Biblical Ice Age Chronology

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Despite claims from the culture, the Ice Age challenges secular science. The three mandatory requirements for the development of an ice age are discussed. Noah's Flood sets the conditions for an Ice Age climate with volcanism providing summer cooling on the continents and warm ocean water providing enough evaporation for abundant snowfall. The Ice Age persisted, though waned with time as the forcing mechanisms decreased. A chronology for the Ice Age is estimated by the time it took to cool the warm oceans to their present temperatures. Using the heat balance for the oceans and atmosphere and a 25% decrease in solar radiation, the time to reach glacial maximum in the Northern Hemisphere would have been about 500 years. To catastrophically melt the ice sheets would have taken about 200 years, netting a 700-year Ice Age. Evidence is also presented for only one ice age.

Secular scientists have had difficulty not only explaining one Ice Age, but determining how many during the 2.6 million years of the Pleistocene. For 60 years, they claimed there were about 4 ice ages, based on certain features on the continents. Now they claim about 50 ice ages of various intensities during the Pleistocene (Walker and Lowe, 2007). Ice ages occur in regular succession every 100,000 years for the past one million years and every 40,000 years older than one million years. This number is largely derived from oscillations in the oxygen isotope ratio of foraminifera carbonate skeletons in 57 deep-sea cores, dated and pieced together for 5 Ma (Figure 1). These oscillations just happen to match the eccentricity and tilt cycle of the astronomical or Milankovitch theory of ice ages. Circular reasoning has always been a part of determining the number of Pleistocene ice ages (Oard, 2023).

Requirements for an Ice Age

If we assume uniformitarianism, it is claimed to take 100,000 years, or even 40,000 years, to produce an ice age assuming conditions existed to favor it. The Bible provides an alternative, and the evidence fits with only one Ice Age. But first we need to discuss what conditions are required to produce an ice age (Table 1). Our high latitude winters are already cold enough. Summers need to be so cold that most of the winter snow remains from season to season. This is the first requirement. The second requirement is much more snow. This is a major problem for secular ice age theories. Their models indicate colder winters and summers which would dry the atmosphere. This is one of the most significant reasons why there are over 60 theories on the origin of the Ice Age. A third requirement is that climate change needs to persist for many years for the buildup of ice sheets.

Requirements for an ice age
1) Much colder summers
2) Much more precipitation
3) Climate change must persist for hundreds of years

Table 1. The three main requirements for an ice age.

If cooler summers are a primary requirement for an ice age, we need to ask: how *much* cooler do they need to be? Williams developed a computer model that calculated the energy balance over a snow cover in northeast Canada and estimated the amount of spring and summer cooling that would be needed over northeast Canada for 2.5 cm or more of snow to remain until the fall (Williams, 1979). Even with favorable conditions to keep the snow over the summer, the winter snow still melted back to northeast Canada with summer temperatures 12°C below normal. If these temperatures could occur in a climate oscillation, the air would be able to hold 60% less water vapor, as shown by the dashed lines on Figure 2. But in the northern United States, temperatures would have to cool down over 30°C (Pickard, 1984).

Ice Age Experts Don't Know

These above requirements make it clear that minor cooling will not lead to an ice age. It would take a severe climate change to cause glaciation. Ice Age expert J.K. Charlesworth, who in his two-volume book, expressed the problem as follows: "Pleistocene phenomena have produced an absolute riot of theories ranging from the remotely possible to the mutually contradictory and the palpably inadequate" (Charlesworth, 1957, p. 1,532). This included the astronomical theory. That was back in 1957, but the years have not been kind to researchers.

The 18–25 August 1997 *U.S. News and World Report* dedicated the entire issue to the top 18 mysteries of science. One of those was, "What causes ice ages" (Watson, 1997, p. 58–59)? Daniel Pendick wrote in 1996: "If they hadn't actually happened, the ice ages would sound like science fiction" (Pendick, 1996, p. 22). In 2001, David Alt, retired professor of geology at the University of Montana, exclaimed: "Although theories abound, no one really knows what causes ice ages" (Alt, 2002, p. 180). A 2008 issue of *Nature* conceded: "Perhaps the longest-standing puzzle in the Earth sciences is what caused the Northern Hemisphere ice sheets to come and go" (Raymo and Huybers, 2008, p. 284). Explaining one ice age is difficult; explaining many of them has generated a Gordian knot for secular earth science. Does the Bible offer a better explanation?

The Biblical Ice Age

Since Ice Age features, such as hummocky ground moraine, lateral and end moraines (Figure 3), scratched bedrock, erratic boulders, etc. are found on the surface above Flood deposits in many areas, it is logical to deduce the Ice Age occurred after the Flood. This presents the distinct possibility that Noah's Flood provided the unique climate for a subsequent Ice Age.

The Flood was a gigantic volcanic event that likely also involved multiple small and some large meteorite (or comet) impacts. The Chicxulub impact is an example of a large meteorite impact. These events would blast particles and aerosols, on the order of a micron in diameter, high into the stratosphere. The larger particles would have settled out in a matter of weeks to months, but the aerosols, mainly sulfuric acid (H_2SO_4) droplets about 1 micron in diameter, would float in the stratosphere for anywhere from 1 to about 10 years, depending on their initial height. So, after the Flood, there would have been a shroud of ash and aerosols in the atmosphere. Since we know that large volcanic eruptions cause global cooling, the particles and aerosols left in the atmosphere would cause a quick cooling over continental areas and jump start the Ice Age. The Ice Age would begin immediately after the Flood in favorable areas, far from onshore flow of warm air. Central Canada and possibly the north-central United States would be favorable areas. Copious Ice Age volcanism would replace the particles that fell to the earth and would have continued the cooling for hundreds of years. The cooling would affect only summer temperatures, since there are several processes in place to warm the winters.

The sea surface temperatures in the post-Flood oceans would be much warmer at mid and high latitudes than today resulting in a much higher evaporation. Several factors would warm the oceans during Noah’s Flood: the fountains from the great deep, volcanism, and impacts. Dynamic currents would have mixed the ocean so that it was warm from pole to pole and top to bottom. The warmer the ocean, the greater the evaporation. For example, if all other conditions remained the same, there would be *seven* times as much evaporation at a sea surface temperature of 30°C than at a sea surface temperature of 0°C! The abundant mid and high latitude moisture would be picked up by storms causing heavy accumulation on the adjacent continents.

The strong summer cooling and heavy precipitation would persist for many years, fulfilling the third and last requirement for an ice age. But Ice Age volcanism would wane with time and the oceans would eventually cool, mostly from evaporation. As the ocean cools, the amount of available moisture decreased until glacial maximum was reached. From this it is possible to estimate the length of the Ice Age by how fast these “forcing mechanisms” would change using heat-balance equations for the ocean. And since the heat balance of the oceans affects the atmosphere, the heat balance of the latter must also be estimated. I will first consider the time it takes to reach glacial maximum, then the time it would take to melt the ice sheets.

Timing of Glacial Maximum Different for Different Ice Sheets

Each ice sheet has its own unique climate and environment. So, each ice sheet and mountain ice cap reached glacial maximum at different times. Some even continued to grow after glacial maximum, such as the Greenland, Antarctic, and Barents Sea Ice sheets. The Cordilleran, Laurentide, and Scandinavian Ice sheets, since they are all mostly in the middle latitudes, likely began melting at similar times.

The Barents Sea Ice Sheet probably started to melt soon after glacial maximum because it likely was not very thick and mostly formed over the shallow high latitude Barents Sea. The Greenland and Antarctic Ice Sheets are in the high latitudes and by glacial maximum the surface would have been at generally high altitude. The altitude would have caused them to continue to grow for a while after glacial maximum. Oceanic evaporation at glacial maximum would still have been greater than it is today.

The Southern Hemisphere would have generally acted independently of the Northern Hemisphere. There is very little exchange of heat and moisture in the atmosphere and heat in the oceans across the equator. The much larger Southern Ocean would have retained heat longer than the Northern Hemisphere. This, coupled with Antarctica’s location near the South Pole, kept it from reaching glacial maximum until well after Northern Hemisphere reached glacial maximum. Even if volcanism waned before the Antarctic glacial maximum, which it likely did, the snow and ice would have continued to build up because of the huge amount of moisture available from oceanic evaporation.

The main variable determining the time for Ice Age maximum is how fast the warm oceans cooled, waning volcanism would be secondary. I will assume that the ocean temperature cooled from 30°C to a threshold temperature of 10°C for the ice sheets in the middle latitude to reach glacial maximum. After that, net melting begins.

The Heat Balance of the Ocean

Unfortunately, climate simulations are not sophisticated enough at present to account for the unique and dynamic conditions following the Flood. So, the only way to estimate the ocean cooling rate in even a rough way is to use the energy or heat balance for the ocean with time. This is an equation that adds up all the heating and cooling terms, which results in a change in temperature of the ocean with time. It is like turning on both the air conditioner and the heater at the same time in a room. The change in temperature with time in the room will depend upon which is stronger: the heater or the air conditioner. In the Ice Age climate, the ocean cooling terms, or the “air conditioner,” are the most powerful. It overwhelms the warmth from the heating term, resulting in the ocean cooling with time. The energy balance can be represented by the following equation (Budyko, 1978):

$$F_R - F_E - F_C = -Q/T \qquad (1)$$

where F_R is the average balance at the surface between incoming solar radiation and outgoing infrared radiation; F_E is the evaporation from the ocean; F_C is the conductive (contact) cooling of the oceans due to cooler air over warm water; and Q is the change in heat content of the oceans in time T. The minus signs signify *losses* of heat, i.e. the ocean is *losing* heat. Radiation is warming the ocean and evaporation and conduction are cooling the ocean. Geothermal heat, F_g, from the ocean bottom is very low and can be ignored. These variables are averaged for the whole time for the whole ocean to reach glacial maximum. Figure 4 shows this heat balance.

Estimating time, T, in Equation 1

Solving equation 1 for T (i.e. figuring out how long until glacial maximum) is difficult in the unique post-Flood Ice Age climate. I had to include the heat balance of the atmosphere. Some variables are the same for the ocean and atmospheric heat balance equations, such as the heat transfer from the ocean by conduction and evaporation, but with different signs. I eliminated these from the heat balance equation for the atmosphere to simplify equation 1. Since the cooling of the ocean occurs in the surface layer, I divided up the ocean into areas of estimated net cooling and heating. The net cooling in the Northern Hemisphere was not symmetrical with latitude; it was especially strong off the east coasts of continents and in the Arctic Ocean. So, I simplified by assuming that the area of oceanic cooling occurred north of 40°N latitude. The oceanic cooling in the Southern Hemisphere was symmetrical with latitude, and so I assumed that net cooling occurred south of 60°S. Thus, equation 1 simplifies to:

$$T = -Q(-F_{RE} + F_A + F_O) \quad (2)$$

where F_{RE} is the average radiative heat balance at the top of the atmosphere, which includes solar radiation entering, solar radiation reflected back to space, and the loss from infrared radiation (Peixoto and Oort, 1992, p. 94). F_A and F_O are the higher latitude heat transport by the atmosphere and oceans, respectively. These values were estimated for 10° latitude bands north of 40°N and south of 60°S.

Since there is no way to estimate the variables accurately, I used maximum and minimum possible values for each variable, since the purpose was to only find a *rough estimate* of glacial maximum (Oard, 1987; 1990). Such unlikely ranges also enabled me to smooth over any errors in estimating the values of the variables. Then I chose a 'best estimate', based on a 25% decrease in solar radiation due to volcanism for the entire time it took to reach glacial maximum.

To determine 'Q' in equation 2, we need estimates of the average ocean temperatures immediately after the Flood and at glacial maximum. I assumed the average oceanic temperature immediately after the Flood was a warm 30°C, and dropped to 10°C at glacial maximum, 6°C warmer than the average today. This represents an oceanic cooling of 20°C, which corresponds to a heat loss, Q, of 1.3×10^{26} kJ (3.0×10^{25} cal) for the oceans in time T. So, with estimates of the variables in equation 2 and an estimate of heat loss from the temperature change, I solved for T. The results are presented in table 2. The best estimate was roughly 500 years, corresponding to a 25% average decrease in solar radiation from volcanic ash and aerosols and the best estimates for oceanic and atmospheric heat transport from low to high latitudes. This indicates that, given the right conditions, an Ice Age can develop much quicker than in 40,000 or 100,000 years. Figure 5 shows a graph of the ocean cooling with time in the post-Flood Ice Age.

various low- to high-latitude ocean and atmospheric heat transport scenarios	various volcanic dust and aerosol loading scenarios			
	–10%	**–25%**	**–50%**	**–75%**
$F_A + F_O$ = zero	297 years	256 years	207 years	174 years
$F_A + F_O$ (best estimate)	746 years	492 years	370 years	278 years
$F_A + F_O$ at 40°N & 60°S	1,765 years	909 years	492 years	341years

Table 2. Values of the time, T, to reach glacial maximum for various volcanic dust and aerosol loading scenarios and various low- to high-latitude ocean and atmospheric heat transport scenarios.

How Thick Were the Ice Sheets?

Before we can estimate the total time for the Ice Age, we need to estimate the time it would take to melt the ice sheets. But first, we need to estimate the average thicknesses of the ice sheets at glacial maximum. The average thickness depended upon many variables, but there were two main moisture sources: (1) the amount of evaporation from mid and high latitude oceans, proportional to F_E, and (2) the transport of moisture from low latitudes to higher latitudes, which is part of the heat transport in the form of latent heat in the term F_A. Since the Northern and Southern Hemispheres have different land/ocean configurations, F_E and F_A will be significantly different. A larger ocean in the Southern Hemisphere will provide more moisture for the ice to build up in that hemisphere, which accounts for why the Antarctic Ice Sheet is so thick and why glacial maximum would be later than 500 years. So, I estimated each hemisphere separately.

Again, I used maximum and minimum estimates for the variables (Oard, 1990). The best average estimate for the Northern Hemisphere is 670 m (Table 3). However, two-thirds of the precipitation that falls on non-glaciated land is either evaporated or transpired through the leaves of the plants and trees (Anderson, 1995). Still, there would have been some summer runoff from the ice sheets. I previously assumed that these two processes cancelled each other out as far as determining the ice depth (Oard, 1990). However, that estimate needs revision because re-evaporated water from non-glaciated lands and transpiration would have been much more than the water lost from runoff. So, 670 m would be a minimum, which is close to the best estimate from my 1990 monograph of around 700 m, which compares to the secular estimate for the melted ice sheets of 1,700 m (Flint, 1971, p. 84). So, the mid latitude Northern Hemisphere post-Flood ice sheets were about 40% the size of those postulated by uniformitarian scientists. And because of differences in the progression of the Ice Age, the relative thickness of the ice may have been different to what uniformitarian scientists expect. For instance, the greatest ice sheet thicknesses would have been close to the warm oceans and the major storm tracks rather than towards the center.

Land/water precipitation ratio	**Maximum**	**Best estimate**	Minimum
N.H. precip. even	790	670	560
S.H. precip. even	1,100	960	760
S.H. precip. twice	1,750	1,520	1,210
S.H. precip. thrice	2,040	1,780	1,410

Table 3. Estimated ice depths in the Northern Hemisphere (N.H.) with an even precipitation distribution over land and the ocean for 500 years. For the Southern Hemisphere (S.H.), an even, twice, and thrice distribution of precipitation between the land and ocean was calculated for 500 years. No range is given for precipitation distribution in the Northern Hemisphere while three ranges are given for the Southern Hemisphere. The maximum and minimum values are based on the amount of estimated Ice Age poleward heat transport by the oceans and atmosphere.

The ice depth on Antarctica is more complicated. The storm track would have been close to the Antarctic coast at the beginning, slowly moving northward with time, with most of the precipitation falling on the colder side of the storm. Therefore, significantly more precipitation likely fell on the land than the oceans. I therefore assumed that a minimum ice depth would occur if precipitation was even for land and ocean with a maximum ice depth at three times the precipitation over land than water. The best estimate seemed to be in the middle at twice the amount of precipitation over land as water. Thus, the best estimate is about 1,520 m for 500 years. It can easily be more than this since the range of estimates is 760–2,040 m.

However, the Ice Age in Antarctica did not reach a maximum at 500 years, as discussed above. Antarctica continued to grow, probably for another 500 years. But since the southern oceans had cooled from 30°C to probably around 15–20°C, the amount of moisture available for the second 500-year period would be less than the first period. Assuming the best estimate, only 380 m of ice is needed to be added to reach the current average depth on Antarctica of 1,900 m (Huybrechts et al., 2000). The ice sheet likely reached steady state after 1,000 years, but with some thinning close to the coast and a retreat of the ice sheet from the edge of the continental shelf to generally near the coast.

The average accumulation of ice in the post-Flood rapid Ice Age for 500 years is 1.4 m/yr in the Northern Hemisphere and 2.5 m/yr on Antarctica. These amounts likely varied considerably through the 500-year period on Greenland and Antarctica (Oard, 2021). Little or no accumulation would occur early in the Ice Age on the lowlands of Greenland because of the surrounding warm ocean water. Then the ice accumulation rate likely was much more than 1.4 m/yr at the beginning of ice buildup and then slowed further until glacial maximum was reached. The ice accumulation rate on Antarctica likely was much higher than 3.0 m/yr early in the Ice Age, probably around 10 m/yr or more, then slowing considerably at the end of 500 years.

Catastrophic Melting

The Ice Age climate was very dynamic. The Ice Age began with mild winters and cool summers with little seasonal contrast. Much heavier precipitation than today fell globally. Everything changed after glacial maximum. Summers warmed to melt the ice sheets, but winters became much colder with little precipitation. Figure 6 shows the postulated maximum and minimum temperature change for the mid and high latitude continents of the Northern Hemisphere from the beginning of the Ice Age through glacial maximum, deglaciation, the post-Ice Age warm up, and today. Figure 7 shows the corresponding postulated available moisture.

In calculating the melting time, I used the most scientific method available, and that is the energy balance equation over a snow or ice cover. The details of the calculation are elsewhere (Oard, 1990). Melting especially depends upon solar radiation absorbed, which amounts to 60% or more of the melting. Several processes would aid the absorption of solar radiation during deglaciation, including a drier atmosphere with fewer clouds. Generally, when the surface layer melts, some of the water percolates down into the ice and refreezes. Some of the water falls through crevasses or moulins to either the interior or base of the ice, where it can flow like a river. Meltwater can even flow on the surface and/or form lakes. The albedo (reflectivity) of the snow or ice surface is especially important for the rate of melting. When the ice sheets begin to melt, the albedo changes to much lower values and reinforces ice sheet melt.

I estimated a melt rate of about 10 m/yr at the periphery of the ice sheets. The periphery would be a strip of ice about 700 km wide at the edge of the ice sheets. This melt rate is very close to that in the ablation zone of Norwegian glaciers today (Cuffy and Patterson, 2010, p. 109). At 10 m/yr, the periphery would melt in about 70 years, if the ice depth averaged 700 m. However, the interior of the ice sheets in Canada, Scandinavia, and northwest Russia would melt more slowly because of cooler temperatures, less sunshine, and less loess blown onto the ice to reduce the albedo. So, melting the interior ice would take longer than the periphery, at the most about 200 years. Thus, the total time for the Ice Age is only 700 years. I should emphasize that this is a *rough estimate* of the timespan.

These melt rates are much faster than uniformitarian estimates. And interestingly, very few attempts have been made to calculate the melt rate of ice sheets using an energy balance equation in their models. I did find one report by climate simulation researchers Manabe and Broccoli, who once had a subroutine, probably using an energy balance equation like the one used here, that calculated the melting of the southern boundary of the Laurentide Ice Sheet. The subroutine gave a melt rate of 3.5 m/yr (Manabe and Broccoli, 1985). They were shocked by this result: “An extremely rapid depletion of ice occurs in a relatively narrow belt along the southern margin of both ice sheets” (Manabe and Broccoli, 1985, p. 2,180). Birchfield commented on this at a conference: “A new mass budget calculation for the Laurentide ice sheet by Manabe, produced very large melt rates, implying a long-term, ice-sheet retreat, far in excess of that observed” (Birchfield, 1084, p. 857).

They could not have observed glacial melt; “observed” in the above quote means “inferred according to the geological time scale with its extremely slow processes.” It is presumed that deglaciation takes 10,000 years (Broecker and van Donk, 1970). This is a case where an interpretation becomes an “observation”—a not uncommon occurrence within uniformitarian earth science.

Of course, at a high melt rate of 3.5 m/yr, the ice sheet would *never* become established in the first place. But this high rate (for uniformitarians) is still far less than my calculations of 10 m/yr. However, Manabe and Broccoli began with much thicker ice sheets and an unrealistically high constant albedo of 0.7 for the melt season. Contrast this with an ice sheet about 40% as thick, resulting in a warmer atmosphere. Add an albedo more like 0.3 during melting and more dust on the periphery of the ice sheets, and the melt rate would be close to what I calculated. Moreover, dust would tend to concentrate at and near the surface during each melt season and increase with time (Krinner et al., 2006), causing the albedo to decrease every year.

In a second paper, Rind et al. testing the Milankovitch theory of the ice ages discovered when using the GISS (Godard Institute for Space Studies) general circulation climate model, that first the Milankovitch mechanism fails to produce an ice age (Rind et al., 1989). Second, they then assisted their model by taking advantage of the higher albedo of snow and ice by placing 10 m of ice everywhere ice sheets existed at the last glacial maximum. The snow and ice melted in 5 years! That demonstrated the power of the melting mechanism—to the point that an ice sheet could not get started even under favourable (uniformitarian) conditions.

Only One Ice Age

There are many evidences that there was only once Ice Age, overlooked by secular scientists. I will mention only one, the rest are developed elsewhere (Oard, 1990, 2023). Yedomas are a special type of permafrost feature that contain much organic matter (about 2% carbon by mass), and they are 50–80% ice by volume (Straus et al., 2017).

Practically all organic matter in yedomas come from plants, much of it being grass and sedges (Schirrmeister et al., 2011). This supports Guthrie's contention that the non-glaciated lowlands of Siberia, Alaska, and the Yukon Territory were part of the North-Hemisphere-wide "mammoth steppe." (Guthrie, 1990). Even more interesting is that the yedomas occur only with 'last' ice age:

> "Yedoma deposits started accumulating during the last ice age. No older Yedoma deposits older than the last interglacial (MIS-5e; 130–115 thousand yrs BP) are described so far (Schirrmeister et al., 2013)" (Straus et al., 2017, p. 78).

According to the astronomical theory of ice ages, the next ice age is due soon, after the present Holocene interglacial ends. The present yedomas have not melted away, and if the next ice age occurs, a second yedoma system would be superimposed on what we observe now. However, the lack of yedomas from the 49 or so previous ice ages is strong evidence that there was only one ice age.

Concluding Remarks

Solving the mystery of the Ice Age is an example of how we can use the biblical worldview, with almost the same data, and arrive at totally different conclusions from secular scientists. Observations, known scientific law, and history as recorded in Scripture open the door to a greater understanding of our world. In the case of the Ice Age, basic meteorology was useful in determining how the Ice Age developed, that it was rapid, and there was only one. We can go through the same procedure when it comes to other challenges to biblical history.

Figures captions

Figure 1. Reconstruction of the past 5 million years of climate history, based on the oxygen isotope ratio of benthic foraminifera, which serves as a proxy for ice volume (Robert A Rohde, Wikipedia commons CC-BY-SA-3.0). Taken by combining 57 deep sea cores that must be 'accurately dated'. The low point of each cycle represents an ice age. The 100 kyr Milankovitch eccentricity cycle dominates for the first million years and the 41 kyr tilt cycle before 1 Ma.

Figure 2. Graph of water vapor capacity at saturation (100% relative humidity) versus temperature. Note the 60% drop in capacity as temperature cools from 10°C to -2°C.

Figure 3. The horseshoe shaped end and lateral moraines around Wallowa Lake in the Northeast Wallowa Mountains, northeast Oregon, USA.

Figure 4. The oceanic heat balance showing surface cooling terms F_E and F_C and the heating term F_R with the change in the total heat, Q, in time, T (modified by Melanie Richard). Geothermal heat, F_g is small.

Figure 5. Graph of average ocean temperature following the Genesis Flood. The ocean cools below the average ocean temperature today of 4°C (38°F) at about 600 years after the Flood (drawn by Melanie Richard)

Figure 6. The postulated average winter, summer, and annual temperature with time for the Northern Hemisphere mid- and high-latitude continents from the end of the Flood through the Ice Age to today (drawn by Melanie Richard).

Figure 7. The postulated annual mid- and high-latitude Northern Hemisphere precipitation with time from the end of the Flood through the Ice Age to today (drawn by Melanie Richard).

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