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The Little Ice Age in the North Atlantic Region

Part VII: Constraints on the Great Ice Age

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Abstract

Earlier papers in this series introduced methods of studying past climate change, the historicity of the Medieval Warm Period and Little Ice Age, 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, and how the data obtained from the Little Ice Age should constrain our study of climate change. This paper presents an application of Little Ice Age data to our understanding of the inferred postdiluvian Great Ice Age.

The Great Ice Age—A Major Geologic Inference

Much attention in the past thirty years has been paid to the "Great Ice Age," as we refer to it. Uniformitarian scientists believe in multiple ice ages, over 50 in the past 2.6 million years (Pillans and Gibbard, 2012) and four major ancient ice age periods, lasting tens to hundreds of millions of years, from 250 million to 2.2 billion years ago (Oard, 1997). The former ice ages are called the "Pleistocene ice ages," although they supposedly started in the late "Pliocene," and are believed to be caused by the astronomical hypothesis of the ice age, also known as the Milankovitch mechanism.

The Great Ice Age is a major geologic inference of the relatively recent (postdiluvial) past based on similar features observed around glaciers today, but found over large areas of the middle and high latitudes. These features from the past show the likelihood that there was a recent ice age (Oard, 1990; 2004)—very recent in comparison with traditional beliefs about earth history. Can we learn anything about the Great Ice Age from the characteristics of the Little Ice Age?

Modern glaciers produce a variety of deposits and landforms. These were produced in even larger scale and greater abundance during the Little Ice Age. Similar deposits and landforms that appear subdued by age are found in these same areas, but also across wide parts of the Northern Hemisphere and some parts of the Southern Hemisphere. It is only natural to surmise that at least one ice age of even greater extent than the Little Ice Age occurred during postdiluvian time (Figure 1).

The Little Ice Age as a Model for the Great Ice Age

For a model to be useful, it needs to mimic the properties of interest in the prototype. At the same time, the model needs to differ significantly from the prototype in the properties that cause

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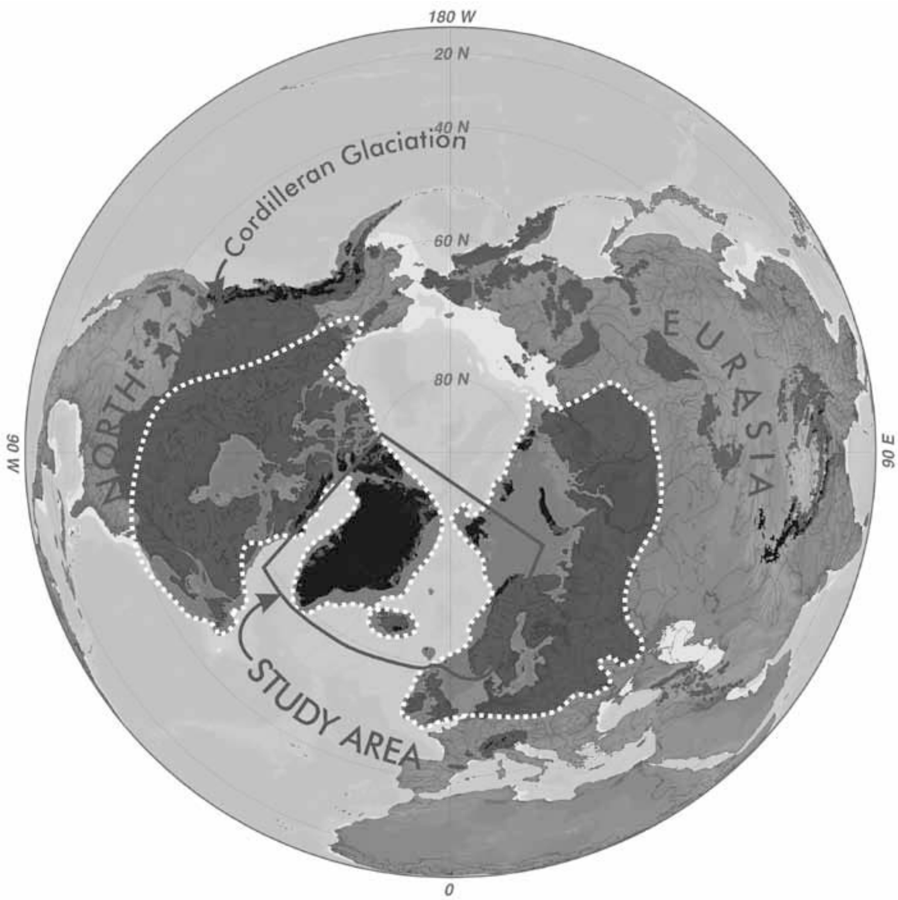

Figure 1. Estimated extent of ice during the Great Ice Age. Dashed white line is approximate extent of continental glaciation. During the Little Ice Age, mountain glaciers (cordilleran ice) increased, but the continental glaciers have never recurred and are therefore inferred from field evidence. Maximum extent indicated in some areas is dubious. Base image from Wikipedia Commons.

difficulties in research, such as scale or time. So, for example, a scale model of a ship or airplane or other vehicle can be made and placed in a flume or wind tunnel where the current speed is proportionately higher than for the prototype; as long as the Reynolds number (which relates key physical proportions) stays the same, the model provides very useful data in evaluating the prototype.

The usefulness of the Little Ice Age in the North Atlantic region (Figure 2) as a model for the Great Ice Age is shown in Table I. While we lack specific climatic data for the Great Ice Age, we have such data for the Little Ice Age (Table II). As a model, it is imperfect: other than the Greenland ice sheet, nothing resembling a continental ice sheet of the type imagined during the early postdiluvian period (or by uniformitarians during the "Pleistocene") is available. Another defect of the model is that it requires *extrapolation* rather than *interpolation*, with the changes in temperature, precipitation, and resulting equilibrium line altitude (ELA—see glossary) being greater for the inferred Great Ice Age than for the observed Little Ice Age. The scale of the glacia-

Measurements Relative to Late 1900's	Little Ice Age	Great Ice Age
Change in Equilibrium Line Altitude	0 to 400 m lower than today	Approximately 500 to 2,000 m lower than today
Drop in Average Summer Temperature	0 to 4°C lower than today	Approximately 4°C to possibly 30°C lower than today
Precipitation	similar to today	greater (probably much greater) than today's values
Sea Surface Temperatures	similar to today to slightly colder	initially greater (probably much greater) than today's values, cooling with time
Volcanic Activity	greater than today with notable eruptions at several times	likely significantly greater than present levels
Insolation	similar to today except for volcanism and several notable periods of low solar activity	solar output unknown, but there was much less reaching earth's surface due to volcanic activity

Table I. Comparison of Little Ice Age and Great Ice Age characteristics. The Little Ice Age provides a very useful but imperfect model for the Great Ice Age.

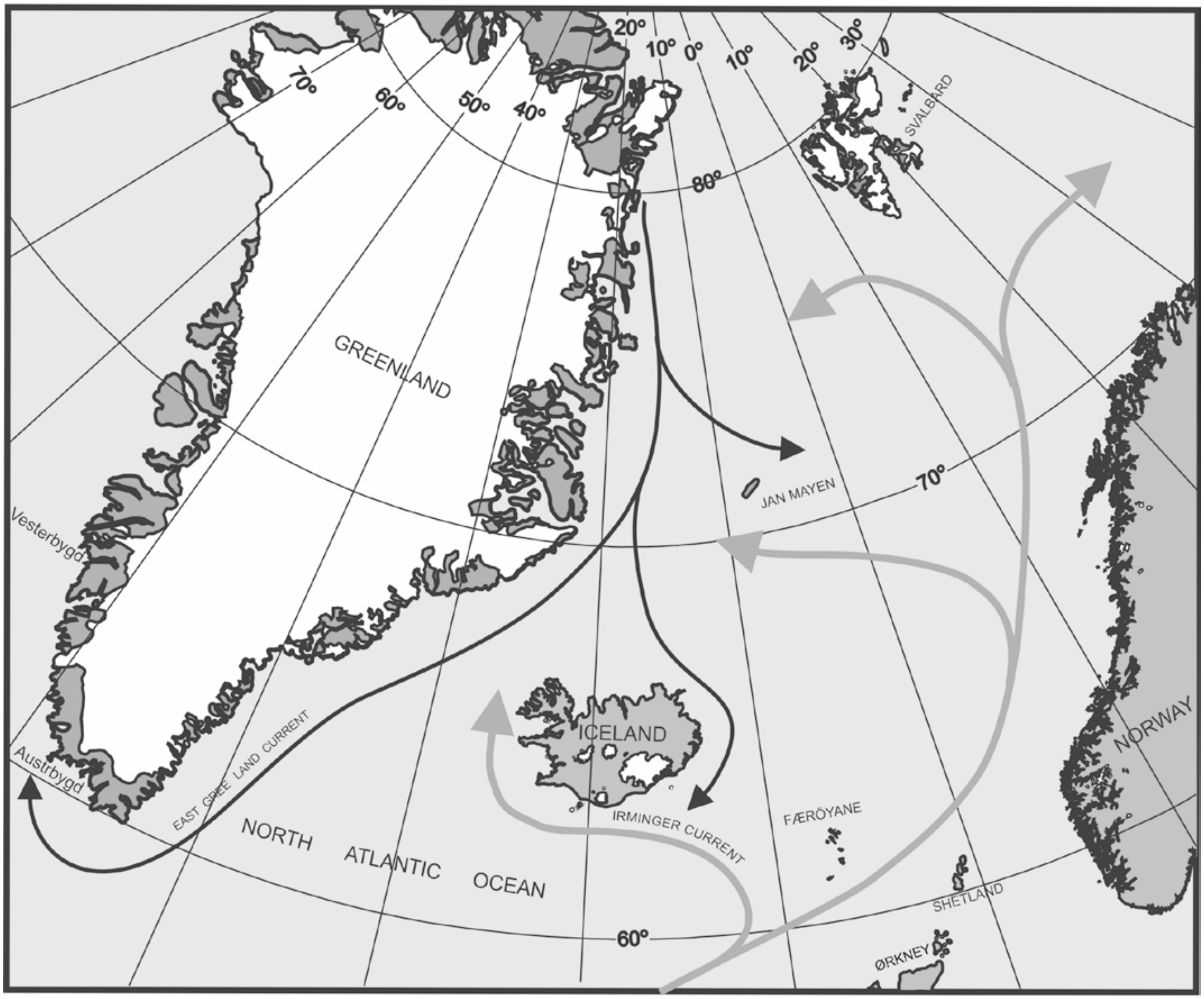

Figure 2. Map of study area. The focus of this series has been Iceland, Norway, and Greenland.

tion and resulting geologic processes is much less for the events of recent centuries, too. However, those data accumulated from paleoclimatology and glaciology do lie between present conditions and the postdiluvial climate we are trying to evaluate. Also, as shown in Table III, observations from the study region have great relevance for evaluating the role of scale and further refining glacial models.

Constraints Provided by the Little Ice Age

Effects of the Little Ice Age in the North Atlantic region were most pronounced in Iceland, a relatively small landmass surrounded by the North Atlantic Ocean, and proportionately least in Greenland, a very large and nearly completely ice-covered arctic landmass surrounded by colder water (Table III). Norway, the coastal side of the Scandinavian Peninsula washed by relatively warm currents, saw proportionately intermediate glacial growth which was more closely linked to winter precipitation than summer temperature. These differences indicate the importance of elevated sea surface temperatures to the creation of vast ice sheets during the Great Ice Age (Oard, 1990).

One of the key variables in studies of glaciation is ELA. Changes in ELA,

	Little Ice Age Inferences			References	
Glacier/Region	Year	Temperature Difference	E.L.A. Difference	Base Year(s)*	Author
Sólheimajökull	ca. 1800	-1.6°C		1960–90	McKinzey et al., 2005
Eiríksjökull	ca. 1875	-1.5°C	-250 m	ca. 1990's	Guðmundsson, 1998
Tröllaskagi	pre-1925		-200 m?	post 1925	Caseldine, 1987; Björnsson, 1980
Tröllaskagi-Hörgárdalur	1800's		-5 m		Häberle, 1991
Tröllaskagi – observed		-2°C	-50 m	1925–1960	Caseldine & Stötter, 1993
Tröllaskagi – theoretical			-300 m		
Iceland in general	1600–1920	-3 to -4°C	ca. 200 m/°C	clima optima	Björnsson, 1980
			-400 m	1960–90	Grove, 2001
Western Norway	*clima optima*	+2°C		1980–2005	Bjune et al., 2005
	1886	-0.4°C		1940	Grove, 1988
	1886	0	0	1950	Grove, 1988
Northern Norway	1600		ca. -150 m	1300	Grove, 1988, p. 414
	1886	-1°C		1940	Grove, 1988
	1910		- 100 to 250 m	1960–90	Bakke et al., 2005
Spitsbergen	1886	-2°C	-110 m	1940	Grove, 1988

* Little Ice Age values in columns to left are compared with indicated base years.

Table II. Summary of some changes in temperature and ELA estimated from Little Ice Age data.

Feature	Iceland	Norway	Greenland
Climate	Temperate/Polar	Temperate	Polar
Setting	Maritime	Maritime and Interior	Maritime and Interior
Landmass	Islands	Large Peninsula	Subcontinent
Glaciers	Europe's largest ice cap, outlet glaciers, small ice caps, mountain glaciers	Small ice caps, mountain glaciers	Second largest ice sheet, voluminous outlet glaciers, limited mountain glaciers
Forcings and Feedback Mechanisms	Sea ice provided very important feedback to enhance lower temperature.	Sea ice not important. Precipitation more important than temperature to mass balance. Temperature drop, but response complex.	Sea ice cover important to temperature drop.
Little Ice Age Advances	*Significant*: most glaciers approached maximum extent of Great Ice Age.	*Moderate*: glaciers advanced but did not overrun previous maximum extent	*Moderate*: ice sheet thickened, outlet glaciers advanced but did not overrun previous maximum extent

Table III. Comparison of features of the land areas emphasized in this study relative to glaciation.

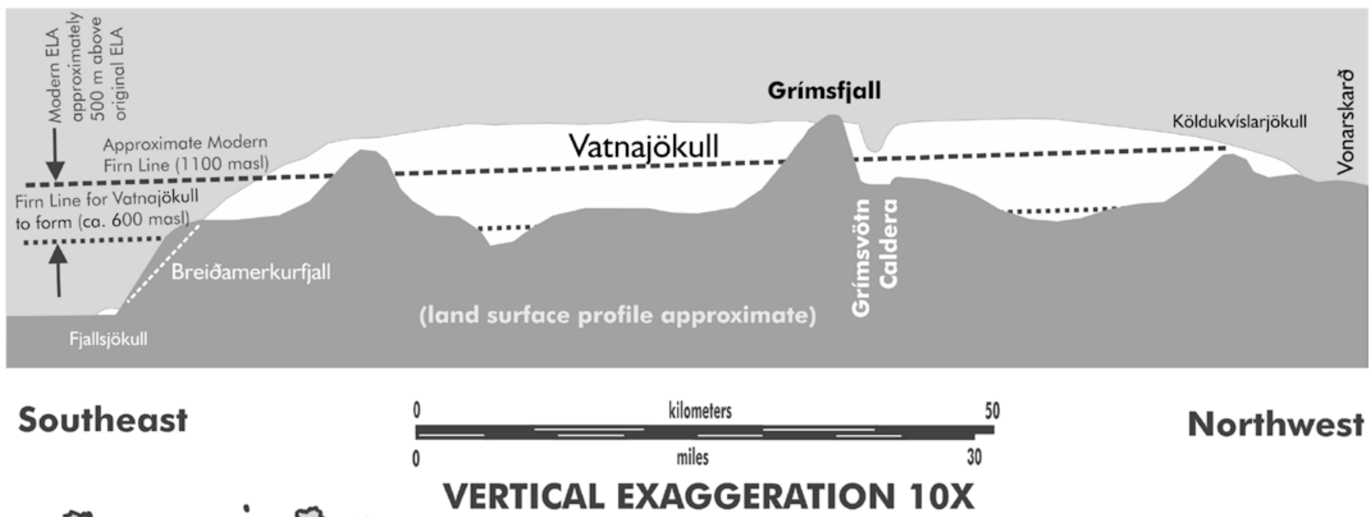

Figure 3. Section through the great ice cap Vatnajökull. Note that the modern firn line is well above the ground surface, indicating that it must have been at least several hundred meters lower during the onset of the Great Ice Age than it is now.

during and since the Little Ice Age, have been estimated for Iceland and Norway (Klevberg and Oard, 2012a; 2012b), as well as other places. Estimating changes in ELA from any unrecorded Great Ice Age(s) is not as simple, as these must be estimated from features inferred to result from "prehistoric" (i.e. unrecorded) glaciation(s). Some key ELA estimates are shown in Table II.

As shown in Figure 3, the firn line (and by extension, the ELA) must have been significantly lower in the Great Ice Age for Vatnajökull to have formed. While the Little Ice Age produced a marked drop in ELA and growth of Vatnajökull, the topography beneath the ice is too low for ice to have formed initially under similar climatic circumstances. The firn line (or at least the ELA) must have been at least 500 m (1,500 ft.) lower than at present to initiate the glaciation that would come to form Vatnajökull.

That Icelandic outlet glaciers typically reached their terminal moraines during the Little Ice Age suggests that conditions did not need to be drastically colder to bring on the Great Ice Age in Iceland. If relatively warm oceans existed (Oard, 1990), then melting near the coast would have been enhanced. The result would tend to be fairly distinct termini and a great deal of glaciofluvial activity. The cold, dry climate of today's Arctic does not promote this kind of aggressive glaciation, either.

Inferences for changes in ELA provide the basis for inferring temperature changes. Some believe the Great Ice Age ("Pleistocene ice ages" in uniformitarian reckoning) resulted from a 2 to 3°C (3½ to 5°F) drop in average global temperature (Mann, 2002). If the Little Ice Age represents a drop of only 0.5°C (1°F) relative to the past century (Luterbacher et al., 2004), then its applicability to any previous ice age is less than if it represents a drop of 1 or 2°C (2 to 3½°F)–or if the Great Ice Age temperature drop were less.

Climate change, not merely reduced temperature, is necessary for the onset of an ice age. Both northern Iceland and western Norway show how glaciers may be more sensitive to precipitation changes than temperature changes, and Appendix A in Part II of this series shows how various climatic variables–average summer temperatures, average winter temperatures, cloudiness, winter precipitation, ELA, etc.–impact glaciers. The Little Ice Age did not result from a simple reduction in global average temperature, nor can global average temperature be accurately inferred from a simplistic approach to that glacial event. Likewise, mere cooling cannot produce large-scale ice ages, as will be shown in the next section.

A Multiplicity of Milankovitch Mistakes

The Milankovitch mechanism or Astronomical Theory of the ice ages is based on slight cyclical changes in sunlight caused by differences in the Earth's orbital geometry. Summer temperature changes at high latitudes of the Northern hemisphere are believed to drive ice ages. Because of the Milankovitch mechanism, secular scientists believe in multiple ice ages with a supposed cycle every 100,000 years for the past 900,000 years and every 40,000 years between 900,000 and 2.6 million years ago. However, the changes in summer sunshine are too weak to cause ice ages (Klevberg and Oard, 2014b), and the 100,000-year eccentricity cycle hardly changes the sunlight intensity at all (Oard, 1984a; 1984b; 1985; 2004; 2006a)! The Little Ice Age was much too short to have been influenced by the Milankovitch mechanism, which operates on scales of tens of thousands of years.

As has been described previously (Klevberg and Oard, 2012a; 2012b), multiple glacial movements have been documented during relatively brief periods during the Little Ice Age in both Iceland and Norway. Many of these advances and retreats occurred on an annual or decadal basis, sometimes over significant distances; these clearly resulted from climatic variability with no connection with the Milankovitch Mechanism whatsoever.

A Single, Relatively Short, Postdiluvial Ice Age

The causes of the postdiluvial Great Ice Age were warm ocean temperatures and abundant volcanic aerosols in the stratosphere left over from the Noahic Deluge and reinforced by copious postdiluvial volcanism (Oard, 1990; 2004). The warmer the sea surface temperatures, the greater the evaporation. Evaporation would be especially strong above the mid and high latitude oceans and be available for strong storms to rapidly dump snow on the adjacent land masses. The time for the Ice Age would depend on how fast the ocean water cooled, which can be roughly estimated by adding up all the heating terms and cooling terms that result in a change in temperature with time. Estimating the postdiluvial change in ocean temperatures from the Genesis Flood to glacial maximum and solving for time resulted in 500 years to reach maximum (Oard, 1990). Based on the energy balance over a snow or ice cover, the melting of the ice sheets in places other than Greenland and Antarctica would have taken less than 200 years. Thus, the total time for the postdiluvial Ice Age was probably only about 700 years.

Although secular scientists believe in multiple ice ages, based mostly on the Milankovitch mechanism, there are many evidences of only one ice age (Oard, 1990; 2004). First, it is meteorologically difficult for even one great ice age to occur under uniformitarian conditions, so the idea of multiple ice ages stretches credulity. Second, most glacial debris is from the "last" ice age. Third, practically all the wind-blown silt (löess) associated with the ice sheets is from the "last" ice age. Fourth, glacial debris is thin and coarse-grained in interior areas of past ice sheets. Fifth, two driftless areas, one in southwestern Wisconsin and one in northeastern Montana and adjacent Saskatchewan, make more sense interpreted in terms of one ice age that missed a few peripheral areas rather than multiple glaciations that consistently missed these areas. Sixth, most of the animal extinctions were at the end of the "last" ice age. Multiple ice ages should have produced multiple extinctions, not just the last. These reasons for rejecting the multiple ice age idea in favor of a single, relatively short, postdiluvial ice age have been provided in greater depth elsewhere (Oard, 1990; 2004; see also references in Appendix A).

Comparing the Little Ice Age and Great Ice Age

While imperfect as a model for an ice age of the scale that most geologists envision, the Little Ice Age is probably the best model available for such a Great Ice Age. A comparison of the Little Ice Age with the inferred Great Ice Age is provided in Table I.

Temperature difference at sea level in Iceland between the Little Ice Age *minimum* and 20th Century *maximum* is about 3°C (Eiríksson et al., 2000). The difference in Scandinavia was at least half that in Iceland (Hass and Kaminski, 1995; Klevberg and Oard, 2012b). A difference of 1°C is roughly equal to about a 25% change in annual precipitation for a given mass balance (Oerlemans, 2005). This means the same ELA could be maintained with a slight warming if precipitation increased, and likewise, if precipitation and temperature both decreased, little or no change in the ELA might result. A rise in winter precipitation concurrent with increasing temperature resulted in only about 50 m changes in ELA for northern Iceland mountain glaciers from their Little Ice Age minima to levels observed in the 1980s (Stötter et al., 1999; Caseldine and Stötter, 1993).

We believe the Great Ice Age was much greater than the Little Ice Age because much warmer sea surface temperatures occurred after the Deluge of Genesis 7–8 than occurred during the Little Ice Age. This would have produced far more evaporation in early postdiluvian time, at the same time that volcanism would have been greater (Oard, 1990; 2004). The volcanism would have resulted in greater summer cooling worldwide, especially at high latitudes and continental interiors in middle latitudes.

The belief that extreme weather events have increased over the past few thousand years (NORPAST, 2001, Appendix 1) may well represent the "stretching" effect of uniformitarian assumptions, attributing greater and greater periods of time to earth history with increasing age. Transfer functions may require revision to meet the constraints of diluvial models based on the accurate historiography of the Bible and

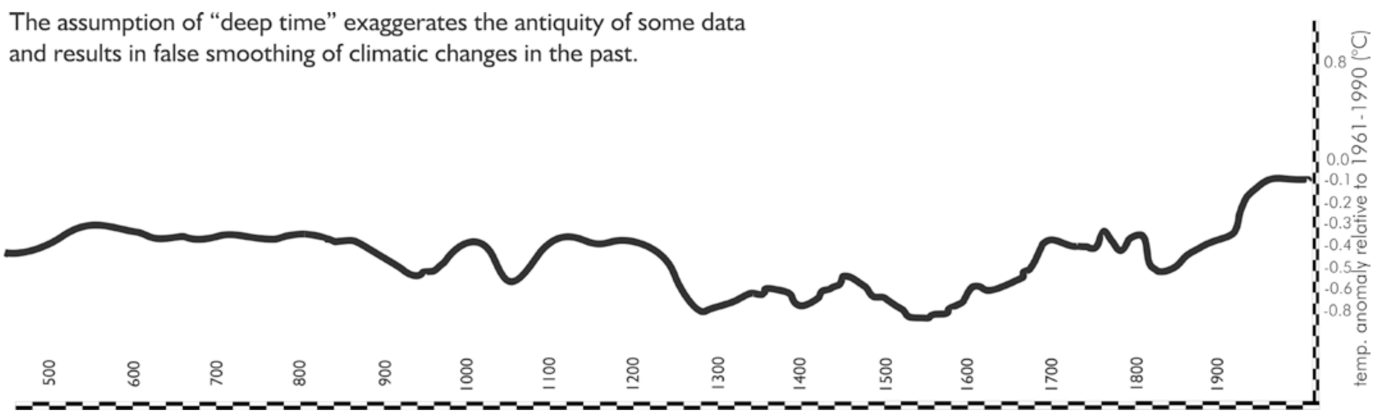

Figure 4. Uniformitarian assumptions may provide a false sense of increasing frequency of extreme weather due to the "stretching effect." Inflation by the assumption of "deep time" tends to get worse the further from the constraints of known history it is, with the result that extreme weather events in the distant past tend to be interpreted as having occurred with more time between them than was actually the case.

the Little Ice Age. This stretching effect is illustrated by Figure 4. In reality, their position makes previous ice ages even less likely when they refer to conditions during the Little Ice Age as "extreme." Thus, while the traditional multiple ice age view is beyond the rescue of Milankovitch, the case for a single, relatively short, postdiluvial ice age with less extreme conditions is robust.

Early Postdiluvial Climate in the North Atlantic Region Was Significantly Warmer

Fossil and pollen paleoclimatic evidence in Iceland for at least one period earlier and warmer than the Medieval Warm Period is strong. Just when and how this occurred is not certain (see Appendix B), but the idea of warmer periods is widely accepted. Evidence for warmer periods in Norway and Greenland has been presented previously (Klevberg and Oard, 2012b; 2014a).

The traditional uniformitarian scenario for Icelandic glacial history includes virtually complete coverage of the island group by ice during the "Pleistocene" and several glacial advances and interglacial periods since, the most recent being the Little Ice Age (Björnsson, 1980). At least 13 glaciations have been inferred from the Esja sediments in Iceland (Sæmundsson, 1980). "Stratigraphical studies in Iceland indicate at least 10 glaciations during the Upper Pliocene and about as many during the Pleistocene" (Símonarson, 1980, p. 174). A similar scenario is proposed for the Scandinavian Peninsula (Lillehammer, 1994).

Post 1920s climate in northern Iceland has been about 2°C (3½°F) warmer, principally in winter, and precipitation has increased with increasing temperature, especially in winter; the presence of sea ice particularly reduces precipitation (Stötter et al., 1999). This illustrates the crucial role of moisture supply in maintaining glaciers in Iceland. Similar conditions exist for Norwegian maritime glaciers, though with less dramatic differences in sea conditions and resulting precipitation (Klevberg and Oard, 2012b). An increase in precipitation along with temperature is often (though not always) inferred for paleoclimates in the study area (Klevberg and Oard, 2012b).

Important Climatic Differences between the Ice Ages

As has been shown, the Little Ice Age climate in Iceland was only a few degrees colder than at present, but glaciers generally advanced to near their Great Ice Age limits in our study area. Yet paleontological data, at least some of which are possibly postdiluvial, indicate significantly warmer ocean temperatures (and thus sea surface temperatures) than at present. This would produce considerably more atmospheric moisture and resulting precipitation, which is in keeping with the prevailing model for the postdiluvial Great Ice Age (Oard, 1990; 2004). Some have estimated that Little Ice Age sea surface temperatures were 3 to 5°C (5 to 9°F) cooler than at present (Balling, 2005). However, it should be noted that modern studies have found that meltwater input to the adjoining ocean did not reduce precipitation, though sea ice, of course, did (Bakke et al., 2005). Thus, it would be reasonable to suppose that significant precipitation would have continued until sea ice cover became adequate to greatly reduce the source of moisture (Klevberg and Oard,

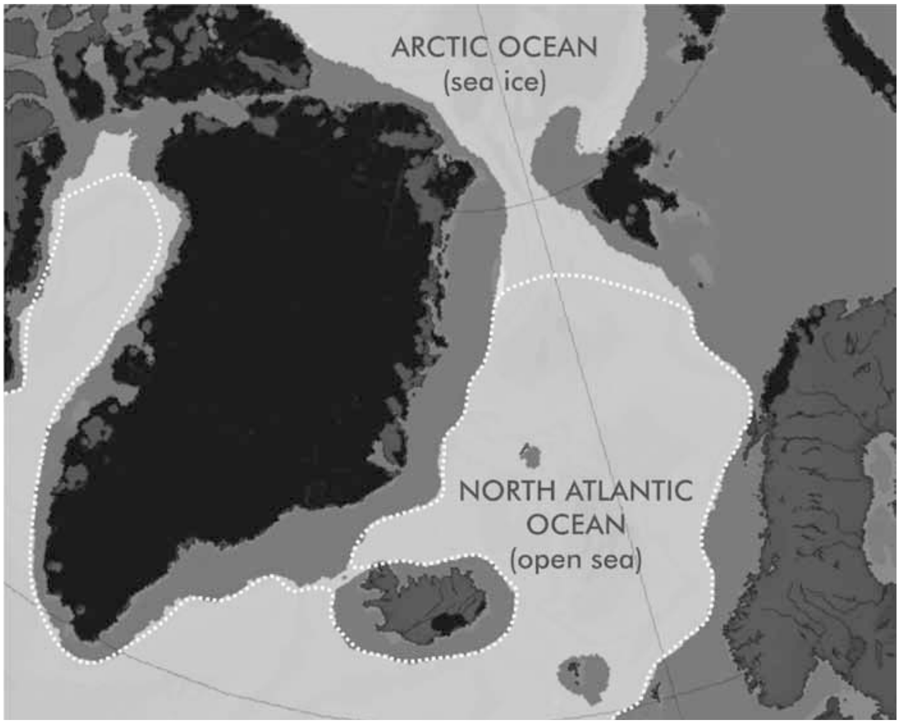

Figure 5. Estimated maximum extent of snow and ice in study area during the Great Ice Age indicated by dashed white line. Relatively warm sea surface temperatures and low albedo from snow and ice over a large area would provide a powerful combination for rapid ice accumulation.

2014b). Inferred sea ice extent at glacial maximum is shown in Figure 5. Features that appear to be glacial in origin are even found on the sea bottom and suggest that at least a portion of the area we have indicated was completely frozen and not just surface ice (Mattingsdal et al., 2007).

"In the maritime Icelandic climate glacier mass balance is very sensitive to variations in air temperature," states Björnsson (1980, p. 206); "a drop in the annual air temperature by 1°C may lower the firn line by as much as 200 m. Any lowering of the firn line will greatly increase the accumulation areas of the ice caps in Iceland." The average air temperature during the period 1600 to 1920 (during the Little Ice Age) was probably 3 to 4°C lower than during the warmest period in postdiluvian time, based on data from Björnsson (1980). It must have been significantly lower at some point before Iceland's settlement for ice to begin accumulating and thus generate Vatnajökull. As shown in Figure 3, Vatnajökull today is largely above the firn line, but the land surface is well below the firn line–as much as 1,000 m. To generate the ice cap would require lowering the firn line hundreds of meters until ice could build up to today's elevation. A similar situation on a much larger scale exists for Greenland and Antarctica as well (Oard, 1990; 2006). Large areas of these land masses are low topographically, some even below sea level, and only the thickness of the ice raises the modern surface to high elevations.

Mass balance is primarily a function of winter precipitation and summer temperature. To some extent, warmer summer temperatures can be compensated for by increased winter precipitation. This relationship has been found to be roughly a 25% increase in annual precipitation to overcome a 1°C (2°F) increase in average temperature (Oerlemans, 2005). As has been documented (Klevberg and Oard, 2012b), precipitation has been shown to be very important and sometimes dominant in Norwegian glacier mass balance. Precipitation must also have been the key variable in the growth of the ice sheet on Greenland during the Little Ice Age; based on isostatic measurements, most of this recent ice has yet to melt (Klevberg and Oard, 2014a).

Enhanced precipitation is a key element in the postdiluvial Ice Age model (Oard, 1990; 2004). If this model is correct, then the relatively dry continental interiors should have been least affected by the Little Ice Age, with its limited supply of moisture. This has been observed to some degree in the North Atlantic study area (Klevberg and Oard, 2012a; 2012b; 2014a). As shown in Table III, Iceland was proportionately most affected by Little Ice Age, and an important difference from Norway and Greenland is the relatively small land mass surrounded by ocean. This difference has also been observed in other parts of the world. For example, while ice advances were observed in the Northern Rocky Mountains, Little Ice Age advances apparently fell short of previous glacier positions, more so north than south (Grove, 1988). Temperature, while important to both the Little Ice Age and Great Ice Age, is not the only variable. Increased precipitation is essential for an ice age to form, something the diluvial model predicts and the Milankovitch mechanism is powerless to provide.

Model Results

Table IV presents a comparison of the Little Ice Age as an analogue for evaluation of the Great Ice Age. Temperature is an important variable, though not adequate in itself to explain an ice age. Temperature is a dynamic variable and often differs greatly across regional boundaries. Summer temperature has a greater effect than winter (since melting versus freezing is the deciding factor for ice volume), and averages are more important than extremes. The Great Ice Age estimate in Table IV is largely a guess based on the proportional change in ELA and would apply to the glaciated areas, not global average temperatures. The ELA is also not a single number: in arctic regions, where the ELA began nearly at sea level, it would hardly change, but at the southern extent of glaciation, a dramatic drop in ELA would occur during the glacial period. As described above, precipitation at the onset of the Great Ice Age was likely significantly higher than it is today across our study area due to the warmer sea surface temperature that could be expected following the great cataclysm of the Deluge. Insolation would likely have been reduced much more so than during the Little Ice Age; while there is no way of knowing solar irradiance during early postdiluvian time, much greater volcanism would have provided ash and aerosols over a large area to reflect much of the solar radiation back to space. If these factors differed from modern values by merely two to three times as much as during the Little Ice Age, the observed difference in ELA between these two ice advance periods could be explained. A large area of ice and snow cover would provide a powerful positive feedback mechanism to increase the extent, severity, and duration of the Great Ice Age. This leaves no role whatsoever for the Milankovitch mechanism, and there is neither need nor evidence for "deep time."

Physical Evidence for a Great Ice Age

No written record of a Great Ice Age has been discovered, though there may be hints of notable climate change compatible with the idea (e.g. Job 38:29–30). Thus, the Great Ice Age is largely inferred from geologic features that appear to be glacial in origin, as first popularized by the famous creationist Louis Agassiz (Imbrie and Imbrie, 1979). The Little Ice Age provides a documented analog that demonstrates the reasonableness of the postdiluvial model for the Great Ice Age (Oard, 1990). The Little Ice Age and modern glaciers have also provided a wealth of data for evaluation of these features, and this will be the topic of Part VIII of this series.

Summary

Paleoclimatology is a complex field with significant limitations resulting from limisted historiography and the vicissitudes of proxy data. One of the applications for paleoclimatology is speculation regarding past continental glaciation. The best model available for evaluating such large-scale glacia-

Variable	Great Ice Age (Inferred)	Little Ice Age (Observed)	Current (Observed)
Land Surface Air Temperature Compared to Today	0 to roughly 12°C * cooler than current	0 to 3°C (0 to 5°F) cooler than current	Based on 1960 to 1990 average
Precipitation	enhanced	near current	
Insolation	reduced	reduced	
Sea Surface Temperature	elevated **	near current	
Volcanisim	significant	occasional	low
Difference in ELA Compared With Today	0 to -1,000 m? (-0 to -3,000 ft.)?	0 to -300 m (0 to -1,000 ft.)	Based on 1960 to 1990 average
Continental Ice Sheets	significant	absent	absent
Ice Caps	significantly enlarged	slightly enlarged	reduced
Outlet Glaciers	advanced	advanced	receding
Mountain Glaciers	significant	advanced	receding

* Many variables affect temperature, including regional and dynamic ones, and this is therefore a rough, or order-of-magnitude, estimate only.

** Elevated temperature would be expected immediately after the Deluge with cooling occurring throughout the ice age.

Table IV. Comparison of degree or extent of important variables between Great Ice Age, Little Ice Age, and present conditions.

tion is the Little Ice Age. As shown in this series:

- The Great Ice Age is not documented historic fact but reasonable inference, one for which there is a wealth of evidence. Thus, nearly all geologists, both creationist and evolutionist, believe that at least one large-scale glaciation occurred in the past.
- The Little Ice Age, being documented historic fact, is the best model available for use in evaluating a Great Ice Age, though it is imperfect, particularly in scale.
- Both energy balance calculations and the Little Ice Age indicate that the Milankovitch mechanism is woefully inadequate to explain continental glaciation.
- Evidence does not support the idea of multiple great ice ages. Observations of modern glacial fluctuations show features traditionally attributed to multiple glaciations (as will be shown in Part VIII of this series).
- Evidence strongly supports a single, relatively recent, postdiluvial Great Ice Age.
- Data from the Little Ice Age indicate that moderately greater cooling and enhanced precipitation could generate an ice age much larger in scale than the Little Ice Age.
- Topography, particularly in Iceland and Greenland, indicates that cooling in the past was several times greater than the drop in temperature observed between the Medieval Warm Period and Little Ice Age in order to lower the ELA enough for glaciation to begin.
- In general, glacier mass balance in the study area appears to respond more to increases in precipitation than reductions in temperature, though both would be needed to generate the Great Ice Age.
- The postdiluvial ice age model provides mechanisms for both lower temperature (greater volcanism than during the Little Ice Age) and greater precipitation (initially warmer sea surface temperatures than during the Little Ice Age). Whereas the traditional, Milankovitch-based models are incapable of explaining continental glaciation, the Great Ice Age is readily explained by the postdiluvial ice age model.

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Glossary

Deluge – a common deluge is intense rainfall (and typically flooding) over a short period of time. When capitalized, it normally refers to what the Hebrew Bible calls the *mabbul*, the unique, global flood of Noah's time.

Diluvial – pertaining to the Deluge.

Equilibrium line altitude (ELA) – the altitude above which more snow accumulates than melts during the year, and below which more ice (or snow) melts than accumulates.

Firn line – the altitude above which precipitation falls as snow and beneath which it falls as rain. It is usually close to the ELA but often differs from it (ELA is based on mass balance).

Mass balance – the balance between the amount of ice that forms and ice that is lost from a glacier in the course of a year. A positive mass balance results in growth of the glacier; a negative mass balance results in retreat.

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Appendix A: Bibliography of Ice Age Research

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Appendix B: Icelandic Paleoflora

Fossil and pollen paleoclimatic evidence in Iceland for at least one period warmer than the Medieval Warm Period is strong. "The global cooling that has occurred on the earth since the Miocene ["oldest" Icelandic fossils] is well documented in the record of fossil floras, owing to the regular spacing apart of plant bearing horizons within the lava pile"(Símonarson, 1980, p. 173). He continues, "Icelandic Tertiary floras older than 8 m.y. are warm-temperate and show close affinity with the recent flora in the Eastern Deciduous forests of North America." "The water temperature (annual mean temperature) in the Tjörnes area during the Lower Pliocene, when the marine *Tapes* and *Mactra* Zones were deposited, was at least 10°C, or about 5°C higher than the present one, as indicated by the presence of *Glycimeris glycimeris* (Linné), *Abra alba* (Wood) and other warmth-loving mollusc species"(Símonario, 1980, p.174). Skammidalur fauna ("Upper Pliocene" molluscs) indicate 2–4°C warmer water temperatures than at present (Símonarson, 1980). "A general cooling throughout the whole period [4,500 years of their tephrochronologically- calibrated, radiocarbon-dated sediment core], is indicated by both the benthic and planktonic foraminifers" (Eiríksson et al., 2000, p. 579). All of these evidences are, of course, referenced to the evolutionist natural history scenario; we generally interpret most of them to be of either diluvial origin or of early postdiluvian age (Klevberg, 2007). If the latter, they would be evidence of a warm climate in early postdiluvian time. More detailed investigation of Icelandic paleoflora and its geologic context is warranted but beyond the scope of this paper.