The Little Ice Age in the North Atlantic Region

Part VI: The Little Ice Age and Climatology

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Abstract

Earlier papers in this series introduced methods of studying past climate change, the historicity of the Little Ice Age as well as the Medieval Warm Period, the importance of the Little Ice Age in understanding climate change and constraining climatic models, and the importance of the North Atlantic region in understanding and applying constraints on climatic and glacial models. Earlier papers included summaries of the effects of the Little Ice Age in Iceland, Norway, and Greenland. This paper presents an analysis of how the Little Ice Age climate-change record should constrain paleoclimatology and speculations on potential climatic-forcing mechanisms.

Constraints Provided by the Little Ice Age

Natural science plays a corrective role, not a creative role, in natural history studies (Reed and Klevberg, 2011). Science deals with the observable present, not the unobservable past and therefore plays the invaluable role of testing the predictions of historical hypotheses. This is the beauty of the Little Ice Age; while climate-change scenarios may proliferate, replete with computer models and even propaganda films, we have in the Little Ice Age historic data that can be used to discount those models that stray far from reality.

As can be seen from Figure 1, even reconstructions of the single climatic variable of average Northern Hemisphere land surface temperature over the past millennium results in a variety of models. How much more widely might "ancient ice age" models deviate from reality? As we have sought to stress throughout this series, climatic inference is just that—inference about history, not scientific observation. There is only so much that can be ascertained from study of proxies in the present. Thus, even among researchers whose worldviews and personal biases are similar, there are sometimes very different conclusions, as shown in Figure 1. As documented in Part I of this series (Klevberg and Oard, 2011a), this results from different data sets, different weighting of those sets, different approaches to statistical analysis, and plain speculation. This is the difficulty with paleoclimatology.

Paleoclimatology is important to us for several reasons. An obvious one is the degree to which we should fear anthropogenic climate change (Gore, 2006) and its political ramifications (e.g., carbon taxes). In science, the primary application of data from the Little Ice Age is to provide constraints on a Great Ice Age and the geologic effects inferred to have been caused by it. Those topics

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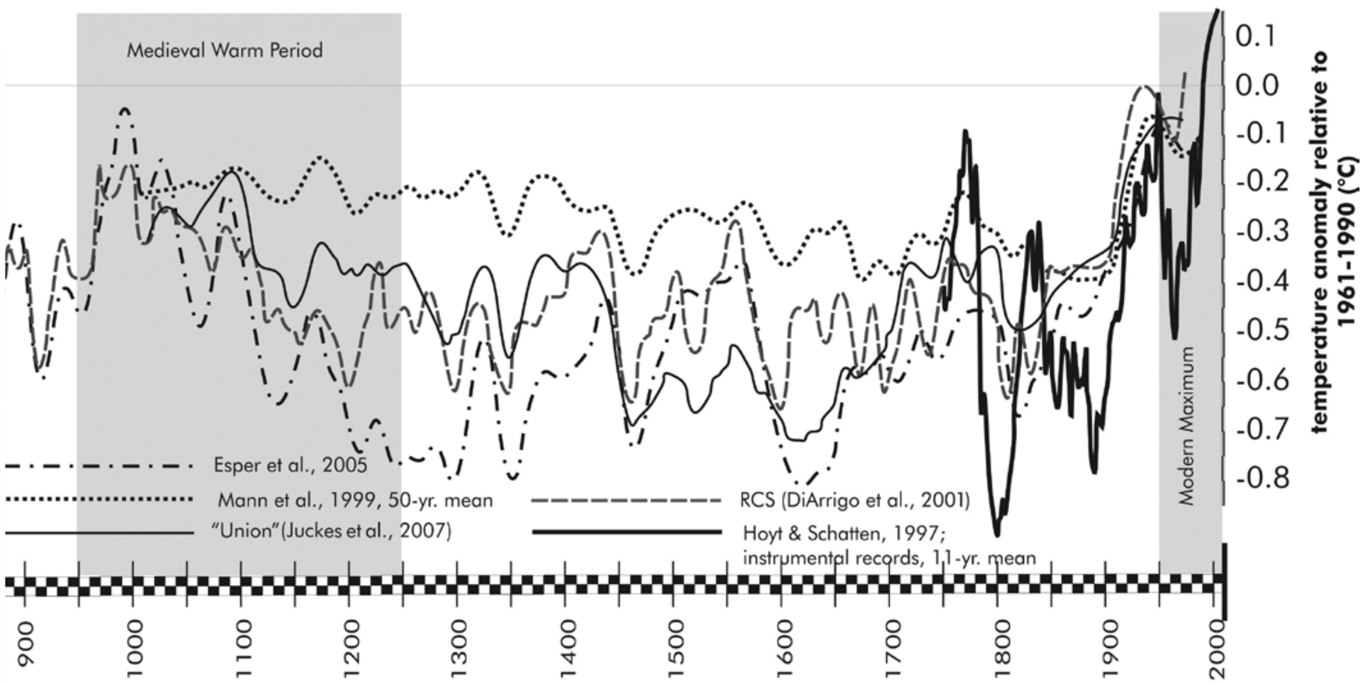

Figure 1. Considerable variability is evident between different reconstructions of Northern Hemisphere land surface temperatures over the past millennium.

will be addressed in the final two parts of this series. This paper addresses possible climatic mechanisms for the Little Ice Age.

Global warming alarmists have tended to play down the Little Ice Age (Klevberg and Oard, 2011b), and an inaccurate explanation of the Little Ice Age will be compounded in evaluating speculations regarding the Great Ice Age. It is therefore important to gain the most accurate understanding possible of the Little Ice Age first.

The Mann et al. "Hockey Stick"

As was outlined in Part I of this paper, modeling past climate is neither simple nor straightforward; much room is available for the influence of bias and subjective elements. In the case of the well-known Intergovernmental Panel on Climate Change (IPCC) "hockey stick" Northern Hemisphere temperature reconstruction (Mann et al., 1998, 1999), these biases include, of course, uniformitarian presuppositions and reliance on uniformitarian-based dating methods, but also a particular opinion on the likelihood of greenhouse-gas-induced global warming. Most creationists are well acquainted with the tendency of science to be hijacked by political or religious causes, such as evolutionism (cf. appendix). The proxy data used for this controversial temperature reconstruction probably differ more by data type than by source region, though this does not appear to be clearly stated by the author (Mann, 2002).

While criticisms of the Mann/IPCC "hockey stick" by McKitrick (2005) and McIntyre and McKitrick (2003) have been substantiated (Briffa and Osborn, 2002; Guiot et al., 2005; Juckes et al., 2007), follow-up work by Mann and others has not resulted in large-scale changes to the result (Mann et al., 2004). Use of the climate field reconstruction methods answers at least some of the criticisms of McIntyre and McKitrick, as spatial coverage is very important (Esper et al., 2005; Guiot et al., 2005; Juckes et al., 2007; Luterbacher et al., 2004; Rutherford et al., 2005; von Storch and Zorita, 2005). As mentioned in Part I of this series, use of the chronology from the CO_2-sensitive bristlecone pine (cf. Figure 2 in Mann, 2002) may have been a significant factor in generating the "hockey stick" curve of Mann et al., as may choices in transfer function creation (Esper et al., 2005; Juckes et al., 2007). The dismissal by Mann and Jones (2003) of the "flawed study" by Soon and Baliunas (2003) is, in our

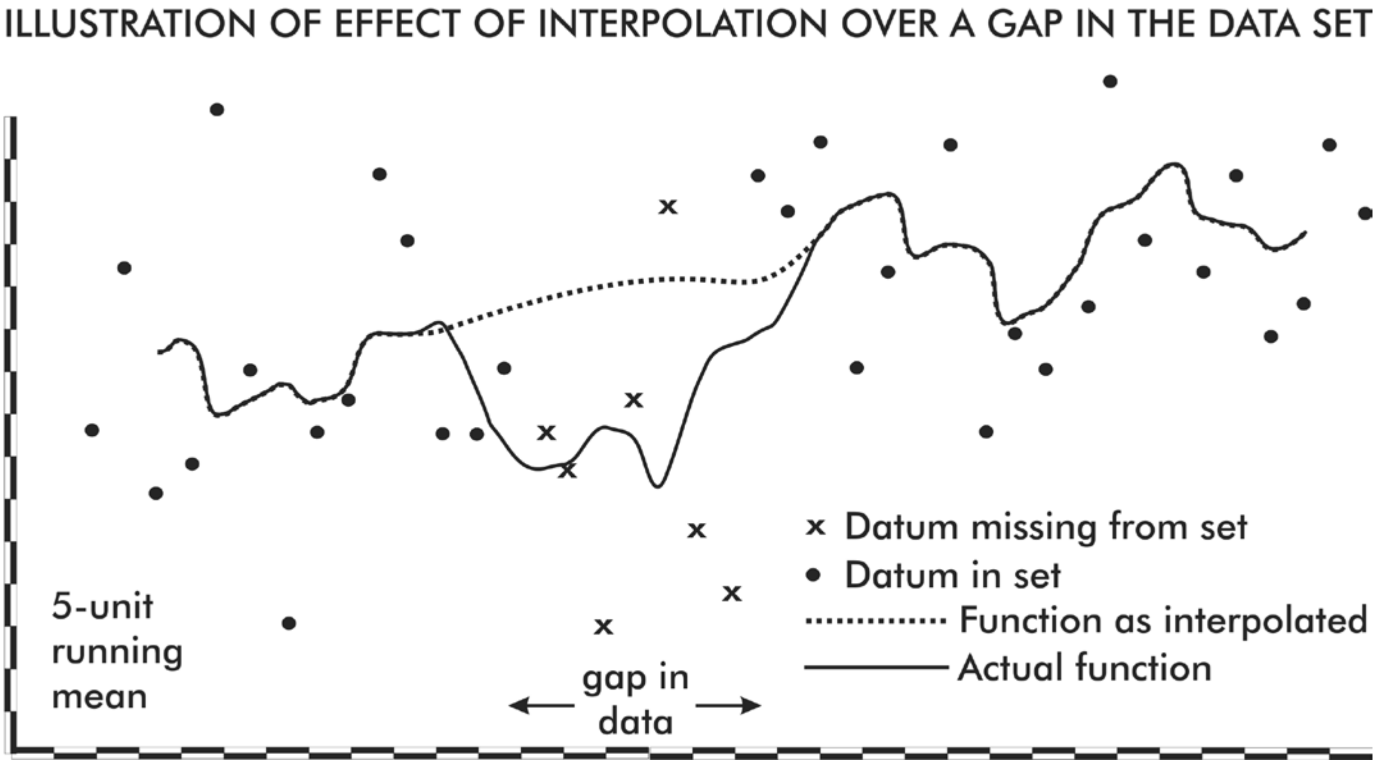

Figure 2. A gap in data can lead to serious errors in paleoclimatic reconstruction. This becomes more of a problem back in time, when data sets are fewer and less complete.

opinion, at best inadequate, and their study clearly justifies more than such a nonchalant dismissal. Newer work indicates refinements in technique that may alter earlier reconstructions (Christiansen and Lungkvist, 2012). There is no "consensus" here.

Of particular concern for any model purporting to reveal the effect of atmospheric CO_2 on climate change is the use of the CO_2-influenced portion of the instrumental record for calibration of the model. This is not an easy problem to solve, as the instrumental record available for calibration and verification is mostly limited to the period of time during which carbon dioxide concentrations were increasing. It may be neither possible nor necessary to account for this in the models if the greenhouse gas concentrations are responding primarily to natural changes, but neither would it be possible to tell if that is the case.

History versus Science

Not uncommon are news reports of individuals who have been incarcerated for years and then exonerated based on DNA evidence. Many have been exonerated or convicted based on forensic evidence, yet how such evidence can be manipulated is the stuff of crime novels and movies. Forensic evidence can be invaluable in discrediting untrustworthy witnesses, but it must not be used without them (Deuteronomy 17:6). Science is a useful servant to history, but cannot replace it.

Mortimer Adler, one of the foremost philosophers of science, pointed out long ago that science and history operate under distinctly different rules of investigation (Adler, 1965). These differences are shown in Table I. Paleoclimatology and historical geology, which deal with the unobservable past, are therefore branches of history (albeit using scientific technology). Why, then, has the scientific establishment worked so hard to blur this distinction? Why have historians sought to make their discipline an "empirical science" (Windschuttle, 1997)? William Morris Davis, the highly influential American geologist, promoted the replacement of scientific (descriptive and classificatory) terminology with historic (genetic) terminology and origins stories (Davis, 1954). These issues have been addressed elsewhere on a foundational level (Reed, 2001, 2005; Reed et al., 2004, 2006; Reed and Klevberg, 2011).

Whether researchers recognize these methodological differences will be reflected even in the data acquisition phase, as was pointed out in Part I of this series (Klevberg and Oard, 2011a). An element of judgment also enters into the weighting of the data that are selected. Thus, the models that result may deviate significantly from reality. How this has occurred in paleoclimatology and current climate modeling will be shown in this paper against the backdrop of the Little Ice Age.

Table I. Differences between historical and scientific methods.

Science	History
ongoing	unique
repeatable	unrepeatable
directly observable	not directly observable
primarily inductive	primarily deductive
relies principally on measurement/observation	relies principally on testimony/observer
failure to recognize limits leads to distortion and faulty conclusions	failure to recognize limits leads to distortion and faulty conclusions

Limitations of Modeling

Computer models are nothing magical. Models, computerized or not, are simply organized collections of thoughts of how things may behave under certain conditions. They are therefore dependent on the quality and quantity of the data employed, as well as the way those data are interpreted.

Limitations from Data

The natural limitations in proxy data available were mentioned in Part I of this series. However, there is another type of data limitation that arises from the nature of historical study. This is illustrated by Figure 2. The problem can be severe if the discontinuous variable occurs either wholly within or wholly outside the calibration + verification period.

Limitations of Analysis and Modeling

Some have recognized the limitations of climatic modeling (Frauenfeld, 2005; Friis-Christensen and Svensmark, 1997; Oard, 2009; Soon et al., 1999). Legates (2005, p.144) lists these limitations: (1) incomplete understanding of the climate system, (2) coarse resolution, (3) inability of models to reproduce many vital phenomena, and (4) interconnected nature of the climate system.

On predicting climate responses to CO_2, CH_4, O_3 and aerosols, Posmentier and Soon state, "A logistically feasible validation for such predictions is essentially inconceivable." They continue, "It follows from Oreskes et al. that the intrinsic value of a climate model is not predictive but heuristic or educational, helping to add to knowledge without providing conclusive fact" (Posmentier and Soon, 2005, pp. 243, 244). This may be illustrated (heuristically) relative to carbon dioxide, where cause and effect are not clearly distinguishable (Figure 3).

Limitations from Bias

The role of bias in the selection and weighting of proxies was outlined in Part I of this series. A great deal of judgment is necessary in evaluating proxy data, determining the degree of smoothing to use, inferring confidence intervals, choosing regression algorithms, constructing neural networks, etc. Any model will necessarily express the bias imparted by its proxy data and the transfer functions derived from them, as described above for the Mann et al. "hockey stick."

Ogilvie and Jónsson (2001) make the important point that proxies have largely been calibrated to rising temperatures; other relationships might exist if proxies were calibrated to falling temperatures. Common warming trends from the mid to late Little Ice Age to the late 1900s and present decade have been in the range of 1.5°C in the Baltic countries (Tarand and Nordli, 2001) to 4°C in Iceland (Grove, 2001). Estimated temperature changes outside our study area appear generally to agree with these long-term warming data (e.g., New Zealand more than 1°C, New Guinea approximately 1°C, per Grove, 1988). Popular climate models that indicate changes over the past millennium of 1°C or less are thus almost certainly wrong.

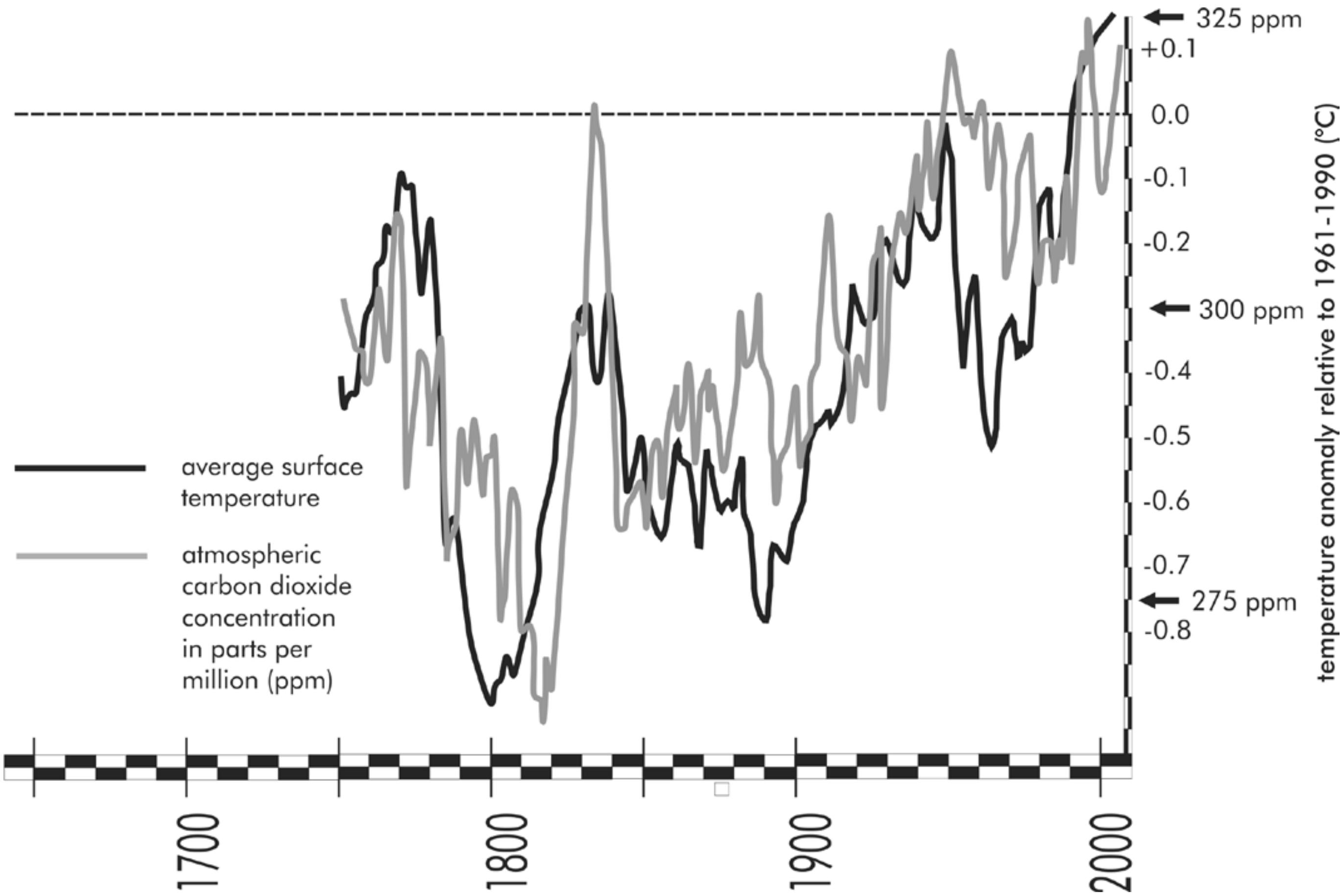

Figure 3. The instrumental temperature record for Northern Hemisphere land temperatures and atmospheric carbon dioxide concentration. The increase in carbon dioxide has largely occurred since the end of the Little Ice Age. What is cause, and what is effect? Warming temperatures cause release of carbon dioxide from oceans and soils, which in turn causes atmospheric warming, which releases more CO_2 into the atmosphere. Data compiled from Briffa and Osborn (2002), Hoyt and Schatten (1997), and Juckes et al. (2007).

Limitations from Regional and Feedback Effects

Another limitation in climatic modeling is spatial bias introduced by the locations of the observations. The "urban heat island effect" is a well-known example of this, but it is far from the only one. On top of biases introduced by weather monitoring point layout are regional feedback systems in the atmosphere and oceans.

The North Atlantic Oscillation

In the North Atlantic Ocean, permanent low pressure is centered over Iceland (the Icelandic Low), while a permanent high-pressure area is centered over the Azores (the Azores high). Oscillations in the strength of the pressure difference between the Icelandic Low and the Azores High influences the weather in Europe. Since westerly winds are proportional to the north-south temperature difference, the stronger the pressure difference, the stronger the westerly winds. A positive North Atlantic Oscillation (NAO) is an above-average pressure difference, while a negative NAO is a pressure difference below average (Figure 4). The NAO varies from year to year, and it especially affects winter weather. A positive NAO, with a strong pressure difference and strong westerly winds, causes cooler summers and mild, wet winters in northern Europe but dry winters in southern Europe. A negative NAO results in weak westerly winds, hot summers, and cold winters in northern Europe, but the storm track is diverted south with more storms in southern Europe and North Africa.

The NAO also affects the weather in eastern North America. A positive NAO results in more southwest winds with a milder, wetter winter. A negative NAO

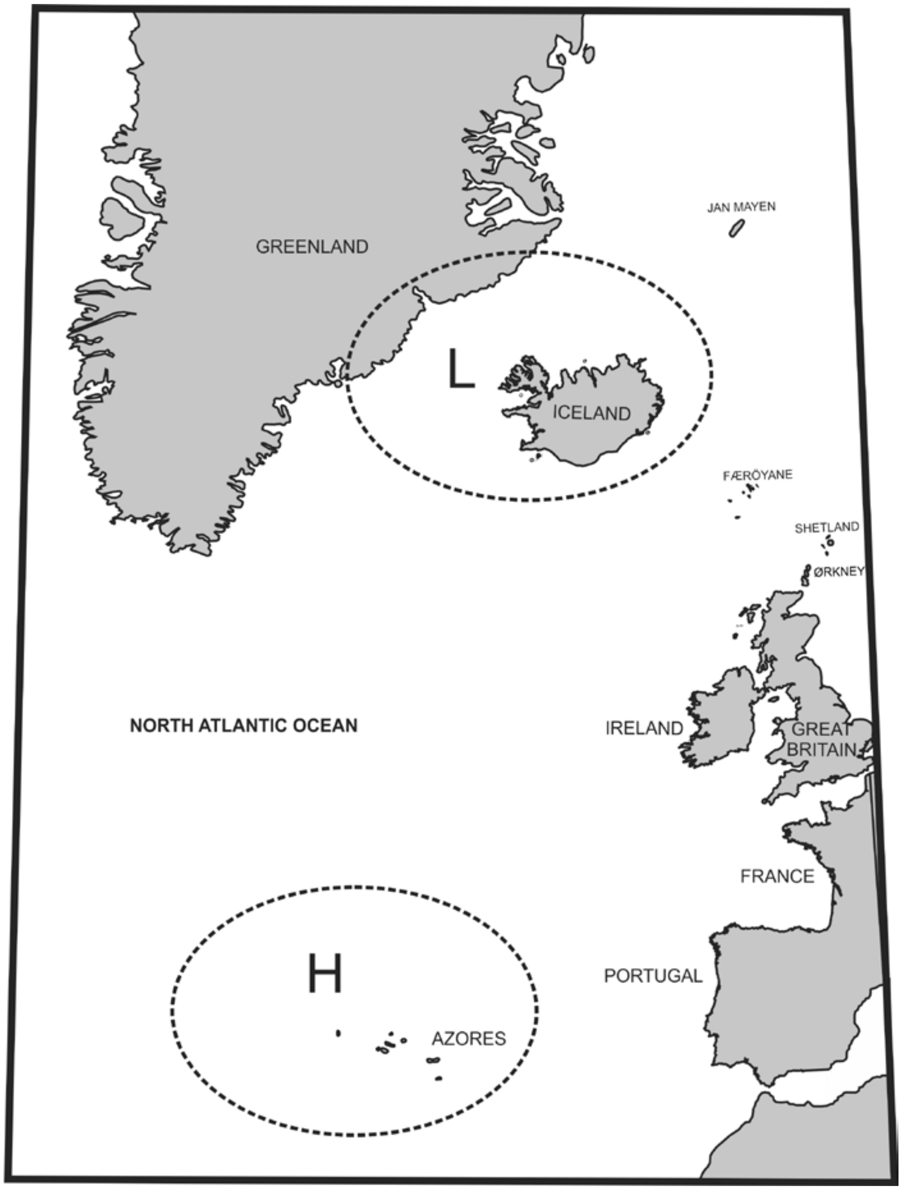

Figure 4. The North Atlantic Oscillation in normal position. A negative NAO has high pressure over Iceland and low pressure over the Azores. The NAO can explain variations within the Little Ice Age but not the event itself.

causes more cold Arctic outbreaks and heavier snow in winter.

The NAO is believed to be caused by sea surface temperature (SST) anomalies (Rodwell et al., 1999). The temperature of the ocean changes slowly and is believed to affect the atmosphere: warm SSTs result in a warmer atmosphere and more high pressure aloft, while cold SSTs cause a cooler atmosphere and lower pressure aloft.

The NAO has been given considerable weight by some as a potential explanation for much of the climatic deterioration of the Little Ice Age (Fagan, 2000). It has been strongly correlated with winter precipitation in Norway (Bjune et al., 2005). In general, the NAO produces a "seesaw" effect between Greenland and Europe (Barlow, 2001; Fagan, 2000). However, despite the arguments of some (Mann, 2002), it cannot explain the Little Ice Age itself but only the complexities of the decade-scale variations within it (Barlow, 2001; McKinzey et al., 2005). Attempts at reconstruction of the NAO using proxies have had limited success (Jevréjeva, 2002; Luterbacher, 2002). If the global average temperature increase is real, then the NAO cannot be used to explain away the Little Ice Age any more than the present cooling of Greenland denies global warming (Hansen, 2006). The NAO likely does not cause any net changes for the region as a whole nor for the whole earth.

The El Niño—Southern Oscillation

The El Niño-La Niña phenomenon in the South Pacific Ocean is a well-known teleconnection similar to the NAO. Like the NAO, the El Niño-Southern Oscillation (ENSO) can explain decadal-scale variation but not long-term climatic shifts like the Little Ice Age (Frauenfeld, 2005). The NAO and ENSO may be thought of together as the Arctic Oscillation, and the dominant mode of the Arctic Oscillation appears to respond much more strongly to intensity changes in solar ultraviolet radiation than to concentration of greenhouse gases (Frauenfeld, 2005).

The Pacific Climate Shift

In 1976–1977, an apparent increase in ENSO frequency occurred that remains to this day, as does the mystery of its explanation (Frauenfeld, 2005). Meanwhile, the NAO paralleled the increase in greenhouse gas concentrations until the mid-1990s, after which it decoupled and went negative. "But the time series itself is nonlinear and, especially in light of the NAO's negative departures during the late 1990s, such linear trend descriptions are as meaningless as the global warming implications they are purported to support" (Frauenfeld, 2005, p. 163).

Other Regional and Feedback Effects

Barlow (2001, p. 109) states that about 40% of mild winters in Europe result from westward displacement of the Siberian Anticyclone rather than the North Atlantic Oscillation. Interactions between the Baffin Trough and Iceland Low are important to temperature trends between Iceland and Greenland. Good correlations between seasonal weather anomalies, the Central European Zone Index and the NAO Index about a century ago have not continued in more recent decades (Jacobeit et al., 2001). A complex relationship between the NAO and atmospheric patterns over the Mediterranean, North America, and the Pacific are postulated (van Loon and Rogers, 1978, 1979; Wallace et al., 1995). All of these represent regional and relatively short-term mechanisms that add to the complexities of the Little Ice Age, but do not explain the ice age itself.

Possible Climatic-Forcing Mechanisms

The two obvious choices for driving climate change are volcanism and changes in insolation (solar radiation striking the earth). Volcanic eruptions are generally understood to result in a net cooling of the earth. Changes in solar irradiance (i.e., the rate of radiative energy given off by the sun) could cause warming or cooling of the earth relative to the average value, as well as interacting with other climatic variables. In recent years, the potential role of greenhouse gases has been emphasized. Major forcing mechanisms are summarized in Table IV.

Volcanism

It is well established that volcanism causes cooler temperatures on the earth (Oard, 1990; Salzer and Hughes, 2007), at least initially. There are, of course, a number of other variables related to the temperature change, such as the intensity of the eruption, frequency of eruptions, how much SO_2 reaches the stratosphere, the season of the eruption, the latitude of eruption, and the state of the climate system during eruption (e.g., whether El Niño is occurring). Major volcanic eruptions are listed in Table II and indicated on Figure 5.

"There seems little doubt that volcanic activity influences climate but the extent of this influence is controversial" (Grove, 1988, p. 368); the great Krakatau (a.k.a. Krakatoa) eruption, for example, produced no observable glacial advance. The eruption of Mount Pinatubo in 1991 produced tropospheric cooling of 0.7°C and surface cooling of 0.4°C, but was short-lived (Christy, 2005). Volcanism can cause winter warming of mid and high latitudes by causing more storminess and mixing of the air, retarding the formation of inversions, but the net yearly temperature change is colder temperatures. The sulfur aerosols in the stratosphere produced by the volcanism usually affect climate for only a few years but can last up to about ten years. These aerosols can have a greater effect than ash in producing cooling (Bardintzeff and McBirney, 2000). It is believed that pulses of volcanic activity substantially contributed to the decadal-scale climate variability of the Little Ice Age (Ammann and Naveau, 2003; Salzer and Hughes, 2007). In combination with atmospheric feedback mechanisms like the NAO, volcanism may account for over half this variation (Christy, 2005). However, others point out the complexities of volcanism and feedback mechanisms (Sadler and Grattan, 1999), sometimes postulating a net *warming* (Robock, 2000). Some have pointed out that atmospheric aerosols can have a moderating effect on climate (Fan et al., 2008).

Solar Irradiance

Although changes in volcanic aerosols in the stratosphere have a significant influence on climate, the effect is on the short timescale–approximately a decade. Strong volcanic eruptions occurred during the Little Ice Age, including Tambora and Lakí. However, the Little Ice Age lasted half a millennium, so a long-term mechanism is required. Krakatau, one of the most significant eruptions, occurred at approximately the end of the Little Ice Age, so volcanism alone cannot explain the long-term climate change.

Ultimately, virtually all of our earth's warmth comes from the sun. Without it, Earth's interior warmth would radiate to space and the surface would become very cold. The greater question to climatology is to what extent the subtle variations in the amazingly stable solar irradiance may induce terrestrial climate change. There is a long-term natural forcing of climate that appears to correspond with changes in solar irradiance (Loehle and McCulloch, 2008). The amount of insolation has long been considered a constant; in fact, it was called the "solar constant." We now know that insolation varies a slight amount, and this slight amount is correlated to temperature variations on the order of a few degrees Fahrenheit. The intensity of the solar irradiance varies with the number of sunspots: a high number of sunspots corresponds with increased insolation and warmer terrestrial surface temperatures, and vice versa. This seems counterintuitive, since sunspots are cool areas relative to the rest of the surface of the sun, but the sunspots are more than balanced by faculæ (Foukal, 2003)—hot spots of increased irradiance. There is an 11-year periodicity in sunspots, and many atmospheric scientists believe this cycle can be correlated with climate (Scafetta and West, 2008). But there are also longer-period fluctuations, and it is these longer cycles that are of particular interest to the question of what caused the Little Ice Age (cf. Figure 5).

Sunspots have been recorded ever since the telescope was invented. In general, there were relatively few sunspots during the Little Ice Age, while there has been a relatively large number since (Figure 5). During the Little Ice Age, five periods of especially low sunspot frequency were observed (Table III), the most notable being the Maunder Minimum between 1645 and 1715 (Figure 5). This was also the most intense time of the Little Ice Age (Fagan, 2000). The trend in sunspot number, and thus insolation, appears to provide the best correlation for the long-term

Table II. Major volcanic eruptions over the past thousand years. Data from de Boer and Sanders, 2002; Robock, 2002; Sigurdsson, 2000; Ward, 2009.

SUMMARY OF MAJOR VOLCANIC ERUPTIONS					
Volcano	**Country/Region**	**Date**	**V.E.I.***	**Ejecta (km^3)**	**Latitude**
Eldgjá	Iceland	934			64.4N
Changbaishan	China	1000	7	96	
Quilotoa	Ecuador	1280	6	21	0.8S
New Hebrides	Vanuatu	1399	?	36–96	16.7S
Barðabunga	Iceland	1477	5+	12.5	64.6N
Bouganville	New Guinea	1580	6	14	6.1S
Huaynaputina	Peru	1600	6	30	16.6S
Santorini	Greece	1650	6	60	36.4N
Long Island	New Guinea	1660	6	30	5.4S
Lakagígur	Iceland	1699	6	14	64.4N
Tambora	Indonesia	1812	7	150–160	8.2S
Ksudach	Russia	1822	6	18–19	51.8N
Cosiguina	Nicaragua	1835	5	5.7	13.0N
Askja	Iceland	1875	5		65.0N
Krakatau	Indonesia	1883	6	20–21	6.1S
Okataina	New Zealand	1886	5		38.1S
Santa Maria	Chile	1902	6	5.5–20	14.8N
Ksudach	Russia	1907	5	2	51.8N
Novarupta	Alaska	1912	6	28	58.3N
Cerro Azul	Chile	1932	5+	9.5	0.9S
Bezymianny	Kamchatka	1955	5	2.8	56.0N
Agung	Indonesia	1963	5	1.1	8.3S
Mt. St. Helens	Washington	1980	5	1.274	46.2N
El Chicon	Mexico	1982	5	2.3	17.4N
Hudson Cerro	Chile	1991	5	4.3	45.9S
Pinatubo	Phillipines	1991	6	11	15.1N

*Volcanic explosivity index

Data from Sigurdsson (2000), Bardintzeff and McBirney (2000), Robock (2002).

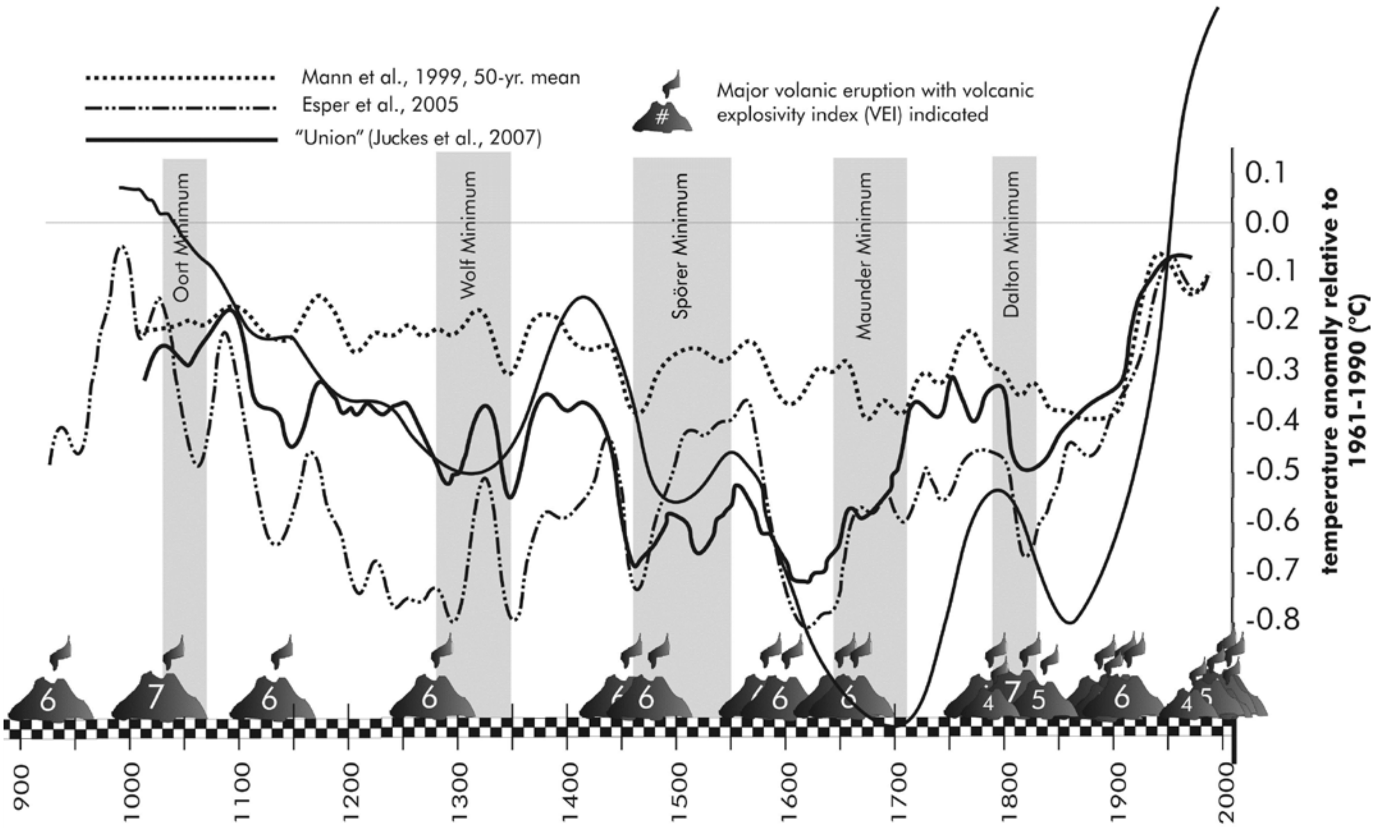

Figure 5. Some well-known temperature reconstructions shown with solar minima and notable volcanic eruptions, the two most probable forcing mechanisms for the Little Ice Age.

trends of the Little Ice Age; volcanism only accounts for short-term variations in global temperature (Ammann and Naveau, 2003; D'Arrigo et al., 2001; Fagan, 2000; Lean et al., 1995; Pang and Yau, 2002). Comparisons of ^{14}C and ^{10}Be provide a proxy for solar irradiance, and cycles on the order of a decade (Schwabe Cycle), a century (Gleissberg Cycle), two hundred years (deVries or Suess Cycle), and longer have been identified (Baliunas, 2005).

Overall, changes in solar irradiance appear to explain about half of the global temperature variations observed (Baliunas, 2005; Balling, 2005), and even global warming proponents generally acknowledge it as an important variable (Mann et al., 1998), though some have disputed any important role for this variable (Gore, 2006; Mass and Schneider, 1977). The solar cycle appears to no longer dominate after 1990 (Thejll and Lassen, 2000), which may indicate a less important role for insolation but might also indicate a lag time in important feedback mechanisms or the effect of oceanic cycles. Scafetta and West (2006, 2009) state that solar irradiance still accounts for 25 to 35% of the warming between 1980 and 2000 using the better Active Cavity Radiation Irradiance Monitor (ACRIM) composite total solar irradiance. Only in recent years have satellites been launched that are capable of measuring the slight variations in solar irradiance (Baliunas, 2005), and the record is too short for sweeping conclusions and certainly too limited to deny the role of solar irradiance variations. "Viewing the sun as redolent with coruscations in magnetic winds, particles and electromagnetic radiation billowing on scales of seconds to millennia and accompanied by changing fluxes of cosmic rays traveling near the speed of light that produce nothing more adverse than quaint auroral displays and cosmogenic isotope blips in records from environmental repositories seems an absurd assumption to hold while facing observed past ecosystem change and their evident correlations with solar variations"(Baliunas, 2005, p. 232). More recent research appears to strengthen the position that variations in solar irradiance are one of the most important forcing mechanisms (Brugnara et al., 2013).

Table III. Periods of unusually low sunspot activity during the Little Ice Age.

Periods of Low Sunspot Activity	
Years	**Designation**
1040–1080	Oort Minimum
1280–1350	Wolf Minimum
1460–1550	Spörer Minimum
1645–1710	Maunder Minimum
1790–1820	Dalton Minimum

Greenhouse Gases

Water vapor, methane (CH_4), carbon dioxide (CO_2), and oxides of nitrogen are "greenhouse gases," i.e., gases that tend to trap infrared radiation (heat) in the atmosphere and produce a warming effect. Their effectiveness is from greatest to least in the order listed above (Oard, 2006), but CO_2 is the gas that receives greatest attention in the press. Water vapor contributes approximately 95 percent of the 36°C (65°F) greenhouse warming effect that keeps us all from freezing to death; CO_2 contributes only a minor amount.

Mankind has little control over water vapor, while many agricultural and urban processes produce methane and carbon dioxide. Anthropogenic CO_2 is considerably larger than anthropogenic CH_4 but a tiny fraction of natural carbon reservoirs (Soon et al., 1999). Yet the effect of carbon dioxide has been greatly exaggerated in the current global climate-change scare, perhaps because climatologists routinely simulate the temperature rise with a *doubling* of CO_2 and get anywhere from a 1½ to 6°C (3 to 11°F) warming. The range of variation is due to the many models used by various institutions and the degree of complexity of the models.

However, nature has run its own experiment with the rise of carbon dioxide and other greenhouse gasses (e.g., methane). Carbon dioxide concentration has risen 30–35% since the end of the Little Ice Age, and the other greenhouse gasses have increased another 30% in "carbon dioxide equivalency" units (Oard, 2006). So essentially CO_2 has risen 60–65% while the global temperature increase has only been about 0.7°C (1.2°F)—assuming these temperature records are correct, which they probably are not (Balling, 2005). Since no one knows how much of this temperature increase was natural—and we know that a significant part of it was natural—we will assume half of the CO_2 is anthropogenic, from burning fossil fuels. This then means that the entire human contribution to carbon dioxide since the Little Ice Age has resulted in a temperature rise of 0.35°C (0.6°F), showing the prevailing computer models are all far too sensitive to carbon dioxide. (At this rate, a doubling of CO_2 would cause only about a 0.5°C (1.0°F) increase in global temperature, which makes even the model that produces the least temperature rise three times too high!) The coauthor has worked with such models for thirty years and understands their limitations; the models have a difficult time grasping such variables as solar and infrared radiation processes, cloud processes, ocean-atmosphere feedback processes, and the changing reflectivity of snow and ice cover under various atmospheric conditions.

The atmosphere is not nearly sensitive enough to carbon dioxide for the observed changes to have had much influence on twentieth-century global warming, the Little Ice Age, or the Medieval Warm Period. Besides, there was likely little change in carbon dioxide during the Little Ice Age. The increase in CO_2 has largely occurred since the Little Ice Age ended (Figure 3), and some believe it is what has saved us from the grip of this ice age (Grove, 1988)! Much of the observed increase may simply be the natural exsolution of carbon dioxide from the oceans and other natural reservoirs (Elberling, 2005; Jones et al., 2000), with the fossil fuel contribution being likely far less than the 50% we assumed above (Soon et al., 1999). Carbon dioxide concentration tends to lag temperature, not lead it, which discounts the role of CO_2 as the driving force of the temperature increase (Posmentier and Soon, 2005). In addition, up to a third of the above temperature increase may be an artifact of the measurement techniques (Balling, 2005). "The result that emerges is that current climate model estimates of global temperature changes owing to increased atmospheric CO_2 concentration remain highly uncertain" (Soon et al., 1999, p. 159).

Table IV. Summary of major climatic-forcing mechanisms.

Climatic-Forcing Mechanisms	
Mechanism	Effect
Insolation	Direct proportion
Volcanism	Inverse
Greenhouse gases	Direct proportion
Ozone	Direct effect on stratosphere
Cosmic rays	Uncertain (probably direct)

Milankovitch Mechanism

While the Milankovitch Mechanism (changes in insolation caused by slight differences in distance from the sun and tilt angle) is the undying favorite of uniformitarian explanations for ancient ice ages, the large timescale over which it would apply renders it completely powerless to explain the Little Ice Age (Grove, 1988; Guiot et al., 2005; Mann, 2002). It is also inadequate to explain any previous ice age (Oard, 1984a, 1984b, 1985). Even in light of the inadequacy of the Milankovitch Mechanism to explain a small fraction of Little Ice Age forcing, it receives its due homage in such discussions (Schwarzschild, 2012), probably because there is nothing else within grasp for those who cling to traditional old-earth thinking.

Feedback Mechanisms

There are two types of feedback mechanisms: positive and negative. Positive feedback mechanisms serve to strengthen the causal signal, while negative feedback mechanisms tend to put the brakes on the change in climate and hold it closer to equilibrium. Important mechanisms are listed in Table V.

Ice and Snow

Ice and snow form an obvious positive feedback mechanism for cooling. Their reflectance (albedo) serves to return some of the sun's energy to space that would otherwise warm Earth. The result is lower land, sea surface, and air temperatures, so more of the precipitation that falls will fall as snow. Lower temperatures result in reduced melting, and glaciers tend to grow. Thus, growing glaciers tend to promote glacial growth, and shrinking glaciers tend to accelerate their own demise.

Miller et al. (2012) suggest ice cover may hold the key to explaining the Little Ice Age. They combine radiocarbon dating of recently exposed moss from Baffin Island ice caps, varves in Iceland, Icelandic foraminifera in sediment cores, and volcanic aerosols from ice cores in Greenland to infer that major volcanic eruptions triggered growth of sea ice that then produced the century-scale changes of the Little Ice Age. Coordinating these disparate data can be problematic to say the least (Eiríksson et al., 2000; Oard, 2005), but the feedbacks involving sea ice and snow cover are doubtless important (Bengtsson et al., 2004).

Clouds

The feedback effect from cloud cover is not so clear. Nocturnal cloud cover reduces heat loss to space, but cloud cover during the day reflects considerable solar radiation and absorbs some of the rest so that less reaches the ground. The altitude of clouds also has a bearing on how they affect surface air temperatures.

Table V. Summary of major climatic feedback mechanisms.

Climatic Feedback Mechanisms		
Mechanism	**Feedback**	**Effect**
Snow albedo	Positive	High albedo reflects radiation, low albedo absorbs radiation.
Greenhouse gases	Positive	Warming from GHGs results in exsolution of CO2 and more water vapor production; decrease in GHGs results in more absorption of CO2 and less production of water vapor.
Sea ice cover	Positive	Sea ice cover affects albedo over ocean, as well as winds, currents, and water vapor production. More ice reduces marine moderating influence but may also reduce snowfall.
Vegetation	Positive or Mixed	Vegetation moderates climate. More vegetation decreases albedo and warms cold regions.
Cloud cover	Negative or Mixed	Increased water vapor production increases cloudiness. Reduced solar radiation by day, but less nocturnal radiative cooling. Water vapor is also the most effective greenhouse gas. Rising temperatures increase cloud cover.
CFCs and decreased ozone in stratosphere	Positive or Mixed	Increased CFCs decrease ozone, which results in increased radiation to surface. CFCs and ozone are greenhouse gases.
Stratospheric Temperature	Positive	Decreasing stratospheric temperature with decreasing ozone results in greater ozone destruction and more stratospheric cooling (effect on troposphere is uncertain).

Vegetation and Land Use

Vegetation and land use can greatly impact surface air temperatures. This is clearly illustrated by the "urban heat island effect" or by its opposite—the moderating effect of an "urban forest." On a regional scale, widespread deforestation can result in more extreme climate, and the drier air resulting from desertification can act as a positive feedback mechanism to produce drier conditions with greater temperature extremes. As mentioned in Part III of this series (Klevberg and Oard, 2012a), loss of woodland and soil in Iceland likely worsened climatic deterioration there.

Ozone

Ozone is a greenhouse gas, and ozone depletion produces a cooling effect (Balling, 2005), at least of the stratosphere. Stratospheric cooling has been observed concurrently with land surface air temperature increases. More cosmic radiation would be expected to reach the earth's surface with less ozone to intercept it. How the troposphere and stratosphere interact is incompletely known.

Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are present in the atmosphere only at very low concentrations and may not have a significant direct impact on climate; however, they are known to be very effective greenhouse gases on a per-mole basis and should not be discounted. More importantly, they may have a profound impact on ozone, which is the reason for their being banned under the Montreal Protocol (Lu, 2013). This is particularly true in the polar regions, where ice crystals in stratospheric clouds facilitate ozone destruction at rates several orders of magnitude higher than in lower latitudes where these ice crystal substrates are lacking (Lu, 2013). Ozone is thought to dampen solar forcing (Shindell et al., 2001), so a reduction in ozone would make solar forcing more effective.

Other Feedback Mechanisms

Other feedback mechanisms, some poorly understood, include sulfate aerosols, ocean currents, and atmospheric dust. Volcanic aerosols can interact with ozone in the manner of CFCs, with complex results due to the uneven effects between the polar and tropic regions and between the stratosphere and troposphere (Robock, 2000). Svensmark (2007) proposed a link between galactic cosmic ray intensity and cloud cover, but this has been widely disputed (Hebert, 2013; Lant, 2003; Sloan and Wolfendale, 2008). Nonetheless, regardless of whether Svensmark and others have overstepped their data, cooling of the lower troposphere, minimum solar irradiance, and maximum cosmic ray incidence (extraterrestrial ions) do coincide (Baliunas, 2005). Sulfate aerosols from volcanic eruptions are not as obvious as volcanic ash but may be more important in inducing cooling (Ward, 2009). Several other possible feedback mechanisms have been proffered (Yndestad, 2006).

Is the Earth Warming?

A disturbing trend is the tendency for questions such as "Do you believe in global warming?" or "Do you recognize the fact of climate change?" to be posed without the scientific mooring necessary for meaningful discussion. It becomes a political litmus test rather than a genuine effort at understanding nature. Is Earth warming? Compared to what?

The Earth Has Been Warmer Than at Present

While some in the popular press are careful to talk about "climate change" rather than "global warming," the overall dominance of one particular view on a scientific question is amazing. The word "consensus" comes up repeatedly, as if the scientific method were somehow democratic. An article entitled "The Truth About Denial" in *Newsweek* magazine asserted, under the heading "consensus," "Current warming is 10 times greater than ever before seen in the geologic record. The chance that the warming is natural is less than 10 percent" (Conant et al., 2007). While popular media make such brash statements, few practicing scientists believe this hype (McKitrick, 2005). Virtually no geologist, evolutionist or creationist, would accept the *Newsweek* statement.

Warmer periods than the present in ancient times (by evolutionist definition) are widely accepted (Balling, 2005; Lillehammer, 1994; Follestad and Fredin, 2007; MacDonald et al., 2000; Posmentier and Soon, 2005; Tarasov et al., 1999; and virtually any historical geology textbook). Iceland experienced warmer conditions in recent millennia per evolutionist dating (Björnsson, 1980; Caseldine and Stötter, 1993; Wastl et al., 2000). Plant remains have been uncovered well above treeline on the Hardangervidda in Norway that appear "fresh" yet are far higher than their present range (Grove, 2001). Pine stumps indicate that the treeline here was much higher in the past than it is today (Lillehammer, 1994). Evidence from northern Norway suggests the Medieval Warm Period was more significant and the modern (post-Little Ice Age) warming less than IPCC pundits proffer (Bakke et al., 2005). Still warmer conditions apparently existed farther back in time (Bjune et al., 2005) and in many parts of the world outside the study area (Pellatt et al., 2000; any historical geology textbook).

The Earth Has Been Colder Than at Present

In light of the evidence provided in this series, little need be added than the fact that global average temperatures have been significantly lower (i.e., a few degrees Celsius) in the past. Excellent documentation of this in regions other than our study area can be found especially in Grove (1988) but also in many other sources (e.g., Björnsson, 1980; Follestad and Fredin, 2007). Some well-attested modern climate models for the past millenium also indicate significant Little Ice Age cooling (Briffa and Osborn, 2002; Guiot et al., 2005; Figure 1). Traditional ice age theories hold to considerably colder conditions in the past.

Scientific Approach

To approach the question of whether measurable climatic warming is occurring globally requires not only adequate spatial and temporal data collection, but also a datum against which to compare the climatic data. Global warming (or cooling) relative to what?

We also need to be clear which data set is being examined. Most of the data considered of late have been surface air temperatures, while temperatures in the troposphere have warmed significantly less than claimed on the surface (Christy, 2005). The tropospheric temperatures are probably more important for effective climate modeling.

Humility is essential to good science, even though social pressures may exist for scientists to overstep the justified inferences from their data. "In fact, people have little understanding of the exact nature and causes of climate change, in spite of—or perhaps because of—the vast amount of sensational literature available" (O'Keefe and Kueter, 2005, p. vii). "Our greatest problem is not ignorance; it is the presumption of knowledge" (O'Keefe and Kueter, 2005, p. viii).

A related question that seems to be ignored or stifled is whether global warming would be a bad thing. Climates have changed in the past, and the effects of those changes may be complex. In at least some instances, positive changes may result from increases in average temperature (McCarl, 2010) or atmospheric carbon dioxide concentration (Robinson et al., 2007).

The Earth Will Be Hotter Than at Present

Whether one believes in "global warming" now, real global warming is coming. Hegerl et al. (2006) consider the IPCC published climate sensitivity of 1.5–4.5 K (about 3 to 8 °F) to represent the maximum, but this assumes uniform conditions. Unusual conditions are indicated in Revelation 16:8–9. This insight is not dependent on our knowledge or perception but has been provided to us by the One who has been present and in control of our planet's climates throughout its history (Psalm 147:7–8). We can be confident of its fulfillment in the near or distant future.

Speculations on Climate Forcing

The effects of the Little Ice Age were significant. For instance, glaciers advanced all over the world, temperatures were significantly cooler, and the equilibrium line altitude was about 150 m lower than at present (Klevberg and Oard, 2012b). Before that, the Medieval Warm Period was just as dramatic on the warmer side.

As can be seen from Figure 5, both solar variations and volcanism seem to have some connection with temperature fluctuations of the past millennium but no completely clear correlation. The clearest appears to be what was likely the coldest period of the Little Ice Age, which began with significant volcanism closely followed by the Maunder Minimum. Neither forcing mechanism appears adequate, nor do greenhouse gas concentrations explain climatic history. "However, the natural radiative forcings are either weak or, in the case of explosive volcanism, short-lived … thus requiring substantial internal feedback. The LIA [Little Ice Age] is particularly enigmatic. Despite extensive historical documentation and a wide array of proxy records that define climate change during the past millennium … there is no clear consensus on the timing, duration, or controlling mechanisms of the LIA" (Miller et al., 2012, p.1).

Miller et al. (2012) are right to acknowledge the importance of feedback mechanisms. While quite possibly flawed (cf. Vinje, 2001), their sea-ice feedback model does show promise for explaining much of the climate change in our study area. Yet it still does not explain climate change elsewhere. Regional causes cannot explain the Little Ice Age. "Glaciers on every continent have expanded in the last few centuries; the Little Ice Age was a global phenomenon" (Grove, 1988, p. 354).

"Many workers have concentrated their attention on one possible cause, more or less ignoring the rest, whereas it is very likely that several factors are involved. Explanations advanced fall into two main classes, those which rely on internal adjustments within the atmosphere-ocean system and those invoking external factors to account for changes in the mean temperature of the globe"(Grove, 1988, p. 359). This is correct. While we believe variations in solar irradiance were the primary driving force for the Little Ice Age, we do not discount the role played by volcanism and various feedback mechanisms (including CO_2 and CFCs), particularly on the decadal to century scale (cf. Bertrand et al., 1999; Lu, 2013).

Such climatic changes as the Medieval Warm Period and Little Ice Age have virtually nothing to do with the amount of carbon dioxide. In fact, from proxy studies, atmospheric carbon dioxide concentration changed little during those periods. Such marked natural fluctuations in climate are telling us that the current global warming of up to 0.7°C (1.2°F) is at least partly natural, especially in view of the high number of sunspots and low amount of volcanic effluents in the stratosphere for the twentieth and early twenty-first centuries.

The debate today rages (when not stifled!) over the percentage of greenhouse warming that is natural and the percentage that is man-made. Every extreme is represented in the marketplace of ideas. We know from our study of the Little Ice Age that the IPCC, most of the media, Al Gore (2006), and other alarmists who say that man is nearly 100% responsible, are exaggerating (Horner, 2007; Lomborg, 2007). Furthermore, they are being unscholarly, since most refuse to consider natural fluctuations or the role of CFCs. They can cause great harm if they manage to get all they want politically and economically. The motivation here cannot be an honest search for the truth!

Summary

To what heights (or depths) would current climate modeling have ventured without the constraining influence of historical records and the Little Ice Age? These constraints should remind us that humility is a prerequisite for good science. If we are to effectively "think God's thoughts after Him," we must approach the study of nature with humility and wonder. Our knowledge of climatology is rudimentary at best, and in relation to the past, science cannot discover truth but serves simply to temper historical speculation.

Yet progress has been made. Based on what has been shown in this series thus far, we present the following conclusions:

- The Milankovitch Mechanism has no explanatory power for the observed Little Ice Age and probably none for previous glaciation(s).
- Changes in solar irradiance have had an important and global effect on climates but cannot be the sole source of the Little Ice Age.
- Volcanism has had an important role in climate change, especially in triggering cooling. However, its role is regional and short-lived, and therefore inadequate to explain the Little Ice Age.
- Feedback mechanisms appear to be very important but poorly understood. Such mechanisms include ice and snow cover on land and sea, cloud cover, land use, weather feedback patterns (e.g., NAO, ENSO), and possibly ocean current changes, greenhouse gasses, chlorofluorocarbons, and cosmic rays.

Since any speculative ice age would be similar in kind to the Little Ice Age and differ from it only in magnitude, the same causal relations would apply. The Little Ice Age as an analog for a Great Ice Age (or ice ages) in the past will be addressed in Part VII of this series.

Historical records set the Little Ice Age apart from times of glacial advance that preceded it. There is no substitute for eyewitness accounts. For that reason, members of the Creation Research Society place their confidence in the God who was present and active at the creation of the universe rather than the unconstrained speculations of those who were not. In regard to climate change, this not only gives us confidence that the climatic system is likely to be more complex and resilient than fearmongers allow, but we also acknowledge that our moral actions may affect climate far beyond the scale of the "urban heat island effect" or even global warming (Revelation 16). This calamity we will not avert by merely reducing our "carbon footprint"!

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Glossary

tropopause: the layer in the atmosphere just above the troposphere in which the temperature changes from decreasing with height to increasing with height.

troposphere: the lower portion of the atmosphere, where common weather phenomena occur. It extends from ground level to the tropopause.

mesosphere: the layer of the atmosphere above the stratosphere in which the temperature decreases with height again.

stratosphere: the layer of the atmosphere above the tropopause and below the mesosphere. This is where cosmic radiation reacts with O_2 to form O_3, thus shielding the earth's surface from much of the cosmic radiation.

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Appendix: Political Influence and Junk Science

Junk science and pseudoscience often result from political influence in the awarding of research grants, teaching appointments, etc. (Bergman, 2008). This is also true in the study of climate change, a clear example of the reinforcement syndrome (Oard, 1997). This produces the "consensus." Many have documented the limitations of peer review in science in general, including the use of peer review as a tool to censor creationists (Anderson, 2002, 2006a, 2006b, 2008; Lumsden, 1992) and skeptics of big bang or "standard model" cosmogony (Arp, 1998). The use of peer review by *Nature* and other well-known journals to censor global warming skeptics also has been documented (McKitrick, 2005).

We have heard some informal opinions against Lu's recent work (2013), which is not surprising since he predicts the long-term result of the Montreal Protocol will be the end of global warming. This undermines the IPCC position that carbon dioxide is the culprit and must be controlled at all costs. One frequent criticism of Lu and global warming skeptics seems to be that correlation does not establish causality. This is true and is a good example of the pot calling the kettle black.