A RAPID POST-FLOOD ICE AGE

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Received 22 January 1979

A mechanism for a post-flood rapid ice age of about 500 years is presented. It depends upon cooling over mid and high latitude continents caused by volcanic dust trapped in the atmosphere and by a widespread snow and ice cover. These strong cooling effects are balanced by a strong warming mechanism over mid and high latitude oceans. It also depends upon extra moisture provided by strong evaporation from a universally warm ocean. The resulting accumulation of ice at maximum glaciation is approximately 30% of that postulated by uniformitarian scientists. The present distribution of ice on Greenland and Antarctica is shown to be quite possible from a rapid ice age and the present climate in the time frame allowed by the Bible. As soon as the warm ocean cooled to near its present average, the present climate would begin to set in causing fairly rapid melting of all the Northern Hemispheric ice sheets except Greenland.

The so-called ice age has always been a problem for Creationists. Some Creationists have postulated that the ice age was contemporaneous with the Flood[1], but most feel it followed the Flood[2]. Some Creationists do not believe there was an ice age[3,4]. Burdick gives one reason for this concern over the ice age: "Some Creationists have doubted whether there ever was a glacial age, since they find it hard to see how it could fit in with an Earth as young as Scripture would indicate."[5] Although much has been done, much more needs to be done on the geological and atmospheric ramifications of a universal Flood in order to include an ice age in a Flood model.

Some uniformitarian scientists feel that an ice age makes a global Flood impossible: "The catastrophist idea of the Noachian debacle was finally laid to rest when Louis Agassiz showed that his glacial theory could explain erratics, striations, till, fluvioglacial features, and so on. Old ideas die hard, however, and catastrophist absurdities still appear in the literature of the early 1900's (as they do even today)."[6] However the exact details of the ice age as well as its causes have not been worked out. New scientific information indicates that different interpretations of supposed glacial features is possible: "A good deal of uncertainty, however, prevails with respect to many so-called tillites. Difficulty arises because mechanisms other than glacial ice produce massive, more or less structureless deposits with an overwhelming clay matrix that contains a scattering of embedded phenoclasts."[7] In view of Creationist uncertainty of how the ice age relates to the Flood, and considering the dogmatism shown in the face of unknown causes and uncertain interpretation of the data by some scientists who do not appreciate the historical accuracy of Scripture, it is important to formulate a Creationist model of the ice age.

Without defending the evidence for an ice age, the author proposes a mechanism for generating a rapid ice age on a time scale of several hundred years following the Genesis Flood. The author favors the Flood model of Whitcomb and Morris in *the Genesis Flood* because it makes the most sense Scripturally and scientifically. I will not dwell on many aspects of their Flood model, the details of which can be found in *The Genesis Flood*[2] or in many other books and articles. Throughout this paper the term "post-Flood", for instance in post-Flood climate and post-Flood ice age, will be used to refer to the events within several hundred years following the Flood.

II. Requirements For A Rapid Ice Age

It is claimed that cool wet summers are needed for an ice age.[8] However, it would take thousands of years, and the summers would have to be quite cool to build deep continental ice sheets in the present climate. Besides cool wet summers, wet but not necessarily cold winters are important to the build up of ice sheets.[9] This is especially true for a rapid ice age. In other words, a cooling mechanism, especially for the summer, and an abundant source of moisture, not currently provided by the present climate, are required. The author feels both are supplied in the aftermath of the Genesis Flood by strong post-Flood cooling over mid and high latitude continents and an abundant source of moisture from a universally warm ocean. Post-Flood cooling mechanisms have been discussed many times before by Creationists. Only one of these will be discussed in this paper, as well as one I have not found in Creationist literature. I will also discuss at length a strong mid and high latitude warming mechanism, which has not been considered by Creationists, as far as this author knows. A link between the ice age and warm polar oceans has only been hinted at by Clark[10] and by Whitcomb and Morris[11], but no details have been given.

III. Cooling Mechanisms

Whitcomb and Morris list several cooling mechanisms that would operate after the flood. These are: 1) the removal of the thermal vapor blanket during the flood, 2) the probable dense accumulation of volcanic dust particles in the atmosphere, 3) the newly uplifted mountains, and 4) the essentially barren topography of the denuded lands.[12] Besides these, one other cooling mechanism would be significant: greater reflection of solar radiation back to space and insulation from the warm ground due to a snow cover. There is no doubt that the removal of a pre-flood vapor canopy and the post-flood higher terrain would cause significant cooling from a pre-flood world over mid and high latitude continents. These factors have already been accounted for in the present climate, which is unable to support continental ice sheets, except of course for Greenland and Antarctica. Barren topography however can be heated better by the sun

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than vegetation-covered land, as well as cooled better by terrestrial radiation. This effect would probably be slight in the post-flood climate on a worldwide scale, but might be significant for different continental latitude belts, causing a cooling effect at high latitude and a warming effect at low latitude.

A. Volcanic Dust

There may be some doubt as to the effect of volcanic dust. However, recent scientific information has shown that volcanic dust in the stratosphere is a significant cooling mechanism. This effect has been adequately discussed by Clark[13] and Coffin.[14] Some recent articles document the cooling effect of stratospheric volcanic dust.[15,16,17,18] It is no wonder that Steven Schneider, a researcher in climate change, could say at the 1978 Annual Meeting of the AAAS: "The effects of various types of dust and aerosols (cooling versus warming) are still in heavy debate, *but at least volcanic dust is known to cool* (italics mine)."[19] The greatest response to this cooling effect would be over continents since volcanic dust decreases the solar radiation reaching the surface, while over the oceans the effect would be small, since the oceanic air doesn't depend as much upon radiation to heat or cool it.

During the flood it is believed that a great amount of volcanic activity occurred from the eruption of all the fountains of the great deep.[20,21] As a result a large cloud of volcanic dust would be left over in the atmosphere at the end of the Flood. The geological record indicates much volcanic activity during geological time, which would be compressed into a one-year flood and a period of especially strong post-flood volcanism in the flood model.[22,23] Researchers in climate change do not feel the volcanic activity is significant enough to cause major glaciation because of the long periods of time they allow for the geological record. However they do recognize that an increase in volcanic activity over that of the present would cause continental glaciation: " . . . volcanic explosions would need to be an order of magnitude more numerous than during the past 160 years to result in continental glaciation equivalent to the Wisconsin glacial episode."[24] The cooling effect of volcanic dust deposited into the atmosphere during the Flood would last 2 years in the tropics, but 12 or more years in the higher latitudes, especially contributing to cooler summers.[25] With the addition of more volcanic dust into the atmosphere from strong post-flood volcanism[22,23], the resultant cooling effect would last much longer. Because of the short residence time of volcanic dust, the tropics would be affected least and would probably settle down to nearly the present climate in only a relatively short time after the flood. However the higher latitude continents would be dramatically affected by flood and post-flood volcanism for perhaps a few hundred years.

B. A Snow Cover

Another cooling mechanism that would be operating on the earth soon after the flood is a widespread snow cover. The initial cooling below the freezing point over mid and high latitude continents needed for snow accumulation would be provided by the cooling mechanisms already mentioned. Cooling of these areas would begin as soon as the land emerged from the flood waters. In the present climate it takes only a few weeks in early autumn for the interior of Canada and Siberia to fall below the freezing point from the warmth of summer. Since volcanic dust would be an additional strong cooling factor in the post-flood climate, one would expect that freezing temperatures for these areas would be reached soon upon exposure from the flood waters, possibly even if it were summer. Since wind speed is proportional to horizontal temperature changes, the wind would pick up and become strong at the end of the flood as more and more land became exposed and as it cooled. (This is probably the reason wind is mentioned in Genesis 8:1 as the water receeded.)

The moisture for snow would be provided by the abundant evaporation from warm polar oceans, which would be strongest near the coldest continents.[26,27] This moisture source for snow will be discussed further in Section VI. Residual atmospheric moisture from the Flood and evaporation of wet ground would also be secondary moisture sources immediately after the flood. A snow cover would be established over high latitude continents and appropriate areas of mid latitudes soon after the flood. Once a snow cover is established a positive feedback cooling mechanism would be set up.[28,29] A positive feedback mechanism acts to amplify the value or anomaly of the interacting element (snow cover in this case), while a negative feedback mechanism dampens it.[30] The positive feedback cooling of a snow cover is caused by the increased albedo (reflectivity of solar radiation) of the snow surface, which is about 85% for freshly fallen snow. This compares to the present average albedo for the earth of 35 to 37%.[31] Hence most of the solar radiation falling on the snow surface would be reflected back to space, and therefore would not be available to heat the air. Furthermore, snow is a good insulator and will insulate the air from the warmer ground. The effect of a snow cover is dramatized by the following hypothetical example: "Thus, if snow and ice covered the whole surface of the Earth even for a short time, its mean temperature (equal now to 15 degrees C) would be reduced by approximately 100 degrees C. This estimate shows what an enormous effect snow cover can exert on the thermal regime."[32] Once a snow cover is established over appropriate areas of mid and high latitude continents soon after the flood, the air would be further chilled, more so than if the snow cover were not there.

IV. A Warming Mechanism

The cooling mechanisms in Section III are fairly strong and the temperature would be extremely cold during winter over the higher latitude continents soon after the Flood, if it were not for a strong warming mechanism over the oceans. This mechanism exists today, but is not as strong as it would be in the post-flood climate. Immediately following the Flood, the water of the oceans would be uniformly warm from pole to pole and from top to bottom. There are two reasons for this. First, a pre-flood water vapor canopy would not only cause a uniformly warm climate,[33] but also a fairly warm ocean. Geology attests to a uniformly warm climate for most of geological time, the cause of which is unknown. The evidence of this is found in the fossil record, which corresponds to the pre-flood world. Second, according to the flood model of Whitcomb and Morris, much of the water of the present oceans came from deep within the earth during the Flood: "Presumably great portions of the waters were entrapped below the crust . . ."[34] This water from the "deep" would necessarily be quite warm, probably some of it hot, depending upon the depth of origin. It would be a large amount of water because the flood waters rose above the pre-flood mountains, and the water from the deep is by far the primary source for the flood (the collapse of the vapor canopy adding only a comparatively small amount[35,36]). From the chaos of a global flood, this warm water from the "deep" would be well mixed with any cold water that might have existed in the pre-flood ocean. Following the flood, the warm ocean, including the Arctic Ocean, would give off much heat to the air at mid and high latitudes, exerting a profound influence on the climate.

The heat would be released into the air from the warm oceans by two processes: 1) conduction due to cooler air in contact with warm water, and 2) latent heat of condensation, which is proportional to the evaporation from the ocean. These two processes are expressed by the following equations for the energy flux from the ocean surface:[37]

$$\mathrm{E} = \varrho\, \mathrm{C}_E (\mathrm{Q}_S - Q_{10})\, \mathrm{U}_{10} \qquad (1)$$

$$\mathrm{S} = \varrho\, \mathrm{C}_H \mathrm{C}_P (\mathrm{T}_S - \mathrm{T}_{12})\, \mathrm{U}_{10} \qquad (2)$$

Where E and S are the averages of the exchange between the air and the ocean for water vapor and sensible heat (feelable heat), ϱ is the air density, C_E and C_H are the empirically derived exchange coefficients for water vapor and sensible heat, U_{10} is the average wind speed at 10 meters above the ocean (ship anemometer level), Q_S and Q_{10} are averages of the mixing ratios for air in contact with salt water and at 10 meters, and T_S and T_{10} are average temperatures of the sea surface and the air at 10 meters. In terms of heat, E represents about 590 cal of heat added to the air from the ocean for every gram of water evaporated.[38] The mixing ratio is the actual amount of water vapor present in the air per unit mass, usually expressed in grams of water vapor per kilogram of dry air. Q_S is the saturation mixing ratio for the sea-surface temperature and is proportional to temperature at a constant pressure. Equations (1) and (2) show that the amount of heat added to the air from the ocean is proportional to the wind speed, the air-sea surface temperature difference, and the air-sea surface mixing ratio difference. E and S will be especially strong in regions where cold dry continental air blows strongly over warm ocean water.

A relationship not directly indicated in equation (1), but nevertheless contained in it is that E is proportional to the sea-surface temperature. The higher the sea-surface temperature the higher the evaporation and heating of the air. For example, an air-sea temperature difference of 10 degrees C, when the sea-surface temperature is 24 degrees C, gives a mixing ratio difference ($Q_S - Q_{10}$) of 9 gms/kg. But if the sea-surface temperature is 0 degrees C, the mixing ratio difference is only 2.1 gms/kg. Therefore evaporation with a sea-surface temperature of 24 degrees C is more than 4 times as strong as when it is 0 degrees C for the same air-sea temperature difference.

To estimate the heat liberated by the post-flood warm oceans and the strength of the warming mechanism, two assumptions will be made, which are necessarily speculative due to the nature of the problem. However, I feel the assumptions here and in other sections ot this paper are reasonable within a Creationist framework. First, an estimate for the average temperature of the ocean following the flood is needed. Second, an approximation for the ocean surface area responsible for a net heat loss from the ocean is required. I will assume a pleasantly warm average ocean temperature immediately following the flood of 24 degrees C. The average temperature of the oceans today is 4 degrees C. This is a reduction of 20 degrees C. The volume of the ocean is estimated[39] to be 1.4 billion Km^3. Since the density of sea water is close to 1 $\mathrm{gm/cm}^3$, an average cooling of 20 degrees C would release a total of 2.8×10^{28} cal of heat to the atmosphere.

The ocean surface at mid and high latitudes would be responsible for the net heat loss of the whole ocean. This is because the heat lost from the low latitude ocean due to the processes represented by equations (1) and (2) is more than balanced by the radiative heat gain. With cold mid and high latitude continents and adjacent warm oceans, E and S would be quite high, much higher than presently. This heat loss will only be partially balanced by the radiative heat gain and other processes (see equation (3) and the calculations that follow) resulting in a net cooling of the oceans. As a rough estimate for the area of net oceanic cooling, I will assume the boundary between cooling and no cooling to be 35 degrees north and 55 degrees south (the boundary is farther south in the Southern Hemisphere because the continental cold air source is at the pole and much smaller than in the Northern Hemisphere). Therefore the mid and high latitude ocean surface responsible for the net cooling of the oceans for both hemispheres[40] is $85.56 \times 10^6 \mathrm{Km}^2$. Dividing the total cooling by the total area, the heat liberated to the atmosphere from a unit area of ocean surface is $3.3 \times 10^4 \mathrm{Kcal/cm}^2$.

The significance of this much heat can be appreciated by comparing it to the yearly average radiative heat gain in the tropics (30 degrees north to 30 degrees south), which not only warms the tropical atmosphere, but also adds heat to the higher latitudes by various transport processes. The tropical average is 108 $\mathrm{Kcal/cm^2\text{-}yr}$.[41] The heat gain of the post-flood higher latitude oceanic air is 300 times this value, and therefore is a large quantity of heat.

A good estimate for the heating rate of the post-flood mid and high latitude oceanic atmosphere from the warm oceans is 108 $\mathrm{Kcal/cm^2\text{-}yr}$. This heating rate would not result in tropical air temperatures over higher latitude oceans because much of this heat would be mixed with the cold continental air, resulting in more mild temperatures for both land and ocean. At this heating rate, the ocean would cool to its present average in 300 years. This will also be the time for a rapid ice age to reach maximum glaciation.

V. The Post-Flood Climate

Several unique features of the post-flood climate as they relate to a rapid ice age will be explored, as far as possible, in this section. The horizontal change in temperature between warm oceanic air and cold continental air would be the strongest near the coast, the isotherms generally lying parallel to the shoreline (see figures 3 and 4). In meteorology, this is a zone for storm development. By the thermal wind equation[42], the horizontal temperature change causes an increase in wind speed with height, increasing until a level of no change is encountered. This wind aloft would generally blow parallel to the vertically averaged isotherms, the coldest air being on the left in the Northern Hemisphere, and vice versa in the Southern Hemisphere. The wind aloft acts as a guide to storms, and in the post-flood climate will cause the storm tracks to follow the east coasts of continents in the Northern Hemisphere and the coastline of Antarctica in the Southern Hemisphere. For example, the average wind aloft over the East Coast of North America would generally be from the southwest. Storms would likely develop in the Gulf of Mexico or in the Atlantic Ocean off the southeast coast and move northeastward along the shoreline. This storm track is represented in Figure 3 by the solid arrows. Postulated minor storm tracks are indicated by dash arrows.

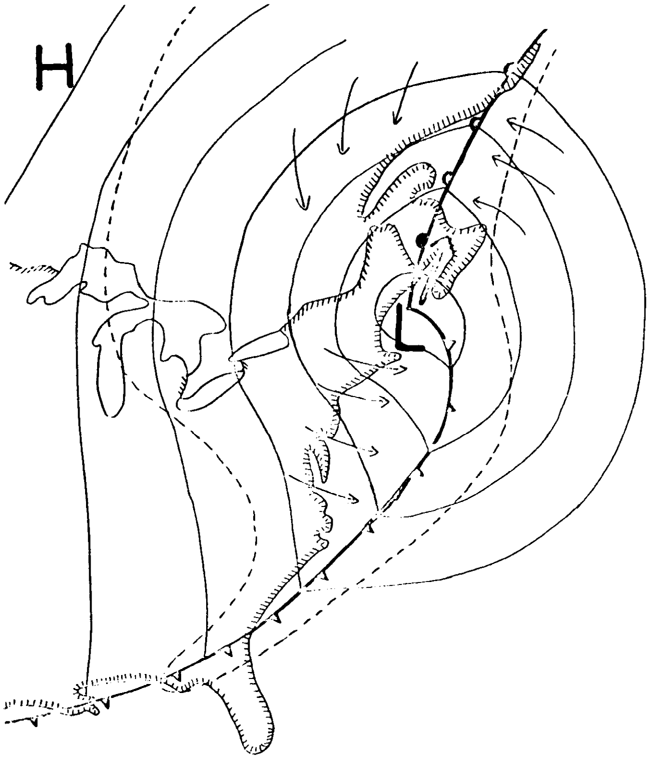

Figure 1. A storm off the coast of Maine moving northeast along the coast (heavy arrow). The lines with teeth and semicircles are cold and warm fronts respectively. The solid arrows are wind directions. The lines around the storm center (L) are isobars. The dashed line encloses the usual precipitation area in modern-day storms.

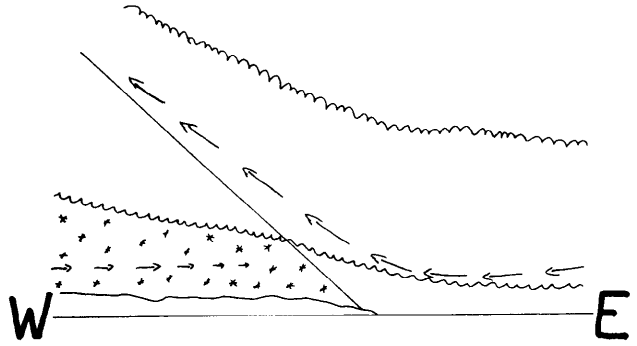

Figure 2. An east-west cross-section through the warm front north of the storm center of Figure 1. The horizontal straight line is sea-level. The irregular horizontal line is the land surface. The arrows are east-west wind components. The sloping straight line is the upper warm front (vertical scale greatly exaggerated). The scalloped lines represent the top and bottom of clouds. The asterisks indicate snow.

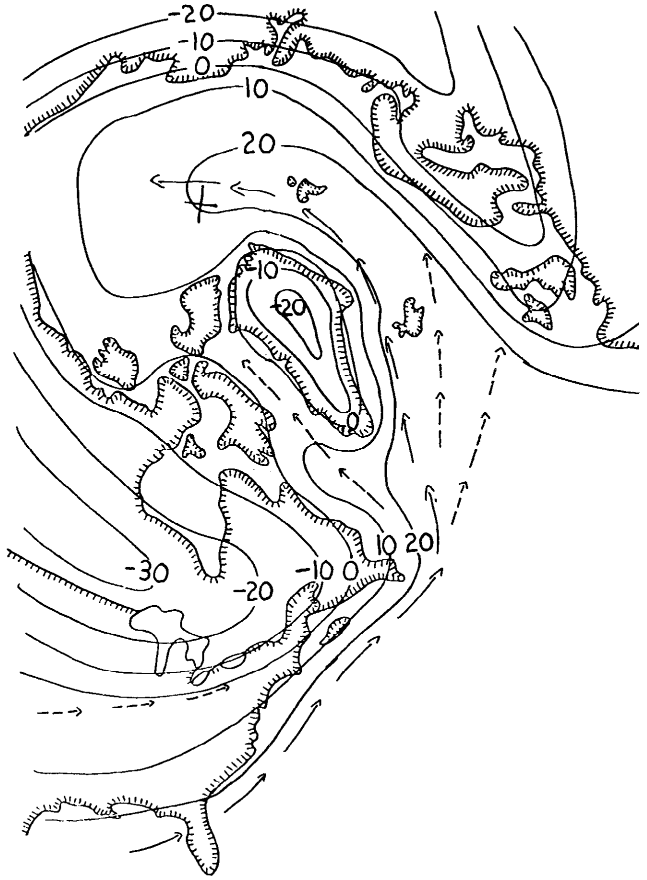

Figure 3. Postulated storm tracks and average isotherms in degrees centigrade for the post-flood climate of the Atlantic Ocean. The solid arrows represent the major storm track. The dashed arrows represent minor storm tracks.

In these coastal storms, cold air would be drawn off the continents and over warm ocean water. This air would be heated rapidly, becoming quite moist in the process. Figure 1 illustrates this situation southwest of a storm center off the coast of Maine. The ocean surface water in contact with the cold air would be cooled and sink, being replaced by warmer water from below and from lower latitudes. An ocean circulation would

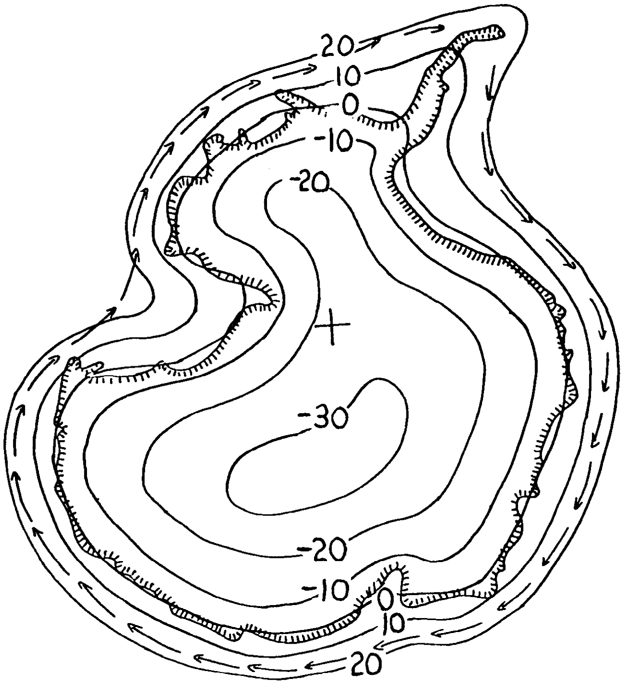

Figure 4. Postulated storm track and average isotherms in degrees centigrade for the post-flood climate of Antarctica.

develop soon after the flood and become quite strong with time, ensuring a continuous supply of warm surface water at high latitudes. The cooler water that sinks would form a layer of cool "bottom water" that would spread out over the whole ocean bottom, becoming colder and thicker with time. To the north of the storm center in Figure 1, warm moist oceanic air would blow inland. However because of the greater density of the cold continental air, it would be forced up and over the colder air. This is a potent mechanism for heavy snowfall. Figure 2 illustrates this concept.

The stormiest conditions with the most snowfall in the post-flood climate would likely be soon after the flood and taper off gradually as the oceans cooled. This is because the horizontal temperature contrast between land and ocean due to the unique post-flood warming and cooling agents should be a maximum soon after the flood. The heat given off by the oceans would act as a regulator or a negative feedback mechanism to ensure that all processes proceed at a fairly constant rate. For instance, if too much heat is released to the atmosphere at one time, it will cause the cold air to be warmer as a result of mixing. If the continental air is not as cold, it will not draw as much heat from the warm ocean, hence, dampening the original heat anomaly.

To visualize the consequences of this unique climate, I will use the storm depicted in Figure 1 to estimate the snow accumulation over appropriate areas of North America for a 300 year long period. This storm is not unlike the Northeasters that clobber the East Coast every winter (actually the storms of the post-flood climate would be much more extensive with heavier snow since they would carry as much as 4 times more water vapor). Since the East Coast of North America would be a favorable storm track (see Figure 3), I will assume that one storm a week forms near Florida and travels northeast, ending up either in the Norwegian Sea or the ice-free Arctic Ocean. A modern-day Northeaster drops about 1 inch of precipitation along the Eastern Seaboard. Assuming this conservative snowfall in the post-flood climate and that no ablation of snow or ice occurs, about 440 meters of ice would accumulate in locations that are cold enough.

In the Southern Hemisphere, the storm track would generally follow the coastline of Antarctica. This is illustrated in Figure 4 with postulated average isotherms. In the present day winter-type storms, most of the precipitation falls in the colder air portion of the storm. Thus, most of the precipitation from storms would fall over the Antarctic continent in the post-flood climate. Similarly to the example of the East Coast storm, if an average of one storm a week passed by any one point near the coast, and if 1 inch of precipitation in the form of snow fell inland for several hundred miles, then about 440 meters of ice would accumulate over Antarctica in a 300 year period.

VI. The Abundant Source of Moisture

If glaciation is to occur at mid and high latitudes, something more than just cooling for a few hundred years is required. An abundant source of moisture is also needed, especially if the ice age is rapid, which it must be in the time frame the Bible allows, [43,44] "From the comparisons given, it would appear that precipitation, in regions already cold enough to support glaciers, is more critical than temperature in initiating glaciation."[45] The problem of adequate moisture has always been acute for uniformitarian scientists because the water vapor content of the air, which is proportional to temperature, is very small in cold regions. Winter-time precipitation in these regions is usually quite light. In fact, the interior of Antarctica, a large part of which receives less than 5 cm of precipitation annually, is one of the driest places in the world.[46] The uniformitarian scientist must appeal to long ages in order to accumulate enough snowfall for an ice age from some perturbing mechanism.

In the post-flood climate, there would actually be two primary sources of moisture for a rapid ice age. The major source would be from strong evaporation off the warm post-flood ocean at mid and high latitudes (called M1), and the other source would be the net poleward movement of moisture from low latitudes by the atmospheric circulation (called M2). The first is operating today, but on a much smaller scale, and the second should be similar to that of present climate. The author feels the first source is the key to a rapid ice age because it provides the additional moisture at mid and high latitudes that the present climate cannot, and without it, there would be no rapid ice age at all.

A. Effects of a universally warm ocean

As already stated, the post-flood climate would be characterized by cold continental air blowing out over warm ocean water, especially during storms. This feature would be strongest along the east coasts of cold continents and along the shoreline of Antarctica. To estimate this effect, E and S from Equations (1) and (2) for stormy conditions will be found using reasonable assumptions. Assuming the water temperature averages 24 degrees C, the air temperature 10 meters above the ocean averages 4 degrees C, the average relative humidity of the air is 50%, and the wind speed at 10 meters averages 15 meters/sec, E equals .59 gms/m^2-sec and S equals 136 cal/m^2-sec. (C_E is 1.84×10^{-3} for the above conditions[47] and C_H is 1.46×10^{-3} for very unstable air.[48]) The latent heat liberated by this value of E is 348 cal/m^2-sec. The total heat liberated is 484 cal/m^2-sec. It is readily seen from this calculation that evaporation is three times stronger than conduction in cooling the oceans. Therefore three-fourths of the total heat loss of the mid and high latitude ocean would come through the agency of water vapor added to the air.

Stormy conditions near continents are not the only situations in which water is evaporated into the air over the oceans, but they are certainly the strongest. If the above stormy conditions occurred over the whole ocean poleward of 35 degrees north and 55 degrees south, the ocean would cool to its present average of 4 degrees C in only 21.5 years. This is, of course, a hypothetical case, but it illustrates the efficiency of storms in not only cooling the oceans, but also in adding abundant amounts of water to the air.

A modern day example of the evaporative potential of cold air blowing over much warmer water is provided by the Great Lakes area during the cold winter of 1976-77. "For most of the country, clearing skies are expected after the passage of a winter cold front, but near the Great Lakes the opposite is true. The cold Arctic air spreading over the lakes picks up heat and moisture which produces clouds and snow squalls that stream inland as far as 100 miles (161 km)."[49] This effect has been known to dump up to 102 inches of snow in 5 days just east of the Great Lakes. Even though the Eastern U.S. was drier than normal during the winter of 1976-77, the colder-than normal weather patterns caused tremendous snowfall downwind of the Great Lakes. Fifty-one days of lake-effect snowfall produced as much as 466.9 inches of snow at Hooker, New York.[50] Extend these conditions to whole continents and large areas of the ocean, where sea-surface temperature averages 24 degrees C instead of about 0 degrees C, for a 300 year long winter, and one can visualize how a rapid ice age can happen in the unique post-flood climate.

B. The Available Moisture

The net cooling of the post-flood ocean would be partially offset by radiative effects, namely the radiative heat gain at mid and high latitudes, and the net poleward transport by ocean currents of heat gained by radiation in the lower latitudes. (Other effects, like the conduction of heat from the earth to the water, are small and shall not be considered.) This complicates an otherwise simple calculation to find M1, but it can be found using an estimate of the oceanic cooling rate and the equation for the heat budget of the ocean. The equation for the oceanic heat budget is used to find a better estimate of the total time to cool the oceans (300 years was only a rough estimate) which takes into consideration the above mentioned radiative effects. Multiplying the cooling time by the rate of evaporative cooling gives M1.

The oceanic heat budget equation is:[51]

$$Q_s - Q_b - Q_h - Q_e = O \qquad (3)$$

where Q_s is the absorption of radiation from the sun and sky, Q_b is the infrared radiation from the sea surface, Q_h is the conduction of sensible heat to the atmosphere, and Q_e is the latent heat due to evaporation. Equation (3) is for a long-term average or steady state, but in the post-flood ocean another term, Q_n, the yearly average net heating of the ocean, is needed. Equation (3) then becomes:

$$Q_s - Q_b - Q_h - Q_e = Q_n \qquad (4)$$

This equation is the same as the equation for the total energy exchange at the ocean surface.[52] Q_n equals -2.8×10^{25} cal/T, where T is the total cooling time of the oceans in years. To solve this equation for T, I will divide the volume of the ocean into tropical and polar volumes, the dividing lines in the post-flood ocean being 35 degrees north and 55 degrees south. Equation (4) now becomes:

$$(Q_s - Q_b - Q_h - Q_e)_{Tr} + (Q_s - Q_b)_p - (Q_h)_p - (Q_e)_p = -2.8 \times 10^{25}\ \text{cal/T} \qquad (5)$$

where Tr means tropical and p means polar. $(Q_e)_p$ is the evaporational cooling rate needed to find M1. The reason for dividing equation (4) into two volumes is because the tropical portion is equivalent to the poleward oceanic transport of heat from the lower latitudes and is easier to estimate in this form. $(Q_s - Q_b)_p$ is the radiative heat gain at higher latitudes.

$(Q_s - Q_b - Q_h - Q_e)_{Tr}$ and $(Q_s - Q_b)_p$ can be found by using the data for different latitude belts of the present climate provided by Budyko[41] and Lamb.[40] $(Q_s - Q_b - Q_h - Q_e)_{Tr}$ is 1.04×10^{22} cal/yr. and $(Q_s - Q_b)_p$ is 2.68×10^{22} cal/yr. The present tropical climate would be a good representation for the average post-flood tropical climate. However, $(Q_s - Q_b)_p$ would be less in the post-flood climate than in the present due to the presence of atmospheric volcanic dust and warmer sea-surface temperatures. In calculating the post-flood value, there were no radiative data north of 70 degrees north and south of 60 degrees south. This is because $(Q_s - Q_b)_p$ poleward of these latitudes is nearly zero at the present ocean surface due to sea ice. The post-flood climate would have no sea ice, except towards the end of the oceanic cooling off period. Consequently, the value for the 60-70 degree south latitude belt was made equal to the 60-70 degree north value, while poleward of 70 degrees, $(Q_s - Q_b)_p$ was assumed zero in the post-flood climate. Actually the value poleward of 70 degrees would have increased $(Q_s - Q_b)_p$, which partially compensates for the lessening effect of volcanic dust and warm sea-surface temperatures.

From the calculations in section VI A, $(Q_h)_p$ is equal to ⅓ $(Q_e)_p$. This relationship was also found by Bunker off the East Coast of the U.S.[53] This area provides a good model for estimating $(Q_e)_p$ in the post-flood climate because, during winter, cold dry continental air streams eastward over the warm Gulf Stream, particularly during storms. The largest amount of oceanic evaporation anywhere in the world takes place here. From ship observations in this area, Bunker found an average winter-time heat loss from evaporation of approximately 400 watts/m^2 or 95.6 cal/m^2-sec. This is probably a good average value near cold continents in the post-flood climate, but is much too high further out in the ocean where air-sea differences would be much less. To calculate the total amount of cooling for the area under consideration, I will assume the cooling rate is zero far from the cold continents and 400 watts/m^2 near them. Therefore only the cooling rate near the continents need be considered. For the Southern Hemisphere, this smaller area was assumed to be the ocean south of 65 degrees south. In the Northern Hemisphere, the strong cooling area follows the profile of mid and high latitude continents and is therefore irregular, so it was assumed to be equivalent to the ocean area north of 50 degrees north. The total area of strong evaporation for both hemispheres[40] is 28.22 x 10^6Km^2. Therefore the total yearly cooling rate for the polar ocean area of both hemispheres is 11.5 x 10^{22} cal/yr. Substituting all values into Equation (5) gives 1.04×10^{22} cal/yr + 2.68×10^{22} cal/yr − $(4/3)(11.5 \times 10^{22}$ cal/yr$) = (-2.8 \times 10^{25}$ cal$)/T$. So T comes out to be 242 years.

To find M1, $(Q_e)_p$ must be multiplied by T, and then divided by the latent heat of evaporation (590 cal/gm) in order to convert latent heat to its evaporational water equivalent. Therefore, M1 equals 4.72 x 10^{22} grams. M2 can be found by multiplying the total poleward transport of latent heat in the present atmosphere, which is about 8 x 10^{19} cal/day for both hemispheres,[54] by T, and dividing by the latent heat of evaporation. The present atmosphere is a good approximation to the post-flood climate because the moisture source is the lower latitudes, which should be nearly the same in both climates. M2 equals 1.20 x 10^{22} grams. Therefore the total moisture available for a rapid ice age is 5.92 x 10^{22} grams.

VII. The Rapid Ice Age

Not all of the available water vapor north of 35 degrees north and south of 55 degrees south would end up as snow for continental ice sheets. Some of it would fall over the oceans and on unglaciated land surfaces. Since the strongest evaporation would occur close to the shoreline, it is reasonable to expect more precipitation near the coasts than far from the coasts of higher latitude continents. However, as a conservative first guess, I will assume that precipitation was evenly distributed throughout the area under consideration. Since little moisture exchange occurs between hemispheres of the present climate and because of the different proportions of land and ocean, each hemisphere will be evaluated separately. Assuming evaporation is proportional to the ocean surface south of 55 degrees south and north of 35 degrees north, 1.79 x 10^{22} grams is available for precipitation in the Southern Hemisphere and 2.93 x 10^{22} grams is available in the Northern Hemisphere from the contribution of M1. Since M2 originates from lower latitudes, I will assume the value for each hemisphere is proportional to the ocean surface between 0-55 degrees south and 0-35 degrees north. This makes M2 equal to 0.76 x 10^{22} grams for the Southern Hemisphere and 0.44 x 10^{22} grams for the Northern Hemisphere. Therefore, the available moisture in the Northern Hemisphere would be 3.37 x 10^{22} grams, and in the Southern Hemisphere, it would be 2.55 x 10^{22} grams.

In the Southern Hemisphere south of 55 degrees south, 32.23 x 10^6Km^2 is ocean and 14.18 x 10^6Km^2 is land. With an even distribution of precipitation, Antarctica would receive 7.9 x 10^{21} grams of water. Using a density of ice of 0.9 gm/cm^3, this much water would end up as 8.8 x 10^{21}cm^3 of snow at an average depth of 702 meters. The estimated volume of the Antarctic ice sheet presently and during the ice age is 23.45 x 10^{21}cm^3 with an average depth of 1.88 km.[55] The post-flood rapid ice age, therefore, only accounts for about ⅓ o the Antarctic ice sheet.

In the Northern Hemisphere north of 35 degrees north, 53.33 x 10^6Km^2 is ocean and 55.83 x 10^6Km^2 is land. Therefore the land would receive 1.71 x 10^{22} grams of moisture. The estimated area of glaciation, assuming it is correct, is 29.92 x 10^6Km^2.[55] This is 54% of the land north of 35 degrees North, which means that 0.92 x 10^{22} grams would end up on continental ice sheets. However, the situation in the Northern Hemisphere is more complicated because 0.79 x 10^{22} grams of precipitation falls over non-glaciated areas, contrary to the case in the Southern Hemisphere, and hence some of it would be re-evaporated and deposited on the ice sheets. In the present atmosphere, the evaporation from the land between 30 degrees and 50 degrees north is 65% of the precipitation.[56] Assuming the same percent in the post-flood climate, and that 50% of the re-evaporated moisture from the land ends up further north on the ice sheets, an additional 0.24 x 10^{22} grams of moisture would be available. This makes a total of 1.16 x 10^{22} grams or 1.29 x 10^{22} Cm^3 of ice for continental glaciation. Using the standard area assumed for the last ice age, the above volume of ice would pile up to an average depth of 431 meters. This compares to an estimated volume of 5.1 x 10^{22}cm^3 and an average depth of 1.7 Km postulated by uniformitarian scientists.[55] This is about 4 times the amount calculated here for a rapid ice age.

There are two ways of viewing the above figures, both of which could easily be correct. First, the estimate for a post-flood rapid ice age, which is dependent upon a number of assumptions, nevertheless can be off in either direction by a significant amount. These figures are only intended to be a rough estimate. Secondly, the uniformitarian scientists, who also depend on assumptions, could have over-estimated the thicknesses of ice sheets that no longer exist. Flint candidly admits: "A greater potential error lies in the estimation of average thicknesses and volumes of glaciers, particularly ice sheets that no longer exist. Thus far the profiles of such glaciers have been reconstructed by analogy with those of existing ice sheets, which for one reason or another may not be truly analogous."[57] In other words, the thicknesses of ice sheets that no longer exist have been estimated in the uniformitarian way by using present examples, and these present examples, according to Flint, may not be very good.

VIII. The Present Continental Ice Sheets

The figures presented here for the volumes and thicknesses of a rapid ice age are about 30% of the present estimated values for Greenland and Antarctica. How then can these ice sheets be accounted for? One likely possibility is that these ice sheets increased by a significant amount in the present climate. Since ablation through iceberg calving is more-or-less proportional to the volume of ice on the Greenland and Antarctic ice sheets, the present average precipitation would be enough to cause relatively fast growth when they were much smaller. The yearly average precipitation of Greenland ranges from 15 cm in the northern interior to more than 90 cm along the southern edge.[58] This represents an average of about 30 cm/yr. Antarctica has a yearly average precipitation of 17 cm.[59] At first, practically all of this precipitation would represent accumulation, but as time went on and the ice sheets grew larger and larger, more and more accumulation would be lost through ablation. If an average of 10 cm/yr of ice was added to the Antarctic ice sheet for the first 3,000 years after the maximum of the rapid ice age, and none thereafter to the present day, 300 meters would be added to the 702 meters already estimated for a rapid ice age. Similarly, at a rate of 20 cm/yr for 3,000 years, Greenland would add 600 meters to its rapid ice age total of 431 meters. This illustrates that a good proportion of the Greenland and Antarctic ice sheets probably built up as a result of the present climate.

In a rapid ice age, a maximum average ice thickness of 431 meters was calculated for the Northern Hemisphere. However, this average would certainly have large anomalies. Above-average thicknesses are expected over continental areas near the warm ocean and near the main storm track. Greenland satisfies both of these conditions and therefore more than 431 meters of ice would be expected at the maximum of a rapid ice age. How much more is, of course, uncertain.

In calculating the average ice thicknesses in a rapid ice age for both hemispheres, the assumption of an even distribution of precipitation north of 35 degrees north and south of 55 degrees south was used. However, this is probably not a good assumption because of the unique characteristics of the post-flood climate. As discussed already, favorable areas for most of the precipitation would border the storm tracks. The interior of continents should accumulate lesser amounts of precipitation while the oceans far from land should receive little. The unevenness of precipitation would especially affect the distribution in the Southern Hemisphere. Since the storm belt would encircle the shoreline of the Antarctic continent, and since most precipitation from winter-type storms would fall south of the storm track, Antarctica would accumulate more precipitation then the oceans. I will indicate the possibilities with a few calculations. If Antarctica were to receive all the precipitation, 2260 meters of ice would result. This is, of course, hypothetical, but it shows how crucial the assumption of an even distribution of precipitation is. A more reasonable possibility is that Antarctica received twice as much precipitation as the average of the surrounding oceans. In this case, Antarctica would accumulate 1060 meters by the end of a rapid ice age, leaving the normal climate the task of building the ice sheet up to its present thickness.

To sum it all up, it is quite possible that a rapid ice age followed by the modern day climate can account for the thicknesses of ice sheets on Greenland and Antarctica within the time allowed by the Bible.

The Melting of the Northern Hemispheric Ice Sheets

No discussion of a mechanism for a rapid ice age would be complete without a brief mention of why the ice sheets would melt and how long it would take. This section does not include the Greenland and Antarctic ice sheets, since very little melting would take place on them. There are no historical accounts of ice sheets over areas now devoid of ice, and the Bible does not leave much time for an ice age. Therefore, it is expected that the ice from a rapid ice age would melt in a short time compared with the uniformitarian time scale.

At the end of the 242 year period of oceanic cooling, the evaporation from the oceans would be much less. Also, the heating of the oceanic air would also be much less. The storm tracks would no longer favor the shoreline of the mid and high latitude continents, but would follow something more like a modern-day distribution. Presumably, the volcanic activity from the Flood and immediately after the Flood would have settled down by this time so that fewer dust particles would be suspended in the atmosphere. The presence of ice sheets at higher latitudes would keep temperatures below the present average (see Section III B). Consequently, sea-surface temperatures at mid and high latitudes would also be below average causing evaporation to be below the present average. The net affect of this climate change is that much drier conditions with more sunshine would prevail, particularly over ice sheets in winter. Temperatures would be below the present normal at mid and high latitudes, but probably much warmer during summers than in the post-flood climate. The ice sheets would not accumulate very much snow during the colder months, and would significantly melt during the warmer months, particularly along the southern terminus.

Recent ice-age climate simulation experiments[60] using high speed computers can shed some light on conditions at ice age maximum. Using assumed uniformitarian conditions for the postulated Wisconsin glacial maximum, the supposed July ice age climate was simulated. The main difference in boundary conditions between the computer model and the post-Flood ice age maximum is the height of the ice sheets. A thinner ice sheet in the post-Flood case would result in warmer and drier conditions than in the uniformitarian case. It was found in the computer simulation that the temperatures over non-glaciated areas would average about 5 degrees C cooler than the present. The average worldwide atmospheric water vapor content would be 30% less, cloudiness would average about 8% less precipitation would be down 15% from the present, and the poleward transport of moisture would be less by 30%. The overall result would be cooler, drier conditions, with more sunshine. The melting of snow and ice is hastened by more sunshine,[61] which should nearly compensate for the cooler temperatures. Therefore the climate at maximum glaciation should result in rapid melting of continental ice sheets in the summer. The computer simulation results bring up an interesting problem for uniformitarian scientists. How could an ice sheet grow to the postulated maximum under uniformitarian conditions, when climatic conditions at maximum would greatly favor melting?

A rough estimate of the melting time for the post-flood rapid ice age can be found by comparing it to the melting of present day glaciers and mountain snow fields, recognizing there are limitations in comparing a relatively small scale phenomenon to the large scale melting of continental ice sheets. During the early part of this century, the climate of the earth has been calculated to be a little warmer and drier than normal. Under these conditions, Flint showed that a portion of the Vatna Glacier on Iceland decreased in thickness by about 100 meters in 46 years between 1890 and 1936.[62] If the post-flood continental ice sheets of the Northern Hemisphere decreased at the same rate, even though the climatic warming was much greater in this case, they would melt in about 200 years.

Another modern-day comparison would be the melting of the winter-time snow accumulation in the Cascade Mountains of the Pacific Northwest. These mountains accumulate about 2 meters of water by mid spring. With cool summer temperatures and a fair amount of cloudiness, this accumulation manages to melt by early fall. Summer temperatures on the post-flood ice sheets during the melting period would be cool, so the Cascade Mountains should provide a good model. Since very little winter precipitation would accumulate on the ice sheets, an average decrease of 2 meters a year would be a good estimate. At this rate, it would take 236 years to melt the ice sheets of the post-flood rapid ice age. Therefore, the total length of the ice age from the end of the flood to the melting of the ice sheets is on the order of 500 years, and that is rapid compared to uniformitarian estimates.

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he pursues his investigation of the peoples of prehistoric Britain.

One important lesson that should be drawn from this revised interpretation of the past concerns the danger of placing too much importance on a limited range of archaeological artifacts. The traditional picture of British Neolithic society is very dependent on the study of graves and gravegoods, and inadequate attention has been given to other sources of information. The consequence has been that an artificial picture has predominated. This danger of selectivity leading to erroneous conclusions must be very carefully watched when studying nomadic peoples, because they leave behind so little for archaeologists to recover and study. For example, consider the life of Abraham, who led a nomadic way of life. He was a civilised man and he enjoyed the benefits of civilised life. He was wealthy and powerful, so that he had personal dealings with the Pharaoh of Egypt and the king of the Philistines, and he also defeated other kings on the battle field. He was one of the important people of his day—and yet his burial chamber was all that he left for posterity. An archaeologist could have little idea of the significance of this man from a study of his grave. Other nomads may have been just as civilised as Abraham, and yet have left just as little tangible evidence of their advanced culture.

Attention has been drawn several times in this article to the importance of presuppositions in the study of the past. In the study of early man, evolutionary views have predominated and archaeologists generally appear to be unconscious of the fact. A proper discussion of Thom's work has been seriously impaired by a commitment to evolutionary principles, and the resistance to the new ideas has been largely a result of prejudice rather than rational thought. The evidences for the British Neolithic being advanced in social structure and cultural attainments are now very strong, and it is time for the facts relating to neolithic peoples in other parts of the world to be re-examined.

Acknowledgements

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