, however, not dramatic enough to find an obvious manifestation in Chinese history. Chinese historians wrote that mulberry trees grew and elephants and rhinoceros roamed on the plains of north China, when the legendary King Huangti ruled at about 3000 BC. The conditions then were not marginal, so that a moderate temperature-decline was not to cause a crisis.

## 3 A Little Ice Age during the "centuries of darkness"

There was a return to warm and more humid climate during Second Millenium BC. The agricultural economy of the Near East flourished during Late Bronze Age, as indicated by studies of history and archaeology, and by the pollen record preserved in the sediments of the Dead Sea[22]. The clusters of the warm centuries were followed by a Little Ice Age (LIA f) at the beginning of Iron Age. There was much evidence of a change during the global cooling to more arid conditions in the Middle East[22], and the consequences were devastating to the farming communities

there[4]. The Hittite Empire perished, the Mycenae declined, and a dark age came to the Middle East. The "centuries of darkness" started shortly before 1000 BC and continued till after 800 BC (James, 1991)[23].

In Europe, there was evidence for a trend of severe cooling toward the end of the Late Bronze Age. The temperature drop in the high latitudes was accompanied by an increase of precipitation. The Alpine glaciers advanced again, and the lake-level rose. The Lake Dwellers of Zurich had to abandon their settlements for a second time at about 800 BC[17]. Meanwhile, the tree-line was depressed, when broad-leafed trees in mixed forests were replaced by conifers. Salt mines were abandoned, and commerce was curtailed[24].

Global cooling also visited China toward the end of the Second Millennium BC. Prior to that the climate was warm and wet in northern and central China. The change came during the last two centuries of the millennium: there were many cold and dry years. Droughts and famines were commonplace during the reigns of the four last West Zhou kings Li, Xuan, You, and Ping. Weakened by the internal rebellions, King Ping was forced by foreign invaders to abandon Xi'an, and the capital was moved to Luoyang at the beginning of the Eastern Zhou Dynasty, 771 BC.

## 4 The great demographic movements during the first Christian centuries

The cold and arid climate changed to a warm and humid one, and there was a little climatic optimum (LCO e) during the Roman-Hellenistic era in the Mediterranean regions. The Greek City States flourished after a dark age[13], and the City of Rome was founded in the year 753 BC.

In central Europe, the global warming toward the end of the 5th century BC provided an opportunity for the extension of the Celtic La Tene Civilization. The Late Iron Age culture was spread to central and western Europe, while the latest Lake Dwellers rebuilt villages on previously abandoned sites.

During the centuries of little climatic optimum (LCO e), German farmers made their homes on the Baltic shores of northern Europe. The first clusters of cold years may have come as early as the first century BC, if the mass migration of the Helvetians in Caesar's time was caused by bad harvests and famines[5]. The deteriorating climate during the first Christian centuries brought more hunger: one German tribe after another left their farms and ranches in northern Germany. Studies of tree rings, snow lines and glaciers in central Europe and of ice cores from Greenland indicate that climate fluctuated, and the coldest years were those during the age of the Migration of German Nations, from the late 4th century to the early 6th century[13].

Historical records in China also indicate a little climatic optimum (LCO e) during the Spring and Autumn Era and the Age of Warring States (722—221 BC). Rice, the staple crop in southern China, grew in Shandong, Henan, and Hebei, the provinces which are now noted for their winter cold and aridity. Rice could grow, because there were numerous warm and snow-free winters, as recorded in the history of Confucius[25]. The climate continued to be warm and wet during the Qin and Western Han years (221—29 BC). Settlements on the Silk Road at the edges of the Taklimakan Desert were built during those years of warm and wet climate.

The first clusters of cold years came to China also at about the time of the birth of Christ. Wang Mang was an able ruler, but his good government could not prevent revolutions, when cold and drought were to result in widespread famines. There was little peace and prosperity during the Eastern Han Dynasty. Climate continued to deteriorate and chaos caused the final collapse of

the Han Empire.

Extremeley cold and arid climate arrived in central China during the late 3rd century AD. The worst drought was recorded during the reign of the Jin emperors: the drought years continued during the decade 281—290 AD, and the catastrophic climax was the year 309 AD, or the 3rd Yungjia year of Jin Huai Di. Chinese historians stated that the rivers "Jiang, Han, He, Luo were all desiccated, so that people could wade across"[25].

## 5 The Medieval Optimum and the ages of the Vikings and of Ginghis Khan

A stable warm period in Europe from 900 to 1300 AD was the Age of the Vikings. Fields for planting and meadows for grazing in Scandinavia expanded to areas north of the Arctic Circle, and the tree-line advanced significantly to higher altitudes. Dansgaard's isotopic record of the Greenland ice-cores indicates that the warming started in the 7th century and reached its zenith during the 10th, 11th, and 12th centuries. The evidence from tree rings suggests that the precipitation in central and northern Europe was reduced during the warmer years. High-pressure and sunny weather prevailed over Britain, Germany, and Scandinavia, and the summers during the 10th century were mostly warm and dry[13], ideal conditions in northern Europe for cattle-farming.

In China the empire was reunited toward the end of the 6th century. The Sui, Tang and early Song years were again a period of prosperity. This age of Chinese glory (600—965 AD) was on the whole a warm period. Rice fields and bamboo forests did not, however, return to the Yellow River Valley; elephants and rhinoceros migrated to the south had also stayed there. The climate was apparently less optimal: there were reports of heavy snows, bad harvests, and of people starved or frozen to death, from time to time, intervening the clusters of warm years.

Deserts turned green with the global warming of the Medieval Optimum. The Han cities on the Silk Road around the Taklimakan Desert of Xinjiang were rebuilt and again settled, when increasing precipitation accompanied rising temperature. The great Western Xia Kingdom was founded during the 10th century in Ningxia, now a rock desert. The greening of deserts provided the economic basis for the strength of the northern Asiatic nomads. Xia, Liao, and Jin all scored military victories over the Song emperors. The Seljuk Turks went west in the 11th century and founded a colony in eastern Anatolia. Finally the population explosion in the Mongolian steppes provided the manpower for Ginghis Khan's conquest.

## 6 The little Ice Age, the Thirty-Year War, and the downfall of Ming

The Little Ice Age s. s. from 1400 to the mid-1800s was an era of many cold and stormy winters in northern Europe. The average winter temperature during the coldest years between 1550 and 1650 AD in Middle England was higher than 1.5℃, colder than it is there now. The cold-and-wet summers and the short growing-season rendered both cattle- and crop-farming difficult if not impossible. Down south during the very cold years of the late 17th century, the hills of Swiss Midland (900 m altitude) were often snow-covered until May[26]. Alpine glaciers advanced again, and they came down to Alpine meadows at 2 000 m altitude. The Thirty-Year War raged in northern Europe during the coldest years. Famines and epidemics caused the reduction of the German population from 16 to 9 million.

Nor did the Far East escape the miseries of global chill. The last years of the Ming Dynasty in the early 17th century were cold and arid in central China. The worst came during the reigns of the last two Ming emperors Tianqi and Chongzhen. In some forty-odd years, 1601 to 1644 CE,

historians recorded two episodes of "*ba-nien-da-han*", i.e. eight years of extremely severe drought. It was reported, not a drop of rain fell during three whole years[25]!

The first interruption of the cold trend came during the first years after 1700 AD, but the temperature-rise was not steady. There were still many clusters of cold years to come: The years 1769—71 AD were, for example, unusually cold and wet[26]. The second decade of the 19th century also had a cluster of extremely cold years, when Napoleon suffered his defeat in Russia, and when the climate of England was comparable to the worst during the Little Ice Age[13].

The Little Ice Age came to an end suddenly, and the most recent warming trend started during the first half of the 19th century, in Europe and in China. The 20th has been a century of global warming, reaching an optimum during the 1940s. Interrupted by cold spells during the 1960s and 1970s, the global warming returned again during the 1980s and 1990s. Alpine glaciers have been retreating, and will possibly disappear rapidly if the warming trend should persist. The sharp temperature-rise of average global temperature brought alarm to a sensitized public. We should not lose sight, however, of the fact that we have just come out of a little ice age, and the global warming has come, and it will get still warmer no matter whether we burn more or less fossil fuels.

## 7 Climate, famine and mass migrations of people

Julius Caesar in his *Commentary on Gaullic Wars* described a great migration of Indo-Europeans. In March 58 BC, 263 000 of the Helvetii: men, women, and children, and some 100 000 of the Boii and other Celts crossed the Jura Mountains to settle in France. Caesar, who had refused their permission to enter the Roman province, defeated the mob of invaders near Bibracte. It was claimed that the 130 000 survivors returned to Switzerland. Excavations revealed, however, the remains of rectangular dwelling houses, a temple, workshops of iron and bronze workers and of enamelers, etc. Many of settlers did not want to go home, and the Helvetians established a new colony in France.

Why did the Helvetians leave Switzerland? Did they have to?

Caesar did not give an answer. Historians made the usual excuse that the Helvetians decided on a migration because they were hard-pressed by their German neighbours. That does not make sense. The "hard-pressing" Germans did not come until a few centuries later, not to mention the fact that the Helvetians could have more easily defended their home against raiders across the Rhein than to fight the military might of Rome.

Large movements of people in history are not uncommon, and historians almost invariably considered warfare the cause. My thesis is, however, that people moved because they were hungry. We have witnessed one such event recently. In late November, 1996 some 60 000 men, women, and children, the Hutus of Rwanda, went from eastern Zaire to Rwanda in about a week. There was a war, of course, but those who fought stayed behind in their refugee camp. Those who left wanted to have a better life at home when the alternative was death by hunger. The peoples of the ancient time had great mobility. When farming families, men, women, and children all moved, they were not making wars, nor fleeting from invaders. They moved when they could no longer farm at home, and they had to seek an alternative to starvation and disease at home. I shall invoke this driven-by-hunger hypothesis to interpret the several large demographic movements in history.

7.1 The dispersal of the Indo-Europeans and the arrival of Wupu men in Xinjiang

There are good archaeological, linguistic, and anthropological arguments to support a theory that the Indo-Europeans lived in more northerly parts of Europe during the Third Millennium BC. Linguists, many of them German scholars of the 19th century, found a common vocabulary among the various Indo-European languages, and they identified northern Germany and southern Scandinavia as the original homes of the Indo-Europeans[19].

Stuart Mann[27], writting for a British journal in 1943 during the height of the hositility of the World War II, asked for acceptance of the scientifically correct interpretation. Noting that the precisely reconstructed vocabulary common to all Indo-European languages consists of several thousand words, including Wolf, deer, elk, salmon, duck, turtle, beaver, seal, mouse, squirrel, wasp, dog, sheep, goat, sow, ox, horse, birch, beech, aspen, oak, elm, apple, forested mountain, heath, millet, rye, grains, door, wagon, wheels, axel, yoke, saddle, cup, needle, spinning, plowing, seeding, harvesting, easter, yule, etc. he supported the conclusions of his German colleagues. The original Indo-Europeans domesticated dogs, raised cattle and pigs, seeded and harvested millet and rye. They fished, hunted game on land and seals at sea. They rode horses, drove ox-drawn wagons, their women weaved and sewed. They lived on the edge of forests, their houses had doors, and they celebrated festivals at Easter and at Christmas time.

This reconstuction can eliminate a number of regions as the possible homeland for the original Indo-Europeans. The British Isles, northern Scandinavia, northern Russia, Caucasus and a large part of Mediterranean are eliminated because of the absence of beavers and/or squirrels. Northern Scandinavia and northern Russia, situated to far north for the growth of apple trees, oaks, and cereal crops, can also be eliminated. The Russian steppes were not a likely home because there are neither forests nor heaths, and the rivers there, draining into the Black Sea, have no salmons. Since walnut trees and vines were apparently unknown, southern Europe, much of France, southern and middle Germany were also the likely homeland of the original Indo-European people. What is not ruled out are thus the countries around the Baltic Sea, including northern Germany and Poland, the Baltic countries, southern Sweden and Norway, Denmark.

The first dispersal of the Indo-European people took place around 2000 BC. They went to southern Russia, to Greece, to Anatolia, to Iran and to India. The Hittites intruded Anatolia toward the end of the Third Millennium BC, the Indo-Iranians entered Persia and imposed themselves as a ruling aristocracy long before the 18th century BC. The Aryan invasion of the Indian subcontinent may have been as late as 1500 BC, long after the decline of the Hindus Valley civilization.

The presence of an Indo-European people in northwestern China has been known for almost a century; the Tocharians left their 8th-century texts in the caves of Tunghuang. It was always a puzzle that those Indo-Europeans spoke a language that was more German than Persian. Who were they? When did they come to Xinjiang?

We now know the original home and the first dispersal time of the Indo-European people after the discovery of numerous mummies of the Indo-European people in Xinjing[28,29]. The corpses are fully clothed in splendidly colored woolen fabrics, felt, leather boots, and in some instances leather coats. They are clearly of European extraction, characterized by their long noses, deep-set eyes, blonde or light brown hair, etc. The men are fully brearded and the women have long braided hair. The mummies, a woman and a child, from Loulan on the shores of Lop Nor

and associated objects have been dated by $^{14}C$, by stratigraphy, and by archaeology to be 2000 BC. A wealth of artifacts was recovered from the graves, including mostly simple items for use in daily life, such as combs, needles, bowls, pots, hooks, bridles, bells, whorls, spindles, bread, etc. Those people used wheels of a type resembling much earlier examples that had been found in the Ukraine and Russian steppes.

The Wupu men of Xinjiang have been compared to Europeans of Nordic extraction; they are considered relatives to the Scythians and the blond-haired Ossetes. Citing Irene Good, Mair[30] pointed out that the Xinjiang textile "is the easternmost known example of a characteristically European twill patterned weave". There is a "remarkable similarity between plaid woolens from Wupu and from Danish burials at roughly the same time, both in terms of weave and of pattern". Those original inhabitants of the Tarim Basin were the ancestors of the Tocharians of northwestern China. We now understand why their language is "linguistically more closely related to Western European Germanic and Celtic rather than to the geographically nearer Iranian and Balto-Slavic". All available data point to the fact that northern Europe was the original home of the Xinjiang men.

Why did the northern Europeans leave their home and travel across the Russian steppes to come to northwestern China?

The glaciated country of the northern German plains, or the "birch-and-salmon country" between Rhein and Vistula, has the fertile soil to be qualified among the best farmlands of the world. The region was happily inhabited by numerous Germanic tribes during the Roman time, and by their Indo-European ancestors during the Megalithic Age. Why did the Indo-Europeans leave shortly before 2000 BC? Why did they leave again during the late Roman time? Did they have to?

I found the answer during my sabbatical year in Berlin. I vistited local museums in northern German cities, and learned that the fertile country was deserted during the first centuries of the Christian Era. Only after the 6th century AD was the "no-man's land" east of Elbe and west of Vistula resettled, by Slavonic settlers. The Germans came back during the 9th, 10th, 11th, and 12th centuries, and made their reconquests under the pretext of Christianization.

Talking to the people farming today in region between Elbe and Vistula, I realized that a cold climate could be the reason. The farmers nowadays start ploughing in March or early April. In very cold years when the spring comes late, the planting may have to be delayed until mid-May. The year 1996, for example, was a relatively cold year during a century of global warming, the farmers of the Oderbruch district did not start ploughing until April 20th. When the ground was snow-covered or frozen until May in still colder years, the planting would be so delayed that there would be no harvest in the autumn.

Ranchers raised cattle in the Rockies where the growing season is short; there is plenty of water and there is plenty of grass. Why should the Indo-European cattle farmers leave when global chill comes?

Dairy farmers in Switzerland sent their cows to the Alps during the summer, when they cut grass on the meadows to make hay to feed the cattle in winter. The cattle-farmers dreaded cold and wet summers when the grass would remain wet and become rotten. Cattle-farming is thus difficult if not impossible when there are not enough sunny summer days to dry up the hay.

I offer, therefore, a working hypothesis that the planting season could become too short or

the summer days could get too cold and wet during the Little Ice Ages[5]. When that happened during the Little Ice Age 4000 years ago, the Indo-European farmers had to leave; the few left behind had to eke out a living as fishers.

The migrations of the Lake Dwellers in central Europe are more easily understood. The lowland hills are forested, and the Neolithic and Bronze-Age farmers had to cut down forest on lake shores for planting of crops. Then came the deterioration of the climate, bringing much precipitation. The Alpine glaciers started to grow. Winter and spring floods became more and more frequent, destroying the crops. There was the threat that the farmlands were to be drowned by the rising lake level. The people had to go somewhere. Not knowing the limit of the rise of lake levels, they may have preferred to travel to faraway countries, instead of labouring in vain before the next flood.

The demographic movements in the Far East during the Little Ice Age around 2000 BC are not well investigated. Chinese history stated that the Chinese people came to Zhong-Yuan (Central Plains) when Huangti chased away Tze-You, and the event was placed prior to the rule of the Xia Dynasty toward the end of the Third Millenium. Where did they come from? Archaeologists found evidence of Neolithic cultures in northeastern China. Was Huangti a descendent of the northern Asiatic tribes from Siberia who had been driven south by global cooling? We can only speculate, and we still have a lot to learn.

7.2 The Sea Peoples, the Dorian invasions, and the move of the Zhou Capital

The Indo-Europeans were on the move again toward the end of the Second Miltennium BC. Antique writers of Greece wrote tales of the Dorian invasion. The timing of the invasion was commonly placed in the second half of the 12th century BC, but it now considered two or three hundred years later (James, 1991). The invading hordes were to break down the resistance of the Mycenaean powers; the Dorians crossed the Gulf of Corinth and broke into the Peloponese. Chaos and turmoil continued for two centuries in the Greek Peninsula. The last of the great migrations began when the Athenians launched the Ionian Migration, and ended with the occupation of the Cyclades. Excavation has exposed the poverty of the Dark Age in Greece. Poor people lived in hamlets and made war against one another with iron weapons. The Bronze Age had collapsed, and the Iron Age began.

When the Dorians went to Greece, other Indo-Europeans went to western Asia and North Africa. Fragments of pottery, inscriptions in temples, and ruins of burnt out cities give evidence of the first appearance of the Philistines as one of the Sea Peoples. Based upon biblical accounts, a vivid narrative was depicted[31]:

Terrifying reports heralded the approach of these alien people. Messengers brought evil tidings of these unknown strangers who appeared on the edge of the civilized ancient world, on the coast of Greece. Ox wagons, heavy carts with solid wheels, drawn by humpbacked bullocks, piled high with household utensils and furniture, accompanied by women and children, made their steady advance. In front marched armed men. They carried round shields and bronze swords. A thick of cloud of dust enveloped them, for there were masses of them. Nobody knew where they came from. The enormous trek was first sighted at the Sea of Marmara. From there it made its way southward along the Mediterranean coast. On its green waters sailed a proud fleet in the same direction, a host of ships with high prows and a cargo of armed men.

Wherever this terrifying procession halted, it left behind burning houses, ruined cities, and devastated crops. No man could stop these foreigners, they smashed all resistance. In Asia Minor, towns and settlements fell before them. The mighty fortress of Chattusas on the Halys was destroyed···The Hittite empire was obliterated.

A fleet of the foreign conquerors arrived off Cyprus and occupied the island. By land the trek continued: it pressed on into northern Syria···Caught in a pincer movement from sea and land, the rich seaports of the Phoenicians fell before them···On and on rolled this human avalanche by water and by land, forcing its way all the time toward the Nile, toward Egypt.

Other Indo-Europeans went eastward: the Scythians went to southern Russia, the Medes and later the Persians went to Iran and to Babylonia.

Where did those people come from? And why did they leave their home?

Historians could trace their origin to the Balkans, on the edge of the ancient civilized world, and the desire to conquer has been considered the motivation. But they could have come from farther north. The invaders were not only the warriors; they brought their women and children. Why? Is it not possible that the Dorians were originally the hungry people of northern Europe? Like the Aryans before them some 1 200 years before, the Dorians too had to abandon their fertile soil because they could no longer practise cattle- or crop-farming at home.

In China, there is little historical record of mass migrations of the peoples during the period of the Dorian invasions. The Chinese Bronze-Age Empire Shang was replaced by the Iron-Age Empire Zhou around 1100 BC. Who were the Zhou people? They were almost certainly Han Chinese. For some 300 years, a succession of 13 Zhou kings ruled, while the "western barbarians" remained a constant threat. After the last king of the Western Zhou was slain, a new dynasty, the Eastern Zhou, was established with its capital at Luoyang. The move may have been forced by invasions or by mass movements of the northern Asiatic tribers in the periphery of the empire, but the record is meagre.

7.3 The great migrations in Europe and the mass exodus of the Chinese from central plains

The exodus of the Helvetian people during Caesar's time has been a mystery. Historians, as usual, blamed the military threats of their German neighbours. I question this line of reasoning. Why should the brave Helvetian warriors prefer not to defend their home, but to lead their women and children to France where they had to fight against the great super-power of Rome? Even after their crushing defeat by Caesar, the majority of the migrants seemed to have escaped a forced repatriation: like some of the Hutu refugees in Zaire, they elected not to go home, apparently believing in the prospect of a better life in their new home.

The Grent National Migrations or Völkerwanderung refers to wanderings of the Germanic tribes during the 4th and 5th centuries. Invasions are usually cited by historians as a cause for the movements, being precipitated in Europe by the westward movement of the Huns. In fact, the Germans left their homes long before they came into conflict with the Huns.

Many Germanic tribes were identified as the inhabitants of northern Germany during the first century before or after the Christian Era: the Suebi tribes in the Elbe Basin and in Holstein, the Lombards in the Semnones and the lower Elbe, the Saxons in Schleswig, the Varinis in Mecklenburg, the Rugiis in Pomerania, the Burgundians on the south shore of the Baltic and then in the basins, the Vandals in the lower Vistula Basin, the Goths (originally from Sweden) in the

Vistula Basin. At the time, the Slavonic tribes inhabited only the land east of the Vistula River. The Huns invaded southeastern Europe late in the 4th century. The Germanic tribes had, however, started their moves already during the first two centuries of the Christian Era. The East Goths, for example, had reached the Black Sea coast prior to the end of the second century, before they started defending their new home against the Huns in the 4th century. The Suebis and Alamanni moved south into the Roman territory during the 3rd century, before some of them had to cross the Rhine during the 5th century under the pressure of the Huns; they went all the way to Spain. The Burgundians, who had moved to the Main River basin in the 3rd century, founded a powerful kingdom in the Rhine Valley, before their kingdom was overthrown by Attila; they were chased to France also during the 5th century, not earlier. The Lombards apparently remained in northern Germany until late in the 4th century and settled in Austria toward the end of the 5th century, before they came down to Italy and established a kingdom in 568 CE. The Vandals came down a Silesia during the 3rd century and settled in the Theiss River valley in the 4th, before they fled from the advancing Huns and started their great migrations early in the 5th century to Rhineland, Gaul, Galicia, Andalusia and their mass invasion of North Africa. Whereas the mass movements after 370 CE are directly or indirectly related to the invasion of the Huns, one cannot blame the 5th-century Huns in central Europe for the departure of the Germanic tribes from their homeland in the north a few centuries earlier. There had to be another cause.

A most likely cause is hunger!

During the Greco-Roman era, a mild climate prevailed and the agriculature economy flourished in northern Germany. As the climate deteriorated toward the beginning of the Christian Era, there were increasingly more colder anad wetter years in northern Europe. The planting seasons became shorter and shorter, and the harvest brought less and less. At the same time, haymaking was all but impossible during the many cold and wet summers. The economic pressure may have induced many of the tribal Germans to serve as mercenary soldiers, but money could not buy food when there was no food for sale. Faced with mass starvation, the farmers had no choice but to leave home. The Goths left first, then the Vandals, the Suebis, the Burgundians. The Lombards seemed to have stayed behind until the cold climate reached its extreme during the 4th century. All the them left to look for greener pastures and arable lands in the south. They were sooner or later to come into conflict with the invading Huns during the late 4th and the early 5th century, when the northern Asiatic tribes also had to leave their frigid home.

The country left behind in northern Germany was either sparsely populated or a "no man's land" during the time of the Great Migrations. The northern German and Polish plains are, as I have indicated, fertile agricultural lands. When the climate started to get better, the plains between the Elbe and Vistula rivers were again resettled, at first by Slavonic tribes from eastern Europe. The good soil again yielded good crops. With still better climate, more and more Slavonic settlements were built. The Germans did not, however, forget their ancestral homes. After Charlemagne, under the kings of the Franks and the Saxons, re-conquest was organized under the pretext of Christianization. This *Drang nach Osten* continued for many centuries until the trend was reversed only after the World War II.

The early Christian Era was also an epoch of great migrations in China. When Wang Mang was emperor at the time of Christ's birth, there was cold and drought, and there were famines everywhere in the country. Hundreds of thousand hungry people abandoned their homes, and

eight or nine-tenths of those were starved to death. The rest joined the rebellions, they wandered and pillaged, and participated in the overthrow of Wang Mang's Imperium.

After intervening decades of better climate during the early reigns of the Eastern Han emperors, bad climate returned, and the famine in the year 184 AD caused the widespread Yellow Turbans Rebellion. And eventually they certainly caused the final collapse of the great Han Empire.

Then came the Jin and Six Dynasties (221—589 CE). The aridity during the late 3rd century was so widespread in northern and central China that the famines led to death by mass-starvation; there was reported cannibalism. The Western Jin Dynasty, weakened by famines and rebellions, was overthrown by marauders from the north. Five foreign nations established the 16 kingdoms of the Northern Dynasties in central China. The Han Chinese migrated *en masse* to the south, where they were ruled by the emperors of the Eastern Jin and Southern Dynasties. Many of the Hsüs, for example, left their home in Henan (central China), moved to Fujian and Guangdong in the south, and from there they went to Taiwan and to other parts of southeastern Asia. We find today in some Taiwan villages that up to a quarter of the population claim descent from the Gaoyang Hsüs.

There were mass movements of people during those chaotic years. Some Chinese historians also blamed the Huns (Xiong-Nu) and other barbarians as the culprits of having caused the great migrations. Reading the historical accounts of droughts in northern and central China, it seems, however, that the Chinese farmers of central China moved to the warmer and wet south, because nothing grew at home. Yes, the barbarians did overrun China, and the Jin government could not resist. Invasions may indeed facilitate the migration of the conquerors and their familes to settle in the conquered lands, but invasion rarely causes the mass exodus of the conquered people.

A political change at the top could not have forced a mass exodus, but hunger can. Successful invasions may have been a consequence of mass migrations, when there is not enough of a healthy population left behind to support a strong defence; invasions can hardly be the cause of mass migrations.

7.4 The Vikings and the golden hordes of Ginghis Khan

The Vikings were among the greatest invaders in history. They left their homes intent on raiding or conquest. Their descendents settled in Normandy, England, Ireland, Sicily, where the conquered people stayed and continued to till their soil and paid tax to the conquerors. The indigenous people were in fact to prevail eventually, when the invaders were assimilated.

The centuries of the Viking conquests, 800—1050 AD, were clusters of warm and dry years in northern Europe; those were times of rich harvests. There must have been a population explosion as Friderick Schiller described in his *Wilhelm Tell*. There was an increase in the supply of food, but even more an increase in the demand for food. Somebody had to go, but most could stay home. Many did go, still more stayed home, and the home was more glorious than ever.

The greening of grasslands during the Medieval Climatic Optimum (LCO c) strengthened not only the economy of the Vikings in Europe, but also that of the conquering peoples of northern Asia. The strongest nation in China during the 11th and 13th centuries was not the Chinese Song, but Western Xia, a kingdom of Tibetan people in Ningxia and Gansu of northwestern China. Being repeatedly defeated, the Northern Song Emperors had to pay tributes, and humbled themselves as the "younger brothers" of the Xia kings. The Turks of northwestern China went

westward; they were the Seljuks who started in the 11th century to take Anatolia from the Byzantine Empire.

Northern Asiatic tribes also came to northern China in the 11th century. They established the Kingdom of Liao in northern China, and they competed successfully against the Northern Song for the supremacy of North China. Then came the Nüzhen in the 12th century, and they did even better. They not only subjugated Liao and established the Jin Kingdom, but they also marched south, capturing the Song capital of Kaifeng and kidnapping the Song emperors. The Chinese retreated to the south of the Yangtze, where the emperors of the Southern Song found peace in their refuge.

Then came Ginghis Khan and his descendents, in the 13th century. They did better still. They were victorious in Europe and Middle East. Then the Xia Kingdom was absorbed in the Mongol Empire, after 6 campaigns. After that, the Nüzhen-Jin kingdom was subjugated. Finally the Southern Song had to go. Ginghis Khan's grandson, Kublai was installed as the first Yuan emperor of China, when the Mongols established the greatest ever empire in the history of civilization.

Invasion was not the cause of mass migrations of men, women, and children, but invasions did bring many strong and healthy males to new countries, and the conquerors paved the way for the new immigrants. Viking families followed their conquering heros to France, to Britain, to Iceland and to Greenland. The Gorden Hordes settled in southern Russia, and the Seljuk Turks in Anatolia. Their homeland seemed to have possessed an inexhaustible surplus of manpower. Many were gone but still more stayed home; there had been a population explosion. The invaders were not so much driven by hunger as by greed.

Global warming seemed to have favored the conquerors from the north, but their power declined when the bad climate returned. The Mongols stayed less than a century in China. In the second half of the 14th century, cold and drought caused famines. Chinese farmers rose in rebellion. One Chinese leader, Zhu Yuan-zhang, chased away the last Mongol emperor and all other contenders for the throne, and the Ming Dynasty was established in 1368.

### 7.5 The Little Ice Age, the Thirty-Year War, and the downfall of the Ming Empire

The mild climate of northern Europe was replaced by cold and wet years during and after the 14th century. There were many cold and stormy winters in the 16th and 17th centuries, when the climate became frigid during the Thirty-Year War. The first signs of warming did not come until the 18th century, to be followed by numerous clusters of cold and wet years. The Little Ice Age s.s. did not come to an end until the start of the modern warming trend in the mid-19th century.

The changing climate had impact on the political developments in Europe. The Vikings were no longer the all powerful. The cities of the German Hanseatic League suffered economic declines. There was the Thirty-Year War, and Germany was devastated. Soldiers robbed and pillaged during the first half of the 17th century, and the people were on the move again. But they had no place to go, and roamed aimlessly as depicted by Bertolt Brecht's play *Mother Courage*. Historians, as usual, blamed the war and the warriors, but the warriors joined Wallenstein's or Gustov Adof's army because they could no longer farm at home. Not very many people were killed, but many died of starvation or epidemics after they were weakened by hunger. The culprit was obvi-

ously not so much the war, but the cold and wet climate of the Little Ice Age; a global cooling had devastating effects on the agricultural production in many parts of central and northern Europe.

Kennedy[32] pointed out that the nations of western Europe——Spain, France, Britain, and Holland——escaped the miseries of the Little Ice Age. They were spared, because their economy was based upon colonization and trade policies, rather than agriculture. Germany could join the western powers only during the 19th century when the European economy had an industrial basis; dependence upon climate is no longer total when trade and industry take the place of agriculture.

The ill effects of a deteriorating climate were more obvious in China. The Ming Empire, despite of the military genius of its Third Emperor Yung-Le, was never to match the glory of Han or of Tang. The economy stagnated, and there were famines. With more and more cold and arid years, the empire was doomed. The worst drought came during the reigns of the last two Ming emperors Tianqi and Chongzhen, 1601—1644: *Ba-nian-da-han* (eight years of continuous drought) visited central China not once, but twice. The final catastrophes came during the 6th to 16th years of Chongzhen (1633—1643): the whole nation suffered from drought, and starving people were everywhere. Driven by hunger, cannibalism was practised. Peasants rose, and they conquered one city after another and opened one grainary after another. The Chongzhen emperor hanged himself when the rebels entered the Forbidden City. The Ming Dynasty perished, when the well-drilled army of the northern Asiatic tribes from Manchuria took the opportunity to invade China. They crushed the rebellious peasants and established the Qing Dynasty.

China enjoyed peace and prosperity under the good rule of the first Qing emperors; there seemed to have clusters of warm years in the 18th century. The introduction of the corn from North America effected a green revolution during the 60-year reign of Emperor Qianlong, 1736—1796, when the Chinese population quadrupled from 100 to 400 million. The return of the cold and drought during the later years of the Little Ice Age was, however, about to exact its toll: peasant rebellions broke out again during the last decades of the 18th and the first of the 19th centuries.

The modern warming trend started in China since 1840, and China was never to experience a drought catastrophe such as the *ba-nien-da-han*. The global warming seems to have been a blessing.

### 7.6 The great migrations of the Anasazis

The Anasazis of western North America evolved from a hunter-and-gatherer population, and the flowering of the Anasazi civilization started around 900 AD, the age of the Medieval Optimum in Europe (LCO c). The Anasazi farmers built numerous settlements, including some very imposing cliff-dwellings, in the Four Corners region. When the first clustering of the cold years came around 1300 AD, toward the beginning of the Little Ice Age, s.s., Anasazis left their home and went south. The period between about 1300 and 1540 AD witnessed impressive geographic shifts in human settlements. The Anasazis farmers migrated to southern Arizona and New Mexico. They first settled at transient stations, before they finally moved into "aggregated villages". Deprived of farming land, the immigrants had to become pottery makers and traders, living in crowded apartments ("Casa Grande") of hundreds of rooms[33].

Why did the Anasazi leave their homes?

Invasion of foreign tribes (such as Utes or Apaches) was not the cause, because the hostile warriors did not arrive until years after the departure of the Anasazis[34] (Cassells, 1994). The migrations are commonly related to environmental factors, for it is generally recognized that the homes of the Anasaxis were, even at the better times, only marginally suited for farming. A low elevations, the growing season is relatively long, but the precipitation is scant. Some speculated that the Anasazis left because of the very severe droughts during the decade before 1300 AD[33]. In the mountains, rainfall is plenty, but the growing season is short. Minor changes in mean annual temperature would reduce the length of growing season so that the farmers could not hope to mature a crop of maize[35]. Climate change seems thus the best answer to explain the mysterious exodus of the Anasazis. Having abandoned the farms, their descendents became factory workers and traders in the slums of the south.

## 8 Cycles of global climate changes in historical time

Climatic variations discussed in the preceding sections are summarized as follows:

A. Modern climatic optimum a—after 1820
B. Little Ice Age b (*sensu stricto*): 1280—1820 AD, centuries before/after 1600 AD
C. Little climatic optimum c (Medieval) 600—1280 AD, centuries before/after 1000 AD
D. Little Ice Age d (early Christian Era): 60 BC—600 AD, centuries before/after 400 AD
E. Little climatic optimum e (Greek-Roman) 700—60 BC, centuries before/after 400 BC
F. Little Ice Age f (Homeric) 1275—700 BC, centuries before/after 800 BC
G. Little climatic optimumg g (Shang) 1800—1250 BC, centuries before/after 1400 BC
H. Little Ice Age h (collapsed civilization) 2200—1800 BC, centuries before/after 2000 BC
I. Little climatic optimum i (late Neolithic) 2900—2200 BC, centuries before/after 2600 BC
J. Little Ice Age j (man-buried-in-ice), 3400—2900 BC, centuries before/after 3200 BC

The range of the little ice ages and climatic optimums is defined by the first and last clusters of unusually cold or unusually warm years recorded by history. The termination of the LIA b was placed at 1820 AD, after one of the coldest decade of the last few centuries, and the beginning of the Little Ice Age was placed at 1275 AD when the first mass-exodus of the Anasazis began. The LCO c began at about 600 AD when Slavonic people first moved into northen Germany, and when peace and prosperity first returned to China after centuries of chaos. The LIA d was the time when Germanic tribes left their home, and the epoch had its beginning at the time of the exodus of the Helvetians. The LCO e started when Greek came out of the centuries of darkness and when Rome was founded. The LIA f coincided with the "Centuries of Darkness in the Middle East", which may have begun as early as 1250 BC or as late as 1050 BC. The LCO g coincides more or less with the reign of Shang kings of China, and the warm epoch began when the LIA h which caused the collapse of Mesopotamian civilization came to an end. The LCO i was terminated when that Little Ice Age began 2200 BC. The cooling leading to the LIA j started when the Saharan lakes first began to dry up, a century or two before the man-in-ice was buried by the advancing Tirolian glacier around 3300 BC.

The divisions are arbitrary and they can be improved upon when a climatic record is established on the basis of a systematic study. The chronology of the divisions depends upon interpretations of historical dates, which are subjected to significant errors, especially those of the pre-Christian Era. If the periodicity had been regular, the alternating epochs should each have a duration of 600 years: the cold epochs reached their zenith around 1600 AD, 400 AD, 800 BC, 2000 BC, 3200 BC, etc. and the warm epochs their zenith around 1000 AD, 200 BC, 1400 BC, 2600 BC, etc. The historical cycles are, however, not regular, but quasi-periodic.

Climatic cycles have been observed through studies of nature. Schneider and Londer[9] noted, for example, peaks of advances of mountains glaciers around 1700 AD, 800 BC, and 3200 BC. O'Brien and others (1997)[36] found concentrations of sea salt and dust in a Greenland ice core defining cold periods of 1400 AD to the present, 1100—800 BC, 3000—4100 BC. Dansgaard[37] found 2550-year cycles in the $^{18}O$ of his Greenland ice core. Damon and Sonhett[38] found cycles of 2 100 to 2 400 years in the radio-carbon production. Magny[39] found 2 300-year cycle in lake-level fluctuations, with high levels occurring during periods of high $^{14}C$ production at about 1500 AD, 800 BC, and 3500 BC. All the data indicate a quasi-periodic cyclicity of more or less 2 500 years, and the cold epochs corresponded to little ice ages b, f, and j of the historical record.

An examination of the data by O'Brien and others indicates to me, however, that LIA d and f are manifested by less obvious concentrations of sea salt and dust in the Greenland ice core. Millennium cycles of LIA b and d have also been recognized by event-stratigraphy studies of sediment cores from offshore California basin[40]. In summary, we see that all but one of the five quasi-periodic historical little ice ages (b, d, f, j) have been identified as cyclic events in nature. The LIA h is, however, very real, because it was the cooling event which marks the end of the Early Holocene Climatic Optimum. Blinded by an enthusiasm for 2 500-year cycles, this most significant ice age was overlooked.

A most significant cyclicity since the deglaciation is the change in sea-level. Fairbridge and Hilliare-Marcel (1977) found decreases in the rate of sea-level rise, corresponding to global cooling at 1650 AD (1600 AD LIA b), 100 AD (400 AD LIA d), 1200 BC (800 BC LIA f), and 3100 BC (3200 BC LIA j). Ters (1987) gave the following maxima and minima: 1600 AD (1600 AD LIA b), 800 AD (1000 AD LCO c), 200 AD (400 AD LIA d), 300 BC (200 BC LCO e), 700 BC (800 BC LIA f), 1500 BC (1400 BC LCO g), 1800 BC (2200 BC LCA h), 2200 BC (2600 BC LCO i), 2700 BC (3200 BC LIA j). The maxima and minima of the historical little ice ages and little climatic optimums are given in parenthesis for comparison. Considering the lack of precision of the data, the correlations are amazingly good. Most significant is the recognition of a quasi-periodicity that ranges from 1 100 to 1 500 years in both the observational and experimental data.

## 9 Correlation of climatic cycles to fundamental harmonics of solar activity

Since the atmospheric carbon dioxide did not vary cyclically during the last 10 000 years, the Holocene climatic variations cannot be related to the greenhouse effect. The periodicities cannot be orbital either; they have longer durations of some 100 000, 40 000 and 20 000 years. Only the variations of the solar activity have short cyclicities.

Very short-term changes of solar irradiance are manifested by sunspot cycles. A key indicator

is the length of the "11-year" sunspot cycle which actually varies from 7 to 15 years. During the cycle, the number of sunspots and flares on the Sun's surface varies because of the underlying changes in magnetic activity.

Scientists committed to their conviction of an impending greenhouse catastrophe have all ignored the fact that the average global temperature on the Earth during the last 150 years has not varied in step with atmospheric greenhouse effect; it has varied in step with the length of the sunspot cycle of solar activity. When the cycle is longest, the Sun is less active, and the temperature on Earth falls[12,2](Lassen, 1991). The correlation of global temperature variation with the length of the sunspot cycle is so perfect that the chance of the correlation being a freak is considered unlikely[41].

That climate should be influenced by solar activity has been questioned, because annual variations during the last century are commonly less than 1 watt/$m^2$, or about 0.1% of the total, over the period of a sunspot cycle. Perry[42] found, however, evidence that the small variations of solar-irradiance can be amplified to cause significant impact on climate; the solar effect is nonlinear, and a slight anomaly could trigger feedback mechanisms to have a snow-balling effect. Furthermore, the accumulation of heat-deficit or excess during a prolonged period is considerable.

The existence of solar cyclicity of variable periodicity has been explained in terms of fundamental harmonics[12]. Combining sunspot and geophysical data, Perry found variations of solar activity with cycle lengths of 11, 22, 44, 88, 176, 2 700, 20 000, and 100 000 years. The first 5 cycles show a progression of the periodicity:

$$T = 11 \times (2)^n,$$

where $n$ is equal to 0, 1, 2, 3, 4. Expanding the progrssion to $n$ equal to 5, 6, 7, 8, 9, 10, 11, and 12, values of 352, 704, 1 408, 2 816, 5 632, 11 264, 22 528, and 90 112 years are computed. The geometrical progression is a fundamental harmonic progression, with each cycle length being an interger doubling or halving another cycle.

Fundamental harmonics consists of a series of waves with the short wave periods (high frequency) able to drive the longer wave periods (low frequency), and this is possible because the amplititude of the short waves varies. Solar energy is derived from nuclear fusion, and the sunspot cycles are an expression of a cyclicity of this variable periodicity. Perry[42] presented a model to illustrate that the decade-long cyclicity of solar irradiance, as expressed by sunspot cycles, is driven by the high-frequency vibration-waves of millisecond-priodicity, which owe their origin to the variable nuclear magnetic resonance of the fusioning hydrogen and helium atoms in a variable magnetic field. Perry further demonstrated that the cyclicities of variable sunspot cycles can generate low-frequency periodicities of century-long or millenia-long climatic changes.

The change in sea-level along the French Coast (Ters, 1987) has been compard to Perry's solar-output model: the high-and-low stands of the sea-level and the historical little ice ages and climatic optimums b, c, d, e, f, g, h, i, j can all be correlated to the solar-output variations computed by Perry's model[12]. Noteworthy is further the fact that the model suggests gradual cooling and sudden warming in climatic cycles. Global cooling started, for example, from the height of the Medieval Optimum at about 800 AD (LCO c), with oscillations of clusters of lower global-temperature, reaching a nadir in the early 19th century. The glogal warming came suddenly, but it may soon reach its zenith during the next century, to be followed by a millenium of cooling leading to the nadir of the next little ice age[12].

## 10 Correlation of climatic cycles to sunspot minima

The sunspot data obtained during the last 300 years show the fundamental harmonics of the 0th, 1st, 2nd, and 3rd order (11-, 22-, 44-, and 88-year cycles). Prior to 1 715 solar activities were at a minimum, when sunspots were absent for some 70 years. This event is called the Maunder Minimum, 1645—1715[43]. Prior to that was the Spörer Minimum, 1400—1510 AD, and still earlier was the Wolf Minimum 1275—1340 AD. The minima separated by 235 and 140 years respectively could express the variable periodicity (more or less 176 years) of the fundamental harmonic of the 4th order.

The sunspot record, based upon reports of telescopic observations, of solar flares, and of other indicators of solar activity, has been amended by naked-eye sunspot observation, mainly by Chinese astronomers[44,45]. Referring to a list compiled by Wittmann[46], I noticed the following periods of unusully active or unusually quiet epochs:

Maunder Minimum 1645—1715 AD: 16 sightings in 71 years.
(Maximum between Spörer and Maunder, not documented)
Spörer Minimum 1402—1516 AD: No sightings in 117 years.
Yuan Maximum 1350—1387 AD: 43 sightings in 38 years.
(Wolf Minimum 1275—1340 AD, not documented)
Song Maximum 1076—1278 AD: 58 sightings in 203 years.
Tang Minimum 579—807 AD: No sightings in 228 years.
Northern Wei Maximum 478—513 AD: 15 sightings in 36 years.
Six-Dynasties Minimum: 401—477 AD: No sightings in 77 years.
Eastern Jin Maximum 296—400 AD: 30 sightings in 105 years.
Eastern Han Minimum 20—295 AD: Only two sightings in 275 years.

There have been some 6 alternations during the last 2 000 years, and the average periodicity of about 330 years suggests a dominant periodicity of a fundamental harmonic of the 5th order (352 years). In detail, the period for the Little Ice Age b (1280—1820 AD) is found to be marked by the presence of three minima (Maunder/Spörer/Wolf) with the variable periodicity of a fundamental harmonic of the 4th order.

The 1 200-year quasi-periodicity of the historical climatic changes corresponds to a fundamental harmonic of the 7th order. Combining the low-order into high-order harmonics, we have found a correspondence between the solar activity and historical climatic changes:

Maunder/Spörer/Wolf Minimum 1275—1715 AD (LIA b 1280—1820 AD)
N. Wei/Song Maximum 478—1278 AD (LCO c 600—1280 AD)
Eastern Han/Six-Dynasties Minimum: 20—477 AD (LIA d 60 BC—600 AD)

Cyclic variations of $^{14}C$ have also been interpreted as manifestation of varying surspot activities. Damon and Sonnett[38] identified the dominant periods as 11, 88, 149, 207, 649, 909 and 2 272 years, corresponding to fundamental harmonics of 0th, 3rd, 4th, 5th, 6th and 7th order. Eddy[43] recognized on the basis of $^{14}C$ data the Medieval Minimum (200—700 AD), a Homeric Minimum (900—700 BC, correlative to LIA f 1275—700 BC), and a Stonehenge Maximum before 2000 BC (correlative to LCO i 2900—2200 BC). The good correlation of the astronomical

and historical observational data gives credence to Perry's theory that climatic changes are related to variations in solar luminosity[47].

## 11 Has global warming been a blessing to mankind ?

The subtropical latitude lands on Earth are destined to become deserts, because of the normal pattern of atmospheric circulation: the so-called Hadley Cell describes the transport of moisture from the low latitudes to the subtropical and to the high latitudes. The Sahara is a desert because moisture rises in low-latitude lands. The Sahara only became green when monsoons from Equatorial Atlantic could come far enough north.

The storm tracks of the westerlies have a great impact on the weather of the Mediterranean. In January 1955, when the storm tracks were more northerly than normal, Greece suffered drought. Bryson and Murray[4] reasoned that a persistent pattern of storm tracks like that of January 1955 would bring no rain to Mycenae and cause Greece to fall into "centuries of the dark centuries".

The influence of temperature changes to the precipitation patterns in the Far East is even more obvious. The interior of China would have been a desert like Sahara, if monsoons could not penetrate into China. At the present little climatic optimum, the central plains are visited by tropical storms and southeasterlies. The precipitation is life-giving. At times of global chill during the historical past, a high-pressure center was positioned over China. Typhoons were deflected to southern China and the South China Sea. Storms came less frequently to China, thus causing the terrible droughts at the end of the Ming Dynasty or during the Eastern Jin.

In discussing the implications of global warming, the emphasis has been placed on the horrible consequence of sea-level rise because of the melting of polar ice caps: large coastal strips would be drowned, and there might be salt water invasion of ground water. Furthermore, there would be more storm and flood damage. All of these would represent severe damage to economic development. From a global perspective, a climatic warming will bring warm and wet years to North Africa, Near East, and East Asia. The brief summary of the historical records indicates that global warming has been a blessing to human societies based upon an agricultural economy. A global cooling, on the other hand, is to bring years of drought to China and to the Middle East, and to parts of the Americas, where the annual preciptation is even now barely sufficient to supply the water for irrigation.

The effect of global warming has been beneficial also to Europe. Cold years are wet years in northern and central Europe. Too short a planting season leads to crop failures, and wet summers are not for hay-making. The history of mass migrations from the northern German plains suggests that a return of a little ice age will have devastating effect on the agricultural economy of Europe; we tend to overlook the fact that the global warming during the 20th century has been a blessing to the Europeans.

I do not preach that we should continue to waste fossil fuel to promote global warming. Natural variations of atmospheric carbon dioxide will have long-term effect on global climate. The geological record indicates that the atmospheric carbon dioxide has decreased by about an order of magnitude during the last 100 million years. However, at the present rate of fossil-fuel consumption, we might cause a 10-fold increase in 1 000 years. In the long run, the melting of polar ice caps will not only drown the coastal cities, there will also be transgression of seas into interior

lowlands of continent.

The real danger to the well being of mankind is, however, the sudden and unexpected global cooling. China had had a population of 100 million before the population was reduced by 30 million by the catastrophe during the cold and arid years of the last Ming emperors. Thanks to better irrigation and to the development of high-yield wheat and rice, almost enough grains are produced today in China to feed its 1.2 billion population. A catastrophic drought will have, however, unthinkable consequences in China and in other lands of the temperate zone. Europe will not fare much better, when the crops fail during the cold and wet years of the north.

If the cyclicity of changes in terrestrial climate should be 1 000 or 1 200 years in duration, the doomsday may still be many centuries away. The climatic model relating climate to solar luminosity is, however, extremely alarming. The cyclic changes of some 1 200 years are not simple harmonics: we cannot assume that we shall not come to the peak of global warming until 2200 AD, and the little ice age will only come sometime before 2800 AD, many years from now. The global warming may be replaced by a global chill during the next century, to be followed by a millenium of cooling leading to the nadir of the next little ice age. When the warming trend was interrupted during the 1960s and 1970s, the public alarms are manifested by the Cassandra books on global cooling[3,4]. The warming trend of the last decade has turned the tables: we are told that we are entering the greenhouse century[48]. With a decade of medium attention, few now remember the warnings of the danger of the coming little ice age. If Perry is right, the global chill may be just around the corner: we may be facing the first of a worldwide drought before the end of the next century.

We still have time to prepare for the eventuality. If global cooling is to be our nemesis, the research efforts should not be placed in computer-modelling of the greenhouse effect on global temperatures. We should make preparations for the climate of hunger. Plant-geneticists might be encouraged to breed new varieties of grains which could resist drought conditions. We should further recognize the fact that irrigations will not help agriculture if there is no precipitation to recharge the groundwater reservoir. We have to consider the use of solar energy for the desalinization of water to provide supply for irrigation. In the long run, none of those measures would help if the present population explosion and the overemphasis on economic development continued. I see no way that a 6-billion plus population can be sustained if and when the next little ice age should return. There is no alternative to planned parenthood.

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