

Could Global Warming be a Blessing for Mankind?

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(Manuscript received 9 July 1996, in final form 12 September 1996)

ABSTRACT

Accepting the scientific evidence that the increased carbon-dioxide in atmosphere, introduced mainly by burning fossil fuels since the industrial revolution, is to cause global warming, the next question is the consequence: is global warming or the alternative global cooling more of a threat to mankind?

Global temperature changes are to influence regional precipitation patterns. Scientific and historical data indicate that at times of global warming, low-latitude lands in continental interior such as China are wetter, whereas high-latitude countries such as Europe are drier. Both sets of circumstances have been beneficial to agricultural economy. At times of global cooling, low-latitude lands in continental interior are more arid, whereas high-latitude countries are wetter. Both sets of such circumstances are detrimental to agricultural economy.

History also shows epochs of peace and prosperity alternating with epochs of war and famines. Those epochs seem to correspond to epochs of warmer and colder climate respectively. The two global-cooling epochs during the last two millennia were the Little Ice Age of the 16th and 17th century and the age of the Great Migrations of the late 3rd to the 6th century. In those centuries, there were droughts and famines in China, and bad harvests and popular unrest in Europe. The lesson of history suggests that a return of a little ice age would cause such an aridity in China that its 1.2 billion population cannot possibly be fed. At the same time, Europeans may suffer from bad harvest or even starvation.

(Key words: Climate, Greenhouse, Global warming, Drought)

1. INTRODUCTION

There has been considerable ballyhoo in the press medium about the impending catastrophe of a 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. Social scientists held their international congress and they came up with a resolution

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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 inevitable warming. European governments are taking active measures to consider the imposition of 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 orthodox predicted global warming, mainly on the basis of computer-models relating greenhouse effect to global temperatures. Their opponents emphasized the role of evaporation and precipitation, and suggested that the temperature rise initiated by the greenhouse would lead to increased cloud cover globally and to more snowfall in polar regions, and result thus in a global cooling. The 4 billion-years of earth history shows, however, a definite correlation of the global temperature and the carbon-dioxide content in atmosphere: the long-termed effect of greenhouse gases has been to produce global warming (Hsü, 1992). I would thus accept the orthodox prediction that there has been a trend toward global warming because of the increase carbon dioxide in the atmosphere.

What I would like to explore is not whether global warming is or is not going to take place, but to look into the historical records to predict the consequence if such a global warming is or is not taking place. Would global warming be a catastrophe as it is generally believed? Or would the alternative of global cooling bring an even greater disaster to mankind?

The climatic history of the post-Glacial age during the last 15,000 has been recorded by sediments, by trees, by glacial ice, by archaeological remains, and by written history. The influences of climatic changes during the last 2000 years on the changing fortunes of human societies have revealed a systematic pattern. Global cooling brought more precipitation in high-latitude countries and droughts in low latitude lands of continental interior. Both the cold and wet climate in Europe and the cold and dry climate in Asia and North Africa caused serious crop failures in historical time. Whereas the damages by storms induced as a consequence of global warming are causing serious property losses, the famines as a consequence of global cooling could mean the starvation of billions of the world's population. Is it probable that the global warming trend, which started since the middle the last century has been, on the whole, a blessing to mankind?

This work presents a conclusion based mainly upon the work by the staff of the Limnogeological Research Laboratory of the Swiss Federal Institute of Technology during the last 30 years. We have acquired a global view through cooperative researches with Prof. Chen Yancheng of the Geological Research Institute, Chinese Ministry of Chemical Industries, Zhuozhou, China, with Prof. Liu Ping-Mei of National Taiwan University, Taipei, Taiwan, and with Prof. Arturo Amos, of Argentine Academy of Sciences, Bariloche, Argentina. I have relied heavily upon the two monographs by Liu (1982) and by Lamb (1982) on the relation between climate and cultures in China and in Europe. I have intentionally avoided references to North America, because the historical records are too scanty to permit a generalization.

I have written this manuscript in a style to communicate to the general public, and to address to their concern about the consequence of global temperature changes. The conclusion presents a first-order outline and is necessarily still preliminary. The idea was first presented in 1994 to a working group in Taiwan, and has encouraged historical researches by the staff of

Academia Sinica, Taipei, to record the changing climate of China. Such a systematic study on a worldwide basis of the extensive historical data could finally answer the question if global warming, or global cooling would lead to a great catastrophe to the mankind.

2. THE POST-GLACIAL CLIMATE

Whereas the origin of hominids is traced to the far historic past several million years ago, the species *Homo sapiens sapiens* first appeared toward the end of the Ice Age. Studies of sediments on land, under the sea, and of polar ice have given clear indications that the earth underwent numerous episodes of continental glaciation during the last two million years. The last glacial stage reached its zenith 18,000 years ago, when half of North America, all of Scandinavia, and large parts of Europe were crowned by continental ice sheets, comparable in size to the Antarctic Ice Cap of today.

The ice caps of continental glaciation started their retreat after their greatest expansion. The post--glacial time is commonly considered to have begun some 16,000 or 15,000 years ago. Shortly after that Denmark was liberated from the ice cover, *Octopella dryas*, appeared in the meadows on the periphery of retreating glaciers. This small white Alpine flower is still found growing in mountain meadows of the Alps. The occurrences suggest that the climate of the lowland land of northern Europe at that time was similar to that of the present-day Swiss Alps at about 2,000 m elevation. Subzero temperature prevailed during the winter months, when mountain lakes were frozen. The lakes were thawed during the late Spring, when they were fed by melt waters from nearby glaciers. The summer months were cool, and storms might cause snow precipitation.

Scientists called this epoch of the post-glacial climate the Dryas Stage. Climate continued to get warmer then. Meadows were replaced by forests, and the evergreens were replaced by deciduous trees to form the "mixed forests" in Europe. The global climate was, on the whole, as mild as that of today. Then suddenly, about 11,000 years ago, the freeze returned. This brief cold interlude, when the alpine flower *O. dryas* came back to Denmark, is called the Younger Dryas Stage. In less than a thousand years, however, the chill disappeared as quickly as it appeared. A wholly new epoch, called the Holocene, had its beginning some 10,000 years ago, and the global climate has been on the whole warm since then.

There have been climatic fluctuations during the Holocene, but the average annual temperatures have not changed very greatly; deviations are rarely more than 1°C. The global climate was warmer during the early Holocene, 10,000 to 5,000 years ago, and the interval has thus been characterized as the time of *Climatic Optimum* or the *Megathermal* stage (Bradley, 1992). The second half of the Holocene was on the whole colder.

When did the cooling trend start? Was the change to the colder climate abrupt or gradual? Has it been a steady decline, or were there significant and systematic fluctuations?

My associates and I at the Swiss Federal Institute of Technology have been engaged during the last 2 decades to seek answers to those questions. We have learned that the global climate was indeed warmer five to ten thousand years ago, and the period was called *Climatic Optimum* or *Megathermal* (Bradley, 1989). There is, however, no consensus when did the Megathermal end. Boryenkova's (1990) Russian data led her to suggest a 5,300 BP termination. Hafsten (1976) proposed 3,300 BP on the basis of the pollen record of northern Europe.

Some Chinese scientists (Gao *et al.*, 1990) gave a 4,000 BP, others (Kung *et al.*, 1992) a 3,500 BP date, and still another group (Shi *et al.*, 1992) preferred a 3,000 BP date.

The considerable evidence suggests an end of the Climatic Optimum some 5 or 4 thousand years ago in Europe, in North Africa, in Near East, in Far East, and in South America. At any rate, the climate after 3,000 BP was significant colder than that before 5,000 BP. The climatic changes may have been globally synchronous, but the signs of cooling may have manifested earlier in one region, and later somewhere else. The manifestation of cooling in central Europe is the advance of glaciers in the Alps. When did the glaciers come to the Alps?

3. WHEN DID GLACIERS COME TO THE ALPS

Switzerland was buried under an ice cap during the Ice Age, when only a few peaks ore more than 4,000 m in elevation stood above the ice. The ice cap is now gone, but the highest peaks of the Swiss Alps are still glaciated. The Alpine mountain glaciers now come down to elevations below 3,000 m. Are the Alpine glaciers the last remnants of the ice cap of th Ice Age? Or was the ice cap long gone, before the Alpine glaciers made their new appearance? Are we now at the end of the Ice Age, or are we now at the beginning of a new ice age? Studies of moraines provided an incomplete history of glacial retreats during the post-glacial age. My colleagues and I in Zurich have thus searched for indications of changing climate in the sediments of Swiss lakes .

The lakes in Swiss Midland and in southern Switzerland have levels below 1,000 m in elevation; they do not, or rarely, freeze during winter months. The lowland lakes are fed by rivers, and their sediments are muds settled down from river suspensions. Where supply of detritus is a minimum, such as Lake Zurich, lacustrine chalks or marls are precipitated. The lakes in high mountain valleys at 1,500-2,000 m above sea are, however, frozen for several months during every winter. Those lakes are fed by streams which have their source in alpine glaciers, and their sediments are derived from glacial erosion. The sediments from those two kinds of lakes are thus very different, because of the difference of their climatic environment.

Meltwaters from the glaciers come in the spring and summer months. Unlike bubbling brooks at normal time, the spring meltwaters from glaciers are milky green, being colored by their extremely fine suspension. Local inhabitants call meltwaters the "glacial milk." The suspended sediments are mainly silt- and clay-sized particles. The clay-sized fraction in river sediments are normally clay minerals. The clay-sized fraction of a "glacial milk" is different: it includes not only clay flakes, but also extremely fine grains of quartz and feldspar minerals. This occurrence is extraordinary, because quartz and feldspar detrital grains are usually silt or sand-sized. The explanation is simple: the quartz and feldspar detritus suspended in "glacial milk" have suffered an unusual fate: they have been grounded down by the milling motion at the bottom of glaciers, like wheat or rice grains by a millstone. Such very fine quartz and feldspar grains are thus the characteristic sediments of the suspension in the meltwaters from glaciers. If there are no glaciers at the source of the mountain streams, the hard mineral grains could not have been milled down to clay size, there can be no "glacial milk" The presence or absence of this fraction of extremely fine quartz and feldspar in the sediments of mountain lakes could thus answer the query if glaciers have always been present in the Alps since the start of the post-glacial time.

When "glacial milk" of mountain streams enters a lake, the coarser grains of sand and silt are immediately laid down to lake bottom, depositing a silt layer a fraction of millimeter in thickness: this is the summer lamina of an annual sediment, called varve in Sweden. The clay fraction, being the finest constituent of the "glacial milk", remains suspended for several months in lake water. When air temperature drops below zero in early winter, the mountain lakes would freeze, and they are frozen until the next spring or early summer. The clay suspension which has come with the spring floods would now begin to settle slowly onto the bottom of the ice-covered lake. The winter freeze of the lake and of the mountain streams prevents the influx of sand and silt sedimentation into the lake. The winter sediment is thus the settled clay suspension only, forming a paper-thin lamina above the silt lamina. Such a clay lamina is the winter layer of a varve. Now if a lake does not freeze every winter, there can be no annual winter-lamina, and there should be no varved sediments. Lakes of Swiss Midland, for example, rarely freeze in the winter, and there are indeed no varves in those lakes.

Our understanding of the processes of lake-sedimentation led to a prediction that varves should be present on the bottom of mountain lakes which are frozen every winter. We carried out thus a preliminary survey during the late 1980s. The prediction was verified after we found varves in all 12 of the mountain lakes investigated by us. The finding of varves in the mountain lakes of the Swiss and Austrian Alps above 1,500 m altitude permits two conclusions:

- (1) that varves are deposited only in a lake which freezes every winter.
- (2) that varves are deposited only in a lake where glacial meltwater is emptied every spring directly into the lake.

We found annual deposits of lacustrine chalk in Lake Zurich, but no varves in Holocene sediments, because the lake does not freeze every winter, and because meltwater from glaciers is not emptied directly into the lake. But the climate was not always the same. The Zurich region should have been colder during the Younger Dryas. Were varves deposited in the lake during that cold episode 11,000 to 10,000 years ago?

We drilled a deep hole in 1980 into the deepest bottom of the lake, where the drilling penetrated below the Holocene sediments. We found varves in the Younger Dryas sediments of Lake Zurich! Their presence permitted the conclusion that Lake Zurich did freeze every year during the Younger Dryas Stage, and that the meltwater of the Linth Glacier, which stood only a short distance upstream from the lake, was emptied directly into the lake. This conclusion permits the visualization that the climate in the Swiss Midland (400-500 m elevation) 10,000 years ago is comparable to that of high mountain valleys (1500-2000 m) today. No wonder alpine flowers such as *O. dryas*, which are found today in high alpine meadows, grew on low plains during the Younger Dryas time.

The early Holocene Climatic Optimum came after the interlude of chill, and the global temperatures then were, on the average, higher than they are now. Is it possible that the climate of the Alpine valleys was so warm that it was comparable to the lowland's climate of today. If this was the case, we could predict that the sediments of the mountain lakes deposited during the early Holocene should be lacustrine muds, not varves.

We took during the early 1990s several long sediment-cores from Lake Silvaplana and Lake St. Moritz in the Engadine Valley, where the lake level was more or less 1,700 m above sea. Our prediction was verified, the sediments deposited during the early Holocene were

muds, not varves; even the component of extremely fine quartz and feldspar, typical of glacial milk suspension, is absent. We can conclude that the Engadine lakes did not freeze every winter during the early Holocene, and that there were practically no glaciers in the mountains above the Engadine Valley.

When did the glaciers come to the Alps? We could count the varves; each pair of the laminae of a varve is deposited once every year. Andreas Lehmann (ETH dissertation, 1993) counted 3600 varves, lying above the early Holocene mud. The carbon-14 (uncorrected) date for the first varve is 3,600 B.P. This fact suggests the conclusion that the Swiss Alps had few if any glaciers prior to 3,500 or 4,000 years ago.

Was there a change from the early Holocene warmth to a late Holocene cold climate elsewhere in the world? My colleagues and I have been cooperating since 1975 with Chinese colleagues to study the lakes and lake sediments of northwest China.

There was an extremely cold Ice Age in China, but there were no continent-wide glaciation. There was permafrost on the Tibetan Plateau, but no ice cap. The post-glacial warming started in China, as it did elsewhere, some 15,000 years ago. The meltwaters from mountain glaciers were the source to recharge the groundwater of the arid Chinese northwest.

We carried out several studies of brackish and saline lakes of Tsinghai and Inner Mongolia (Wang and Wang, 1994; Chen *et al.*, 1994). The post-glacial sediments of the lakes of northwest Inner Mongolia are either detrital sediments such as sands and muds or chemical precipitates called evaporites. In a few places, an alternation of mud and evaporite deposits were penetrated by drillholes. We asked the question on the paleoclimatic significance of those sediments: Were the lakes always brackish or saline? When, during an interglacial or a glacial stage, was a sand or a mud layer deposited? When, during an interglacial or a glacial stage, was an evaporite layer deposited?

Our sedimentological studies revealed that sands were transported by meltwater-streams and deposited on the bottom of freshwater lake; muds were deposited either in lakes or on playas, and evaporites were crystallized in the brines of saline lakes (Chen *et al.*, 1994). The successions of lake sediments permits a reconstruction of climatic events in of Tsinghai and Inner Mongolia, northwest China:

- (1) Post-glacial, 15,000 -11,000 BP Sand and silt deposition in freshwater lakes.
- (2) Younger Dryas, 11,000-10,000 BP Playa mud deposition at a time when the post-glacial lakes dried up.
- (3) Early Holocene, 10,000-5,000 BP Mud deposition in fresh or brackish water lakes, with rare growths of evaporite minerals in more saline lakes.
- (4) Late Holocene, 5,000 BP- now. Mud deposition in brackish lakes and evaporite precipitation in saline lakes.

Where did the lake water come from? Most of those lake basins are now interior drainage basins. The more brackish lakes are fed by streams and/or by springs, and the saline lakes have brines which seep upward from underground. To trace the origin of the lake waters, we initiated in the early 1990s a program, in cooperation with Chinese colleagues, to investigate the oxygen-isotope geology of the chemical precipitates of saline lakes. Empirical survey has indicated that the δO^{18} of the meltwater from glaciers has a very large negative anomaly,

because of the preponderance of O^{16} in glacial ice. The anomaly is less for chemical precipitates in a lake where the groundwater was recharged by rainfall, and it is even less when the lake water has been salinated through excessive evaporation.

The oxygen-isotopes of the trona deposits of Inner Mongolia saline lakes records a history of paleohydrologic evolution. Rare carbonate minerals in the post-glacial muds are characterized by an extremely large δO^{18} anomaly of minus 20 pro mil. The value indicates that the lake water was derived a groundwater which had been recharged with meltwaters of mountain glaciers (Chen *et al.*, 1994). The post-glacial lakes dried up during the Younger Dryas time, when it was extremely cold and arid. The δO^{18} value was down to zero! This remarkable isotope anomaly is indicative of a catastrophic aridity during the cooling of the Younger Dryas (Chen *et al.*, 1996).

The sudden warming at the beginning of the Holocene came to China, at about the same time as elsewhere in the world, some 10,000 years ago, when the lake basins of Chinese Northwest hosted freshwater lakes again. The Tsinghai lake was filled to a level 120 m. higher than that of the present, and ostracods lived in the freshwater lakes of Inner Mongolia.

The climate during the last 10,000 years has not been uniform: there has been a notable change from the warm and wet climate of the early Holocene to the colder and more arid climate of the late Holocene (Shi, 1992; Chen *et al.*, 1994). The oxygen isotope of trona in the lake sediments of Inner Mongolia has a δO^{18} value which changes from minus 6 pro mil during the warmer early Holocene to about minus 3 pro mil during the colder late Holocene. The change took place during a short interval, sometime after 5,000 years B.P.; the timing was thus more or less contemporaneous to the cooling in Europe at the beginning of the late Holocene.

Was there a simultaneous cooling in the Southern Hemisphere?

I started in 1993 a project to cooperate with Arturo Amos to study lakes in the temperate regions of Argentina. The work is still in progress, but we have obtained sufficient preliminary data to see a synchronicity in both Hemispheres of the change from the early Holocene warm to the late Holocene colder climate (Aristegus, 1996). Warming or cooling changes seem to have been global!

4. THE CHANGING CLIMATE IN HISTORICAL TIME

The climatic changes in Europe and the Mediterranean countries during historical times have been studied by archaeologists, historians and by natural scientists. We have indicated, on the basis of natural history studies, that there was a global cooling some 4,000 years ago. The cooling trend since then has, however, not been steady; colder epochs alternated with warmer interludes.

The early Holocene climate was warmer and wetter in the Saharas, in Near East and in Central Asia. The Saharan rock paintings, depicting scenes of hunters chasing elephants, rhinoceros, buffaloes, hippopotamus, antelopes, giraffes, etc., have been dated by C-14 to be 8,000-7,000 B.P. Toward the 3rd millenium B.C., or 4,000 B.P., there was a global cooling, when the climate in the low-latitude regions of North Africa and Asia became increasingly

arid. The deserts of North Africa and Central Asia expanded, driving the hunters and grazers to the alluvial plains where agricultural civilizations began to flourish in Egypt, Mesopotamia, and China (Lamb, 1982, p. 138-142).

An increasing aridity should have been the cause for the abandonment of bronze-age settlements, as exemplified by the an archaeological study (Amiran, *et al.*, 1992). Tel Arad at the edge of the Negev Desert was first settled during the 4th millennium B.C., and flourished during the early Bronze Age, undergoing urbanization process which occurred throughout Canaan. The Canaanite city had residential quarters, markets, palaces, and a large cistern system to supply water to a few thousand inhabitants. Arad was suddenly abandoned during the collapse of the Middle Bronze civilization in the Middle East in response to a colder and more arid climate.

The time of global cooling 4,000 years ago "was exactly the time when the Indo-Europeans seem to have started moving in all directions from their Pontic homeland" (Victor Mair, 1996). This was apparently the earliest Indo-European migrations which was better recorded in history during the time of *Völkerwanderung* of the 4th and 5th centuries. The exodus may have been related to an environmental pressure at a time when migratory peoples had to search for "green pastures" elsewhere.

The global cooling and the increasing aridity in the low/middle latitudes at the beginning of the Late Holocene have been recorded by Chinese history. When the legendary king Huangti ruled, at about 5000 B.P., mulberry trees grew in North China where elephants and rhinoceros roamed. Studies of natural history indicate, however that a transition from the early Holocene Megathermal to the late Holocene temperate climate took place at about 4000 B.P. (Shi, 1992). The record indicates thus that the first chill came to China at about the same time when the first mountain glaciers advanced in Switzerland.

The favorable climate may have come back again through Shang, and Western Chou dynasties, before many cold and dry years were recorded during the two centuries 3,000 - 2,800 years BP. There were drought and famine during the reigns of the four Chou kings Li, Hsuan, You, and Ping. Weakened by the internal rebellions, King Ping was forced by foreign invaders to abandon Sian; the capital was moved to Loyang at the beginning of the East Chou Dynasty, 800 B.C. (Liu, 1982).

After the collapse of the Middle Bronze communities, the civilization of the Late Bronze age flourished in Near East and Europe. A change to colder and more arid climate is recorded by the salt deposits of the Dea Sea, which were recently cored by J. Negendank (1996). A remarkable cooling also came to Europe at the end of Hallstatt Cultural Period, 800 - 700 B.C., and the timing was synchronous to the Chou event of the Chinese history. The settlements of the lake dwellers of central Europe, who had enjoyed warm and dry climate, were flooded as the water-level of the lakes rose. The alpine glaciers advanced. The tree-line was depressed, and broad-leafed trees in mixed forests were replaced by conifers. Salt mines were abandoned, and commerce was curtailed (Gams, 1937).

Historical records of China indicated that the cold interlude ending the Western Chou was relatively brief. The climate was again optimal during the Spring and Autumn and the Warring States eras (722-221 B.C.). Rice, the staple crop in south China, grew in Shandong, Henan, and Hebei, -the provinces which are now noted for their winter cold and aridity. Rice could

then grow in the north, because there were numerous warm and snow-free winters, as recorded by the history of Confucius.

Europe should have been warm during the Antique Epoch, but the historical record is obscure. Lamb (1982, p. 165) did note that Greece was practically not settled before 850 B.C. and the city of Rome was founded in year 753 B.C. Sediment cores from the Dead Sea by Negendank (1996) indicated clearly a change from the previous cold and arid climate to warm and humid in the Middle East during the Roman-Hellenistic era; the Dead-Sea sediments of this age are distinguished by pollen assemblages from agricultural plants. The flourishing Greco-Roman civilization during the centuries before the birth of Christ was contemporary to a "golden age" of culture in China. This could be a manifestation of a parallelism in cultural developments at an age of optimum climatic.

Chinese historians wrote that the climate continued to be mild and wet during the Ch'in and Western Han years (221-29 BC). Settlements on the Silk Roads at the edges of the Taklimakan Desert were built during those warm and wetter years.

The first significant change to colder climate came when the Han Dynasty was usurped by Wang Mong. He may have been a good ruler, but the cold and the drought brought forth widespread famines. Hundreds of thousand hungry people abandoned their homes, and eight or nine-tenths of those were starved to death. The rest joined the rebellions in the overthrow of the imperium.

Extremely cold and dry climate did not prevail, however, until the late third. The worst drought was recorded during the reign of Tsin emperors, reaching a zenith in the year 309 AD, or the 3rd Yungjia year of Tsin Hwai Ti, when "Jiang, Han, Ho, Lo were all desiccated, so that people could wade across" (Liu, 1982). That the smaller Han and Lo rivers of central China should have dried up could still be envisioned, but it is almost inconceivable that the Jiang (Yangtze) and Ho (Yellow River) were also desiccated. The Yangtze Jiang is 60 m deep below the Yangtze Bridge in Nanking, and is more than a dozen meters deep in its upper reaches. When people could wade across the Yangtze River, the groundwater level must have been tens of meters below the surface. The Chinese historians stated that the catastrophic climax was preceded by three decades of very cold and dry years; it was recorded that drought visited continuously during the decade 281-290 AD. The drought was nationwide, and the famines led to death by starvation and even to cannibalism. The Western Tsin Dynasty of the late third century was overthrown by marauders from the north. Five foreign tribes established 16 kingdoms of the Northern Dynasties in the Yellow River region. The Chinese migrated en masse to the south, where they were ruled by the Han emperors of the Southern Dynasties.

The chaos and cold lasted for more than two centuries until the beginning of the 7th century (Liu, 1982). The aridity during those years must have converted north and central China into a giant "dust bowl." A study of the sediments of a mountain lake, Daqui Hu, in Taiwan has revealed evidence of drought on mainland. The normal sediments of the lake in a forest are dark muds, rich in organic carbon. Two sets of unusual light-laminations are present in the muddy sequence (C. T. Chen, 1993). The laminated sediments are very well sorted quartz and feldspar grains about 10 micrometers across; they are the typical constituents of the wind-blown loess deposits of north China. The lower set of the silt laminations are dated as deposits of the 5th or 6th century. The age suggests that the silts may well have been the dusts

from north China which were blown across the Taiwan Strait during the drought years of the North and South Dynasties.

There is little historical record for the climate of the great chaotic years in the Age of the migration of the Germanic tribes. Studies of tree rings, tree lines and glaciers in Switzerland have indicated that the mild climate which had prevailed in central Europe during the Roman times came gradually to an end during the late 3rd century. The climate fluctuated during the next two centuries, till the very wet and cold years of the 6th century. The Scandinavian glaciers readvanced after the mid-fifth century, and were about to reach their maximum extent thereafter. That the Age of Great Migration was a cold episode in history is verified by the evidence from the Greenland Ice cores; the coldest years were the two centuries from the late 4th century to the early 6th century (Lamb, 1982, pp. 173-186).

I spent last year in Berlin and made numerous tours to surrounding countryside. I was impressed by a gap in history between the time of the 4th and the 6th century. Farmers told us that planting season would be too short during very cold years. Large parts of northern Germany seem to have been no-man's land after the Germanic tribes departed and before the Slavic Tribes resettled the land. The cold and wet climate made the northern Europe a poor place to live just like the cold and arid climate of central China.

After China was reunited toward the end of the 6th century, the, Sui, T'ang and early Sung years were again a period of prosperity. It is probably not a coincidence that this epoch of Chinese glory coincided with another 400 years of warm-and-wet years (600-965 A.D.). The Han cities on the Silk Road were rebuilt and again settled.

The peoples of Europe also enjoyed the warmest climate during the Age of the Vikings. Planting acreage in northern Europe significantly expanded, and when the tree-line advanced to higher altitude. W. Dansgaard's isotopic record of the Greenland ice cores suggests that the warming started in the 7th century and reached its zenith during the 10th, 11th, and 12th century. The evidence from tree rings suggests that the precipitation during the warm years was reduced. High-pressure and sunny weather prevailed over the Britain, Germany, and Scandinavia, where summers during the 10th century were decidedly warm and dry (Lamb, 1982, pp. 189-214).

The good climate did not last forever. A final turn to worse was to come during the late 10th century, when superstitious Christians were waiting for the end of the world. The end did not come, what did come was a millennium of colder climate, drier in low/middle latitude Asia and wetter in high-latitude Europe.

Rice fields and bamboo forests had long disappeared from the Yellow River region in China sometime before the beginning of the second millennium. Elephants and rhinoceros had also migrated to the south. Instead of snow-free winters, there were reports, year after year, of heavy snows, bad harvests, and of people starved or frozen to death. The cold and dry years in China got worse and worse toward the 16 and 17 the century, it was the time of the cold Little Ice Age in Europe. The worst came during the reigns of the last two Mine emperors Tienchih and Chungchen. During the forty-odd years, 1601 to 1644, historians recorded two episodes of "*ba-lien-da-han*," eight years of severe drought. The catastrophes were not local, the history recorded (Liu, 1982):

During the 6th to 16th years of Chungchen, the whole nation suffered from drought, and starving people were ubiquitous. Driven by hunger, cannibalism was practiced. The rebels conquered one city after another.

Chungchen was doomed and he hanged himself when the rebels entered the Forbidden City. The Ming Dynasty perished, when the northern Asiatic tribes from Manchuria came down to establish in Ch'ing Dynasty.

The second set of the silt layers in Daqui Lake of Taiwan includes numerous light-colored laminations in dark muds, and they are tentatively dated as deposits of the 14th to 17th century. Like the older set, those upper silt deposits were apparently also the aeolian detritus from the dust-bowl of north China, blown by northwesterly across the Taiwan Strait during the Little Ice Age.

During the colder period of the second millennium in China, there were brief episodes of warmer and wetter years: in the 13th century (1192-1277 AD, Southern Sung), in late 16th century (1557-1599, Chiatin/Wanli), and during the 18th and early 19th century (1721-1820, Chianlong/ Chiaqing years). The first coincided with the epoch of the Mongol conquest, and the second with the rise of the Manchus. Like the Vikings in northern Europe who flourished in warmer years, it seems that the greening of grasslands also served to strengthen the economy of the conquering peoples of northern Asia. The third last warm and wet interlude coincided with the peace and prosperity of Chianlong's reign (Liu, 1982).

The cooling and aridity in China during the Little Ice Age could be correlated to the desolate record in the temperate regions of West Africa (around 20°N). Cold and drought years in Timbuktu on the southern edge of the Saharas caused many a year of famine between 1617 and 1743 (Lamb, 1982, p. 259).

The climate of northern and central Europe was cold during the Little Ice Age; it was, however, not arid but unusually wet. Mountain glaciers of central Europe came down to 2,000 m elevation, and they laid end moraines on alpine meadows. The northern Europeans suffered cold and stormy winters. The average winter temperature between 1550 and 1650 in Middle England, for example, was more than 1.5°C colder than it is now. The last decade of the 17th century was particularly cold, when the hills of Swiss Midland (900 m. altitude) was snow-covered until April or May (Pfister, 1975). The devastating effects on agriculture led to famines in many parts of central and northern Europe. The colder temperature and increased snow fall caused the expansion of the polar ice-cap, and induced a southward migration of Eskimos (Lamb, 1982, p. 232-266).

The first signs of warming came after 1700, but the rise has not been steady. The years 1769-71 were, for example, unusually cold and wet years, when Alpine glaciers readvanced (Pfister, 1975). After several fluctuations came the warm first decade of the 19th century. The second decade was again a time of global chill, when the climate of England was comparable to the worst during the Little Ice Age (Lamb, 1982, p. 275).

The most recent warming trend started early during the 19th century in China and in Europe, before the Alpine glaciers advanced again. The cold interlude ended, however, almost as abruptly as it came. The 20th century has been, on the whole, a century of warming, reaching an optimum during the 1940s, interrupted by cold spells during the 1960s and 1970s, before the continuing global warming of the 1980s and 1990s brought alarm to a sensitized

public. Alpine glaciers have been retreating, and are rapidly disappearing if the warming trend should persist.

4. CHANGING TEMPERATURES AND PRECIPITATIONS

The first- and second-order climatic changes discussed in the preceding sections are summarized as follows; the years given are estimated, uncorrected C-14 ages.

(1) Post-Glacial Pleistocene, 15,000-10,000 BP

(1.1) Deglacial. 15,000-11,000 BP

(1.2) Younger Dryas. 11,000-10,000 BP

(2) Early Holocene 10,000-4,000 BP: Climatic optimum

(3) Late Holocene 4,000 BP -now

(3.1) Cooling trend causing aridity in middle/low latitude regions of North Africa and Asia, and the growth of glaciers in central and northern Europe at about 4,000 BP.

(3.2) After an warm interlude, a global cooling ending the Western Chou Dynasty in China and the Halstatt Culture in Europe, at 800 BC, or 2,800 BP.

(3.3) Warm interlude of Eastern Chou, Ch'in, and Han in China and Greco-Roman civilization in Europe before the birth of Christ, or 2,500 BP to 2,000 BP

(3.4) Cooling trend in the first Christian centuries, culminating in the cold centuries of the migrations of the northern Asiatic and Germanic peoples from the late 3rd century to 6th century, AD, or 1,700 BP or 1,400 BP

(3.5) Warming interlude during the Age of Vikings, starting from 7th to 10th century in China, and to 12th century in northern Europe, or 1,300 to 800 BP

(3.6) Little Ice Age in Europe and cold/arid years in China, with the zenith during the 16th and 17th Century, or 400 to 300 BP

(3.7) Warming trend since the mid-19th century, 150 BP

Assuming periodic changes, the available data indicate the cooling epochs during the Little Ice Age, the Great Migration, the decline of Western Chou, and the time when the first Alpine glaciers appeared. There seems to be a periodicity of about 1200 years, with the zenith of cooling at 1600 AD, 400 AD, 800 BC, 2,000 BC. The 3,300 B.C. episode of cooling in northern Asia recognized by Borzenkova (1990) may have been a still earlier episode of the periodic cooling.

The direct effect of the rise and fall of temperatures of a few degrees may be insignificant to human activities, but the indirect effects on regional precipitation seems to have had grave consequences. Whereas temperature changes have been global during the last 10,000 years, the precipitation changes are conditioned by regional patterns. The so-called Hadley Cell describes a normal pattern of atmospheric circulation, or the transport of moisture from the low latitudes to the tropical and to the high latitudes. The low-latitude continental interiors on earth are thus destined to become deserts, except in regions where precipitation is brought in by tropical storms.

The effect of tropical storms on regional climate is well illustrated by the geological history of China. A hundred million years ago, in the geological era of dinosaurs, China was a desert like the present Sahara because monsoons could not penetrate into China. The marginal

seas of East Asia did not exist then, and China was screened from the Pacific by Japan, Philippine and Indonesia, which formed coast ranges on the eastern and southern margin of the Paleo-Asia. The Cretaceous (130 to 65 million years before present) formations of China are largely red beds, composed of desert sands and silts. China turned green only during the Cenozoic Era, thanks to the Pacific monsoon, alias typhoon, from the marginal seas of the southwestern Pacific.

The changing climate of the Sahara during the Holocene has been related to storm patterns. Sahara was green during the early Holocene, when storms from the Atlantic could penetrate the Atlas Mountains of North Africa. Sahara is now a desert because moisture rises in low-latitude lands, and tropical storms rarely get into the interior. The frequency of tropical storms from the Atlantic is in turn related to global temperature changes. In warmer times of more remarkable atmospheric pressure gradients, tropical storms tend to be more frequent, and some could penetrate into Sahara to bring precipitation to the land interior.

The changing climate of China during the Holocene has been similarly interpreted. China has now plenty of precipitation; the annual rainfall is more or less 1,000 mm in central China. Much of the precipitation was brought in by seasonal winds and by tropical storms. At times of global warming, storms, alias typhoons, from the Pacific raced in a WNW direction via Taiwan to coastal China. Historians from Academia Sinica, Taipei, have found a positive correlation between the unusually frequent occurrences of typhoon in Taiwan and flood catastrophes in Mainland China. At times of global chill, however, a high-pressure center was apparently positioned over the continent. Blocked by the high pressure, typhoons turned west and bring torrential rainfalls to the Philippines, South China Sea, and Vietnam. They made their way to China much less frequently, if at all, causing the terrible droughts described in the Chinese history.

The precipitation patterns of at high-latitude countries of Europe differ radically from that of low-latitude continental interior. The Europeans share their precipitation with the Africa. We have indicated that the Saharan deserts were grasslands, with palm groves around numerous freshwater lakes, during the early Holocene time. Hunters roamed from Morocco to Egypt and they never seemed to have run short of big games. At the same time, warm and dry climate prevailed in central and northern Europe, there were hardly any glaciers in the Alps. Starting with a global cooling 4,000 years ago, the moisture from the Atlantic has been moving eastward from Gulf of Biscay, and the moist air from the Arctic moving southeastward give rains and snows to continental Europe. Europe's gain is Africa's loss. Few storms from the Atlantic could now penetrate the High Atlas, and Sahara has been turned into stony deserts.

We see that Europe gets less precipitation, while the continental Africa and Asia get more, when the climate gets warmer. Europe gets more precipitation, while the African and Asia get less, when the climate gets colder. The history of Europe is characterized by alternate periods of warm/dry with periods of cold/wet climate, while the history of North Africa, Near East, and China is characterized by alternate periods of warm/wet with periods cold/dry climate.

The consequences of global temperatures on the well-being of human societies are, however, the same, despite of the different precipitation patterns. In warmer times, reduced precipitation in Europe might lead to water-shortage in modern cities but rarely to severe drought, yet the warm climate favors agriculture production. The warmer climate is also benevolent to

the people living in low-latitude continental interiors; the increased precipitation changes desert into grassland and permits grazing and planting cultures. In colder times, increased precipitation, especially as snowfall and late frost in high-latitude Europe, damages its agricultural economy; there has been a systematic correlation of bad harvest to cold and wet years (Lamb, 1982, p. 326). The colder climate brought severe droughts to China, and the Chinese history records many episodes of starvation, famine, or even cannibalism during unusually cold years, which were always arid (Liu, 1982).

5. CLIMATE AND HISTORY

The changing fortunes of human societies have been interpreted in terms of changing climate. The rise of the agricultural civilization in the river valleys of Egypt, Near East, India, and China has been related to the increasing desertification of the continental interior (Lamb, 1982, p. 142). This increasing aridity has been correlated to a marked global temperature during the transition from the early to late Holocene some 4,000 years ago.

The cooling trend was interrupted by twice by warm periods, first during the early Bronze Age and then for several centuries before the birth of Christ. The civilizations of the Spring-Autumn/ Warring States and of the Ch'in/Han era flourished during an age of the mild climate, when the Greeks and Romans reigned in the West.

Historians have found in the catastrophic climate in China during the 4th to 6th century an underlying cause for the retreat of the Han people to the south, where they were supported by the agricultural economy of the warmer and wet south. The barbarian tribes overran North China, where rice fields may have been changed pastures. During the same epoch in Europe, as mentioned above, many Germanic tribes left Scandinavia and northern Europe, probably because they could no longer sustain their population by farming under the very severe climatic conditions. Europe was devastated by the marauding tribes, and the Roman Empire fell. The region between Elbe and Oder was depopulated before the Slavic peoples moved; the Germans did not return until the Christianization movement of the 10th century when the climate was again ameliorated.

The amelioration in the form of warmer and wetter climate which prevailed in China from the 7th to 10th century was favorable for an agriculture economy. The Han Chinese reached the zenith of their cultural development during the T'ang and Sung dynasties. In Europe, it was the Age of Vikings, when Scandinavia became a land of prosperity and where the population grew. While most stayed home, the young and the venturesome went abroad under the population pressure, conquering and immigrating. They raided France, the Great Britain. They established a kingdom in North Africa, another in Sicily. They colonized coastal Greenland, and went as far as Newfoundland in North America, if not farther south.

The most fierce enemies of the Han people under Sung emperors in China were the Hsia people who founded a Kingdom in Ninghsia during the 10th, 11th, and 12th century. Ningxia is now a desert, but the Hsia people seem to have enjoyed a less hostile climate in their hay days. Both the Han and Hsia peoples were eventually subjugated by Genghis Khan's hordes from Mongolia during the 12th and 13th century, before a cooling trend started again, culminated in the cold and arid years of the 16th and 17th century. The downfall of the Ming Dynasty was certainly related to famines brought forth by hostile climate.

In Europe, the Viking kingdoms went into decline after the 12th century, correlative in timing to the start of a global cooling trend. The history of the Medieval Europe recorded many cold and wet winters between 1300 and 1850 AD. The worst was the age of the Thirty Year World War, 1618-1648, during the height of the Little Ice Age. The population in many parts of central Europe was reduced by a third or by a half. Soldiers robbed more but killed less, the catastrophic civilians decimation had to be related to famine and to poor health caused by starvation. The European economy was stagnant until the trend was reversed by the Industrial Revolution in the 18th century, when the economic growth was a reflection of industry and trade, rather than that of the climate-dependent agriculture.

6. GLOBAL COOLING COULD BE A THREAT TO MANKIND

Any departure from norm is likely to produce disturbances in the human habitat. Studies of the Green Peace indicated that the unusual storms resulted from the present global warming trend have brought annually billions of dollars of property damage (Leggett, 1996). In a symposium on hazards of global warming at Davos, Switzerland convened by me in December, 1994, there was a consensus that the long term effect of rising sealevel as a consequence of global warming would require the building or elevating of dikes or seawalls to protect coastal cities, and the cost would be high. Nevertheless the loss of human lives in storms are limited to local disaster-areas, and considerably less than the toll of earthquakes or other natural catastrophes. More serious is, however, the aridity related to global warming. I have not referred to studies of climate and history in North America. Tree rings showing that the aridity during the late 12th century may have been the cause that Mesa Verde Indians abandoned their settlement. I know too little to discern if the North American pattern is also warm and arid like the European, except the drought in the western deserts should have devastating consequences.

The consequence of global cooling in history is clear. Either a cold and wet climate in Europe or a cold and arid climate in Asia, Middle East, and North Africa would drastically curtail global production of food. The effects are not local but nation-wide or worldwide. Drought and starvation seem to me a far greater threat to mankind than tropical storms or slowly rising sea-level caused by global warming.

The expression "yellow peril" was an insult hurled at the Chinese people by Emperor William II of the German Empire, but the catch-phrase became recently the title of best-selling novel in Taiwan. It was postulated a catastrophic flood caused famine and civil war on Mainland China, leading to an exodus of hundreds of millions of starving people. The political consequence of a famine is realistically portrayed by the novel, but the author erred when he thought that flood could trigger such a catastrophe. Indeed, there could be a million homeless Chinese when their fields are flooded. But China has a population of more than one thousand million, and the other Chinese could tighten their belt to help their countrymen in disaster areas. A nation-wide drought has, on the other, an unthinkable consequence. In a talk to the Chinese Academy of Science, Peter Raven (1994) indicated that China used in 1990 more than 95% of their annual precipitation for irrigation, and that the water-consumption could be 100% before the turn of the millennium. When annual precipitation falls short of irrigation usage, the groundwater level will be drawn down. Should there be another "*ba-lien-da-han*" (eight years

of severe drought) in China, one might find again the situation when one could wade across Jiang and Ho, as people did in year 307 AD. The drought in China during the last decades of the Ming Dynasty, or the time of the European Little Ice Age, was apparently not as bad as to dry up the Yangtze and Yellow Rivers, but the consequences were even more devastating because of the greater population. There may have been a few tens of million of Chinese during the North/South Dynasties, but the Ming population has been estimated to range between 100 and 200 million before the catastrophe fell. The famine at the end of the Ming Dynasty was thus far worse, when there were so many more mouths to feed. Now the Chinese population is 1,200 million. If there are a few years of severe drought in the Yellow and Yangtze River regions, the consequence could be as many as half a billion of starved Chinese. There would not be not enough surplus in the world to feed the hungry in China. With such a nationwide drought, the fictional calamity described by the author of the novel *Yellow Peril* would be reality. There would be boat people who come across the strait to invade Taiwan. There would be the mass migrations to South China, to Southeast Asia, to Australia, to North America, etc.,etc. There would be ambitious politicians who seize the opportunity for conquests.

Global cooling causing severe droughts in China would be a serious threat to world peace. A global cooling would not be a blessing either to the people elsewhere. The precipitation patterns of the low latitude countries in response to temperature changes are globally similar. The deserts of Near East and North Africa would become even more arid during cold episodes.

Whereas global cooling could increase the precipitation at tropical latitudes, the increased precipitation is not necessarily beneficial, and the excess could cause catastrophic floods. Neither should the increased precipitation by global cooling in high-latitude countries be a bonus to the Europeans: cold and wet years have been correlated to years of bad harvests in northern and central Europe.

A analysis of changes in precipitation patterns in response to global temperature changes and a reference to history indicate thus that a global cooling could be more catastrophic to mankind than a global warming. Fortunately, the first-order periodicity of natural fluctuations seems to be about 1,200 years: the present trend of the natural global warming may reach its climax in year 2,200 AD. The cooling trend may not start until the second half of the third millennium, and the worst may not come until the year 2,800 AD. The mankind seems thus not to be in the immediate danger of an inevitable doom,. The world's population growth may yet be brought into control. We have may have a population reduced to a size to be sustainable under any contingencies when we have to face the hardship of the next little ice age.

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