

**A CONCEPTUAL TRANSITION MODEL
OF THE ATMOSPHERIC GLOBAL CIRCULATION
FOLLOWING THE GENESIS FLOOD**

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KEYWORDS (Circulation, Atmospheric Circulation, General Circulation, Global Circulation, Hadley Circulation, Model, Conceptual Model, Wind, Storms, Hurricanes, Ice Age, Genesis Flood, Climate, Weather)

ABSTRACT

The extremely energetic events of the Genesis Flood likely would have left the oceans warmer than today and relatively uniform from top to bottom and from equator to pole. Volcanic activity during and following the Flood likely would have caused rapid cooling at the top of the atmosphere, in polar regions, and over continents. The contrast between the warm oceans and cooler continents and polar regions would have resulted in greater storminess and a more intense global atmospheric circulation than observed today. This paper describes a conceptual model of the transition in global circulation, cloudiness, and precipitation from the end of the Flood to that of today. The model will be applied specifically to the interpretation of the ice core record at Camp Century, Greenland.

INTRODUCTION

The catastrophic events of the Flood described in Genesis 6-9 are almost unimaginable. In order for man and all land-breathing animals to have been destroyed in the Flood, the entire surface of the earth would have been devastated. The layers of sedimentary rock covering most of the earth, containing millions of fossils are mute testimony to this event. Scripture says that flood waters covered the highest mountains. If this was the case, many other major geological events also occurred: mountains rose up; valleys were carved out by receding flood waters; volcanoes spewed lava and dust over vast areas; forests were buried; and earthquakes and tidal waves swept the earth. Even the continents may have been broken apart during or shortly following the Flood.

The amount of energy released during these events would have resulted in significant warming of the oceans as noted by Oard [8, p. 158], [9, pp. 23-31]. Heat released by the collapse of the waters above the earth, present before the Flood, and by magma and warm, sub-surface waters during the Flood, would have raised the average temperature of the oceans by possibly tens of degrees above that of today. Not only would the oceans have been warmer, but because of all the mixing, they probably would have been relatively uniform in temperature from top to bottom and from equator to pole. This is not true today. The oceans are colder near the poles and at the bottom as displayed in Marchuk and Sarkisyan [7, p. 171].

The Biblical description of the pre-Flood world gives the impression of a relatively warm environment, with no rain or storms. If this is true, it is likely that no ice sheets existed at the poles prior to the Flood. However, even if they were in existence before the Flood, they would have melted or have been destroyed during the Flood. Even in polar regions today, vast sedimentary rock layers exist below the ice and extend upward in isolated outcroppings called nunataks, testifying to the worldwide effects of the Flood.

Following the main deluge, many of the geologic processes did not cease abruptly, but, rather, decreased slowly in intensity and frequency, much like aftershocks following a major earthquake. Volcanoes probably

continued to release dust and gases into the upper atmosphere for many years after the Flood, causing a pall over the entire earth. The observation of high concentrations of calcium, magnesium, and silicon in the lowest layers of ice cores taken from Greenland may be a reflection of these residual volcanic eruptions. This cover of volcanic dust and gases probably affected the radiation balance over the earth, causing greater cooling over continents and polar regions than we experience today.

The contrast between warm oceans and cold continents probably resulted in intense storminess along coastlines. A description of the effects of the Flood on the formation of an "Ice Age" is described by Oard [9]. He discusses, in great detail, causes of an "Ice Age"; the beginning, progression, and ending of an "Ice Age"; and evidences for a single "Ice Age", rather than many. However, Oard [9] does not treat the evidence gleaned from ice cores, which would support such an alternative model, nor does he describe, in detail, the general circulation which would likely be associated with such a model.

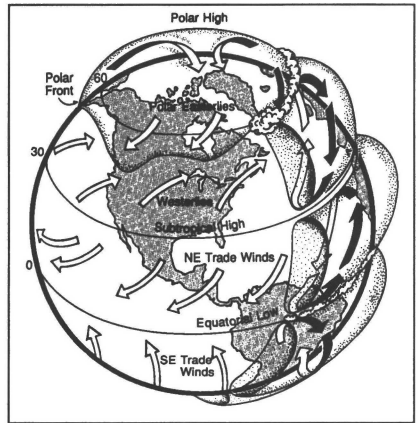


Figure 1 The general circulation of today's atmosphere. Light arrows show air flow at the surface and dark arrows aloft.

THE GENERAL CIRCULATION OF TODAY'S ATMOSPHERE

The general circulation of the atmosphere, as it is observed and understood today, is shown in Fig. 1. It is essentially a circulation modified by the Coriolis forces on a rotating earth as described by Lorentz [6]. The earth is observed to be in thermal equilibrium, but net radiational cooling occurs at high latitudes, near the poles, and net warming occurs in the tropics and subtropics, near the equator. To balance the thermal heat source near the equator with the heat sinks near the poles, the ocean and atmosphere transport heat from the tropics to high latitudes. This heat transfer is the driving force for weather and climate on the earth.

The circulating cells in the atmosphere nearest the equator cause air to rise over the equator and flow toward the poles, then descend near 30° latitude. In the Northern Hemisphere, air is deflected to the right of its path by the Coriolis force, so that the northeast trade winds are created as the descending air moves back toward the equator at the surface. In the rising air near the equator, clouds form, and heavy precipitation falls along a belt around the globe called the intertropical convergence zone, or the equatorial low. Near 30° latitude, where the air routinely descends, few, if any, clouds form, and desert conditions persist in a belt surrounding the earth. This region is a subtropical high.

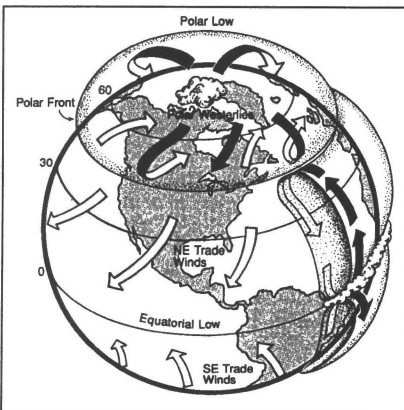


Figure 2 The hypothetical general circulation of the atmosphere soon after the Flood. Warm oceans and large rates of radiational cooling over the poles would drive extreme convection.

Between the subtropical high and the polar front further to the north, westerlies prevail. This region is characterized by winds blowing from the west, as surface air moves north from the subtropical high and is deflected to the right. It is also characterized by stormy weather, particularly in the winter, as storms circle the globe along the polar front.

Near the pole, air descends, as heat is removed by radiation to space. The cold air at the surface moves southward toward the polar front and is deflected to the right, forming polar easterlies. Under the polar high, relatively few clouds and little precipitation form. A typical station in central Greenland today accumulates the equivalent of one foot of water per year in the form of ice and snow. What precipitation does occur remains in a frozen state for long periods of time.

Now, how would this picture likely have been different immediately following the Flood where nonequilibrium conditions prevailed? Fig. 2 shows a two-celled Hadley circulation which may have developed during the latter

stages of the Flood. The most active region in the atmosphere would likely have been near the poles. Prior to the Flood a vapor canopy has been proposed to have existed above the atmosphere creating a relatively warm, stable, uniform climate from equator to pole (See Vail [14], Whitcomb and Morris [17], Dillow [3], Vardiman [15], and Rush and Vardiman [13]).

This canopy would have collapsed during the Flood leading to greatly increased radiational cooling through the atmosphere. Maximum radiational cooling would have occurred at high levels in the atmosphere, directly over the poles. However, at the surface, the oceans would have been warm--possibly as warm as 30°C. Tremendous evaporation rates would have been present at the ocean surfaces, with condensation and freezing aloft. This situation would not only have been convectively unstable, but probably also dynamically unstable.

HURRICANE FORMATION

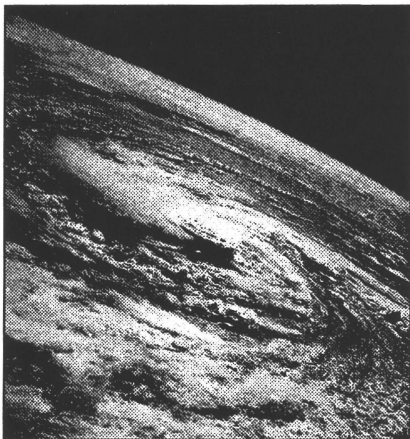


Figure 3 Hurricane Gladys in the Gulf of Mexico during 1968 (NASA).

The organization and intensification of convection in a strongly convective environment such as we have described would be very similar to the organization of a hurricane discussed by Dunn and Miller [4] and Riehl [11]. Hurricanes are one of nature's most devastating phenomena. They occur in the warm, moist environment of the tropics where convective instability is high. Fig. 3 shows an example of a hurricane -- in this case, Hurricane Gladys in the Gulf of Mexico during 1968. Hurricane Gladys filled the entire gulf with spiral rain bands from the coast of Mexico to the Florida peninsula.

Fig. 4 shows a diagram of air motions in such a hurricane relative to the spiral rain bands and the storm center. The typical hurricane contains rainbands spiraling around a central eye. The center-most rainband contains the strongest winds and heaviest precipitation. Ascending air in the main wallcloud and spiral rainbands draw moist air from the subcloud layer and exhaust it aloft. Near the surface, air converges toward the center of the hurricane to replace the air which has been removed vertically upward.

The Coriolis force causes the air to spiral inward in a counterclockwise manner, creating the characteristic spiral rain bands. The outflow aloft spirals clockwise on its way toward the edge of the hurricane and descends, drying the air aloft. Descending air typically occurs in the eye, producing clearing, cessation of precipitation, and weak winds.

Yet, even with all our knowledge about hurricanes, one of the most perplexing mysteries is the question of why hurricane formation is so rare. Although a reservoir of potential energy for hurricane formation exists over large portions of the tropical oceans for much of the year, it is seldom tapped. When conditions near the earth's surface are unusually warm and humid and conditions aloft are cool and dry, cumulus clouds will form. If a slight impulse of upward vertical motion is imparted to an air parcel under such conditions, strong convection will develop. This atmospheric condition is called, "Conditional Instability of the First Kind."

For many years, atmospheric scientists have regarded hurricanes as rare manifestations of an instability similar to that which drives cumuli. If a region of convection develops over the ocean and lasts long enough, it will result in a hurricane. Several conditions are found to be necessary. For example, the ocean temperature must be warmer than 26°C and an existing disturbance of some sort must move into the tropics which will generate convergence of boundary layer air. If these and several other conditions are met, such "organized convection" will lead to the development of a full-blown hurricane. This tendency of "organized convection" to produce hurricanes is called "Conditional Instability of the Second Kind (CISK)."

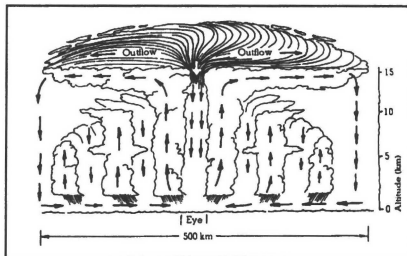


Figure 4 Air motions in a typical hurricane relative to spiral rain bands and the storm center.

In recent years, however, a whole new view of what causes hurricanes to form has developed. Emanuel [5] states that:

The hurricane can be regarded as an elegant example of a natural Carnot heat engine (an idealized, reversible thermodynamic cycle that converts heat to mechanical energy). The reservoir of potential energy for hurricanes resides in the thermodynamic disequilibrium between the atmosphere and the underlying ocean. This is reflected in the fact that air immediately above the ocean is subsaturated, yielding a potential for transfer of entropy from sea to air even though the two media are usually at about the same temperature.

In this new view, called the air-sea interaction theory, the driving force behind hurricane development is not "organized convection" but, rather, the moisture transfer from the ocean surface to the subcloud layer of air which provides the fuel for the Carnot heat engine. If a sufficiently energetic disturbance (winds on the order of 10 meters/second) creates convection over a warm enough ocean (temperatures greater than 26°C through a depth of at least 60 meters) over a long enough period of time (on the order of 4 days), the circulation of a typical hurricane can become established and feed on the energy source in the ocean surface. The trick is creating the proper conditions for the subcloud layer to incorporate moisture from the ocean surface. Apparently, wind speed is the key. Emanuel [5] has shown by computer modeling that his model hurricane will not develop if maximum wind speeds are only 2 meters/second, but it will develop if they are 12 meters/second, all other conditions being appropriate.

The efficacy of air-sea interaction in providing potential energy to balance frictional dissipation depends on the rate of transfer of latent heat from the ocean to the atmosphere. This is a function of surface wind speed. Strong surface winds, which produce a rough sea surface, can greatly increase the evaporation rate. Thus, hurricane development depends on the presence of a disturbance, such as an equatorial wave, to provide the winds required to produce strong evaporation. The evaporation rate is a non-linear function of wind speed. Given a suitable initial disturbance, a feedback may occur in which an increase in inward-spiraling surface winds increases the rate of moisture transfer from the ocean. This brings the boundary layer toward saturation and increases the intensity of the convection, which further increases the inward-spiraling winds.

Despite the current limitations on the understanding of hurricane genesis, Emanuel [5] has generalized his knowledge of the dynamics and energetics of a tropical hurricane to similar phenomena outside the tropics. He believes that polar lows which occur over certain high-latitude oceans (such as the Norwegian Sea) can be explained by the same thermodynamic reasoning. These storms occur in the polar night and often wreck havoc on fishing boats and oil platforms. They form when an exceptionally deep mass of cold air flows out over relatively warm open water, creating a large air-sea thermodynamic disequilibrium. Emanuel [5] analyzed the energy potential of polar lows using the same basic equations as for tropical hurricanes and showed that moderately strong hurricane-like circulations could indeed be maintained under these circumstances. In this case, most of the total entropy difference between ocean and atmosphere results from the large temperature contrast between the two media rather than from an undersaturation of the subcloud layer of air.

THE GENERAL CIRCULATION AFTER THE FLOOD

An extension of this physical reasoning to a polar "hurricane" covering a large portion of the Arctic, as shown in Fig. 2, requires a larger source of energy and a longer period of development. Both of these conditions would likely be present following the Genesis Flood. The entire Arctic Ocean, North Atlantic, and North Pacific would have been warm, and not just at the surface, but throughout their depths. Any surface cooling would have resulted in immediate mixing of warmer water from below. The time required to cool the polar oceans from a uniform temperature of 30°C to temperatures observed today was calculated by Oard [8,9] to be on the order of 500 years. This is more than enough time for a hurricane-like circulation to organize itself and function for a long period. Of course, such an intense circulation might not continue to operate for the entire 500 years, if the ocean temperature dropped below certain threshold values.

In Fig. 2, the storm over the Northern Hemisphere is shown to draw warm, moist air from as far away as 45° latitude. At the surface, north of the interface between the two circulation cells, all the winds would be westerlies, feeding into the storm center near the pole. Aloft, the winds would be easterlies, as the air diverges from the storm center. At the periphery of the storm, the air would descend to make another circuit toward the pole at the surface. Less cloudiness and precipitation would have occurred here, even

though the oceans were warm. Near the equator, an equatorial low, similar to that of today with rising air, clouds, and precipitation would have occurred. It is likely that the intensity of the circulation would have been greater than today, however, with more precipitation.

As the polar storm continued to intensify, it is likely that it developed an eye, such as in a modern hurricane. As it intensified, the precipitation would have formed a ring around the poles which would have moved southward and expanded in size. In addition, the storm would have continued to draw warm, moist air from greater distances to the south -- even possibly south of 30° latitude, as shown in Fig. 5.

At some point, the oceans and atmosphere would have given up enough heat that the precipitation in the ring around the pole would have turned to snow. Once snow began to fall, it would have accumulated on land first (since heat capacity and transfer rates are much less on land than on water). The accumulation of snow on land would have increased the rate of cooling of the atmosphere over the continents, because of the radiational cooling of a higher albedo. The accumulation rate could have been extremely high, when the polar front was near a given location. It also could have varied somewhat as the polar front moved north and south, giving the impression of annual accumulations over shorter time periods.

Over the oceans, since vertical heat transfer is greater due to a larger heat capacity and vertical convection in the water, the atmospheric circulation could draw upon heat from greater depths and the accumulation of snow would be delayed. Since rain and melting snow produce fresh water, layers of salt-free water would have been deposited on top of normal sea water. Fresh water is less dense than salt water, so the precipitation would have tended to remain on the surface. Of course, vertical convection and storm-induced waves would have mixed fresh water with the salt water below reducing this effect somewhat. Since fresh water freezes at a warmer temperature than salt water, a layer of ice may have formed on the surface of the polar oceans before the temperature decreased to the freezing point of sea water. This layer of ice may have eventually closed off the oceans as a source of evaporation near the poles and contributed to greater cooling through the radiational effects of a greater albedo. It is likely that if such an ice layer formed, it would have developed into an ice shelf, which progressed southward from the regions of most-intense precipitation. Due to the lengthy time it probably took to remove heat from the polar oceans and the lower layers of the tropical and mid-latitude oceans, the formation of ice shelves may have been late in the "Ice Age."

Ice sheets in the Northern and Southern Hemispheres probably developed in a slightly different manner, because of a different distribution of land masses. At the North Pole, an open ocean is primarily surrounded by land masses, while at the South Pole, a large continental land mass is surrounded by extensive oceans. This may explain the problem the standard model of the "Ice Ages" has explaining the lack of correspondence between the Antarctic and Greenland ice-core records. The Antarctic ice sheet probably began to accumulate snow fairly rapidly after the Flood, relative to the Greenland ice sheet. Furthermore, the circulation around Antarctica was probably much more concentric than that around the North Pole, resulting in a more uniform accumulation.

Fig. 6 shows the global circulation at a point in time when the polar ice sheets had reached a maximum. Note that a three-celled Hadley circulation has developed, and the polar front is shown further south than is typical today. The polar front generally takes more southerly positions over the continents, because their colder temperatures combine with warm ocean temperatures to induce large standing waves in the general circulation. These standing waves tend to cause more northerly flow over the continents and more southerly flow over the oceans. The oceans are major sources of heat and moisture to the polar and continental regions. Evidence from moraines at the edge of glaciers, and sea-floor sediments beneath the edges of ice shelves reported by Ruddiman and McIntyre [12], show that in the past, an ice shelf extended south of 45° latitude in the North Atlantic. These conclusions were based on the distribution of microorganisms such as foraminifera which are temperature dependent and on ice-rafted debris. A

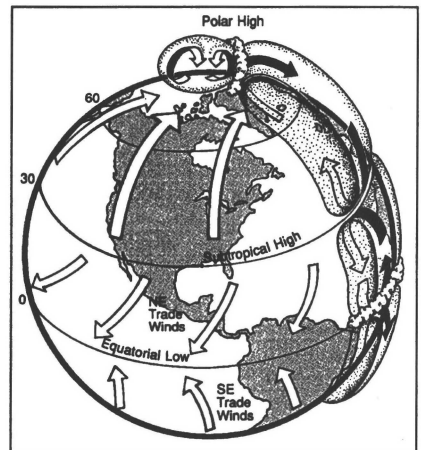


Figure 5 Intense stage of general circulation development over the pole. This stage probably occurred within 100 years or less of the Flood. Note the development of an "eye".

relatively sharp boundary of cold types of microorganisms and ice-rafted debris were found on the ocean floor as low as 45° latitude in the Atlantic Ocean.

As the oceans cooled and more of the ocean surface was covered with ice, the active precipitation zones may have moved further equatorward. The jet streams in both hemispheres probably tended to follow the edge of the ice sheets, since this was where the major north-south temperature gradient would have occurred. The massive ice sheets poleward of the polar fronts capped moisture sources, and amplified radiational cooling.

Once the oceans cooled sufficiently that evaporation was reduced, melting in the summers exceeded accumulation in the winters, and the ice sheets began to recede to those observed today. Only Greenland and Antarctica retain massive ice sheets and continue to accumulate snow.

The driving mechanism for the "Ice Age" in this model was the presence of warm oceans following the Flood. The advance and retreat of the ice sheets was controlled by the time required to cool the oceans, and the distribution of snow and ice was determined by the manner in which the general circulation of the atmosphere was modulated by the temperature differences between the poles and the equator and between land and ocean.

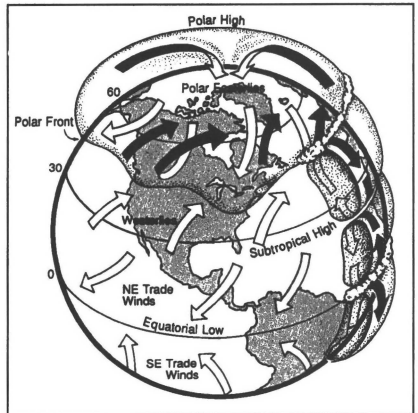


Figure 6 Global circulation at the maximum extent of polar ice caps. This stage probably occurred 500 to 1000 years after the Flood. Note the three-celled Hadley circulation.

NUMERICAL MODEL SIMULATION

In an attempt to confirm some of the ideas suggested in this paper a numerical simulation of the atmosphere was conducted with the Community Climate Model (CCM1) from the National Center for Atmospheric Research (NCAR). The model was installed on a 486 personal computer and validated with a standard simulation run for a perpetual January condition in today's atmosphere. A 600-day run was completed for validation purposes. It was found to match today's atmospheric condition well.

Uniform 30°C sea-surface temperatures were then entered into the model, oceanic ice shelves removed, and the model started again with all other initial conditions the same. A 100-day run was completed in time for this report. The conditions seem to force the model so strongly that equilibrium appears to have been achieved rapidly. However, the model will continue to be run for up to 1200 days in order to be certain. The model behaved significantly different for the warm ocean than for today's conditions.

Fig. 7 shows surface temperature for perpetual January after 100 days of simulated time. The sea-surface remains uniformly warm at 30°C, but the continents cool rapidly, in some locations to -40°C. An extreme temperature gradient is located at all continental boundaries. This temperature gradient would be expected to induce a strong thermal wind parallel to the coast lines.

Fig. 8 shows surface pressure for perpetual January after 100 days of simulated time. Relatively high pressure occurs over the warm oceans. Relatively low pressure occurs over the polar regions and continents. Pressure has not been adjusted to sea-level, so topography strongly influences the values in some locations, such as over the Himalayas in southeast Asia.

Fig. 9 shows wind speed high in the stratosphere for perpetual January after 100 days of simulated time. The wind is strongest in the northern hemisphere, as would be expected in January. The speed of the westerly jet is about 25% higher than in today's atmosphere.

Fig. 10 shows the precipitation rate at the earth's surface for perpetual January after 100 days of simulated time. The precipitation rates are extreme in the polar regions and along the continental boundaries of the northern hemisphere. Rates exceed 10 mm/day over Greenland, Antarctica, southeastern Asia, northeastern North America, northwestern Europe, and western Africa. The center of Asia and North America appear relatively dry. Of special interest is the relatively dry region from the eastern end of the Mediterranean eastward across the continent of Asia. This pattern may have been of particular value to Noah and his descendants as they left the Ark on Mt. Ararat and emigrated south and east.

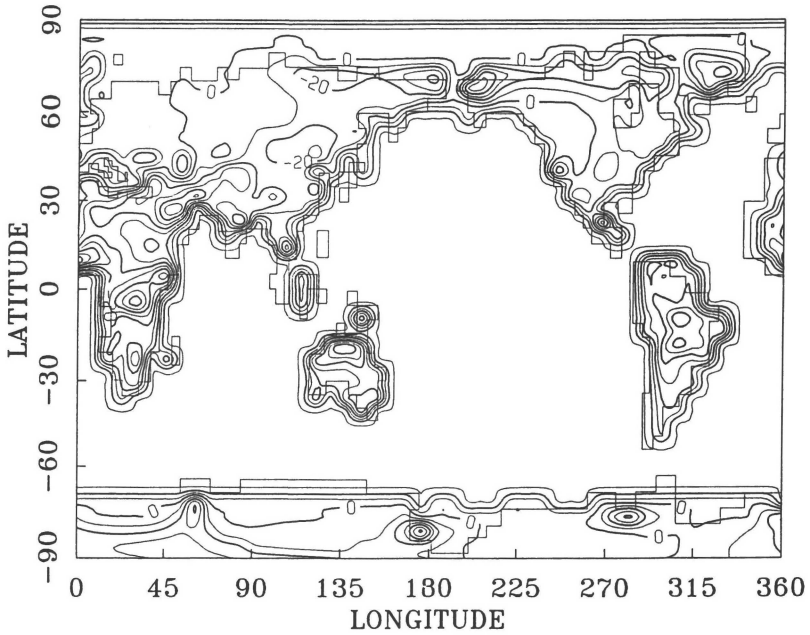


Figure 7 Surface temperature for perpetual January after 100 days of simulated time with the NCAR CCM1 model and initial uniform 30°C ocean surface temperature globally.

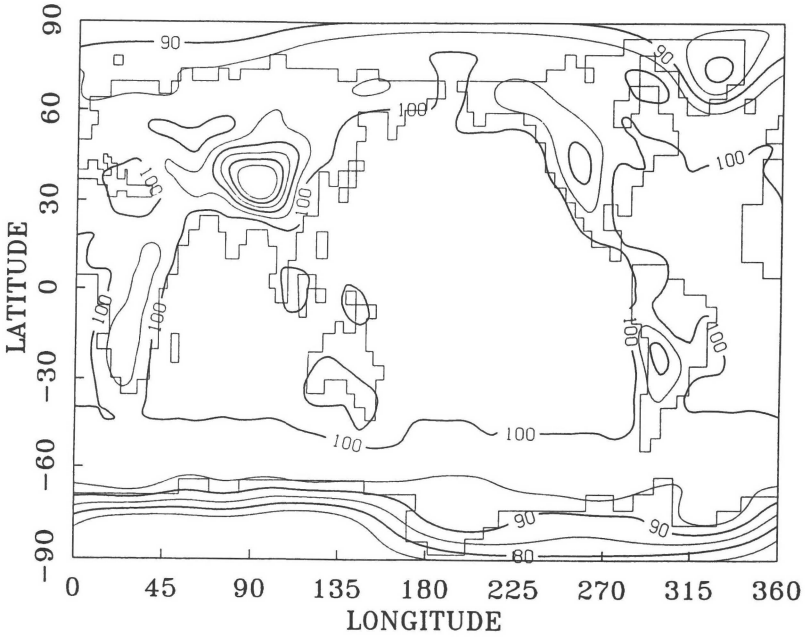


Figure 8 Surface pressure for perpetual January after 100 days of simulated time with the NCAR CCM1 model and an initial uniform 30°C ocean surface temperature globally.

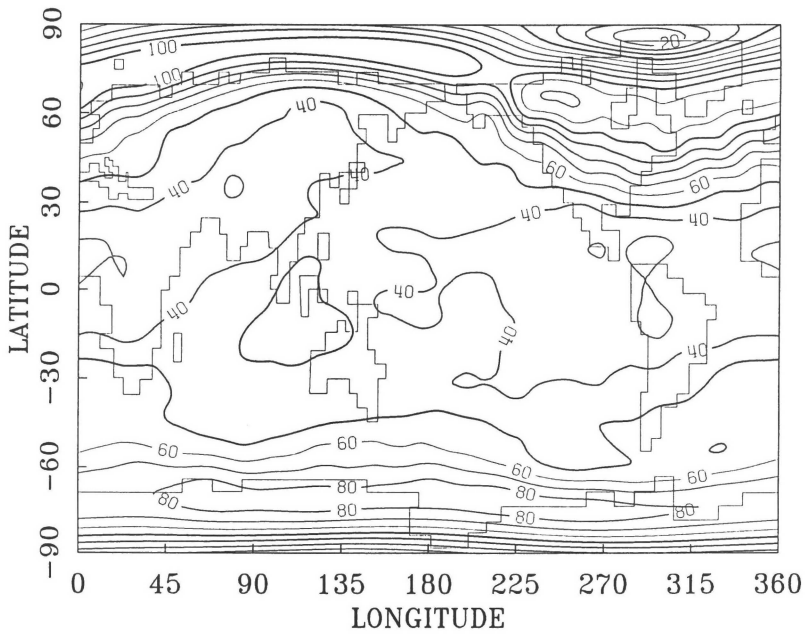


Figure 9 Stratospheric wind speed for perpetual January after 100 days of simulated time with the NCAR CCM1 model and an initial uniform 30°C ocean surface temperature globally.

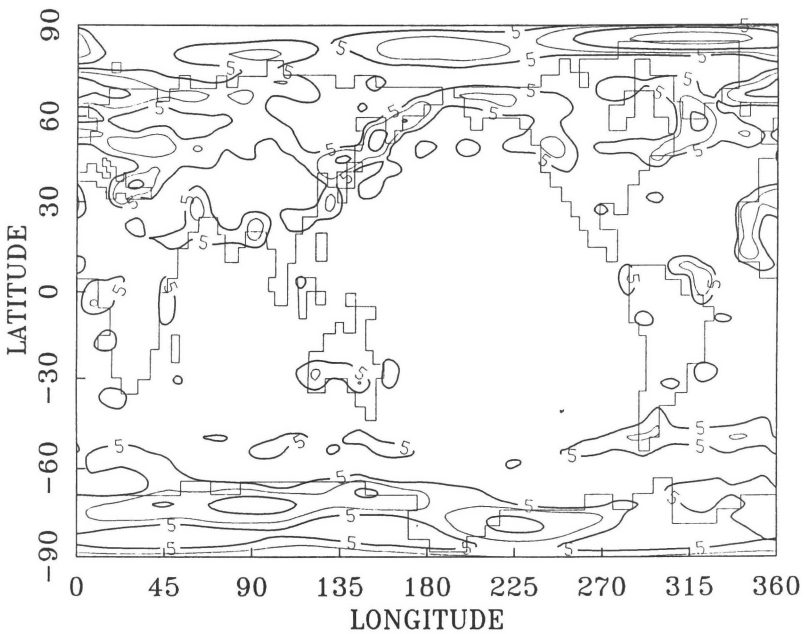


Figure 10 Precipitation rate for perpetual January after 100 days of simulated time with the NCAR CCM1 model and an initial uniform 30°C ocean surface temperature globally.

The primary purpose of this numerical simulation was to develop a young-earth, catastrophic explanation of the "Ice Age." The results offer great encouragement for the model suggested by Oard [8,9] and in this article. They also have significance for a much wider range of topics. For example, the heavy precipitation indicated by the model could be important in erosion of continents following their emergence from the oceans after the Flood, e.g. southeast Asia and western Africa. The precipitation rates are extremely high compared to those of today. The heaviest precipitation occurs in the regions of the earth necessary to explain the ice sheets and glaciers present on the earth today and in the past. A uniformly warm ocean seems to generate the necessary conditions for the rapid formation of ice sheets in polar regions.

These results should not be considered valid yet. They are very preliminary. The model must be run for a much longer period of time to insure that it has come to equilibrium. A full analysis of over a dozen variables must be explored to fully understand the three-dimensional nature of this simulation and the interplay among the variables. The topography must be modified to remove the effects of current ice sheets on Greenland and Antarctica. Simulations must be conducted for decreasing sea-surface temperatures in the polar regions. It is likely that as the sea-surface temperatures in the polar regions decreased, the precipitation rates decreased and more rain turned to snow. Seasonal changes must also be simulated.

GREENLAND ICE CORES

Given the transition in the general circulation of the atmosphere following the Flood, can some of the major features in ice cores be explained? For example, how would the trends in $\delta^{18}\text{O}$ be explained by a young-earth "Ice Age" model? Fig. 11 shows the measured values of $\delta^{18}\text{O}$ versus time for Camp Century, Greenland, according to a typical long-age time model. $\delta^{18}\text{O}$ is defined by:

$$\delta^{18}\text{O} = \frac{R - R_o}{R_o} \cdot 1000 \text{‰(per mil)} \quad (1)$$

where R is the ratio of ^{18}O to ^{16}O in a sample of ice and R_o is the ratio of ^{18}O to ^{16}O in a reference sample, called the standard mean ocean water (SMOW).

The generally-accepted old-earth interpretation of trends in $\delta^{18}\text{O}$ with time is shown in Fig. 11. The last "Ice Age" reached its minimum temperature about 18,000 years ago after about 100,000 years of cooling. Some, as yet, unknown factor caused the "Ice Age" to end and temperatures returned to their normal interglacial values about 10,000 years ago. The increase in $\delta^{18}\text{O}$ after the minimum at 18,000 years occurred over a short period of time. This atmospheric temperature history is derived from Fig. 11 because $\delta^{18}\text{O}$ in ice is believed to be directly related to the temperature of the atmosphere from which the snow was precipitated and the old-earth time model is based on an assumption of relatively uniform snow accumulation over millions of years. For a more thorough discussion of the relationships between temperature and $\delta^{18}\text{O}$ and the use of time models, see Vardiman [16].

Fig. 12 shows the same measured values of $\delta^{18}\text{O}$ plotted against time derived from a young-earth time model. The basic assumption of this time model, discussed in detail by Vardiman [16], is that the snowfall rate was high at the end of the Flood, and decreased exponentially with time to that observed today. Note in Fig. 12 that the period of time from the Flood to the "Ice Age" temperature minimum is somewhat less than the 500 years suggested by Oard [8,9]. However, this is to be expected since it probably took a few years for the temperature to drop sufficiently for snow to begin to accumulate. Recent evidence has been presented by Alley et al. [1] that the rapid change in $\delta^{18}\text{O}$ following the "Ice Age" could have occurred in as little time as 5 years. If this evidence is true, then it is likely that $\delta^{18}\text{O}$ is not dependent only on atmospheric temperature. It does not seem likely that the atmosphere, and probably the ocean, could warm by some 15°C in 5 years. It is more likely that some other factor has caused $\delta^{18}\text{O}$ to change.

Craig [2] showed that a primary factor which causes $\delta^{18}\text{O}$ in precipitation to change is the influence of formation temperature on the fractionation of the two isotopes of oxygen. However, in addition to the dependence upon formation temperature, Petit et al. [10] have reported that

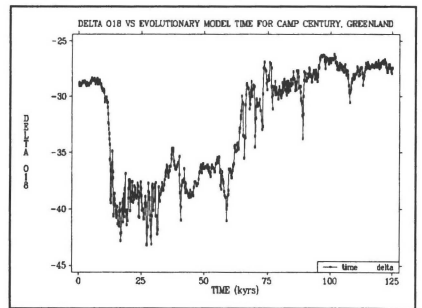


Figure 11 $\delta^{18}\text{O}$ versus long-age model time.

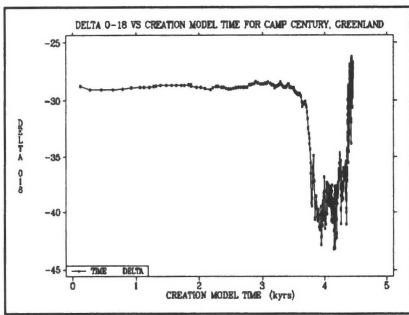


Figure 12 $\delta^{18}\text{O}$ versus young-earth model time after the Flood for Camp Century, Greenland.

the variation of $\delta^{18}\text{O}$ is also a function of the distance of an observation site from the source of moisture, the relative concentration of oxygen isotopes at the source of moisture, and the type of precipitation process. There are probably other factors, as well.

In a changing situation like that following the Flood where the oceans were cooling rapidly; a polar front was probably developing and moving south and then north again; and the precipitation intensity was decreasing exponentially; it is likely that all of these processes would come into play. For example, as the oceans cooled, we would expect $\delta^{18}\text{O}$ to also decrease with cooling temperatures. In addition, the warm oceans would create relatively thick, warm clouds immediately after the Flood. But, as the oceans cooled, the clouds would decrease in thickness and could become

colder. This would cause $\delta^{18}\text{O}$ to decrease, as the type and intensity of the precipitation changed.

Once the snow began to accumulate over the ocean after the Flood, ice shelves probably developed, similar to those of today. The ice shelves covered sources of moisture close to the Camp Century site on Greenland. As the shelves continued to grow southward, the source region for moisture moved further away, lowering the value of $\delta^{18}\text{O}$. Precipitation over the open ocean south of the ice shelves also remained on the surface, diluting the sea water with fresh water already depleted in $\delta^{18}\text{O}$ from a previous cycle of evaporation and precipitation, thus producing a further lowering of $\delta^{18}\text{O}$. We can therefore explain the trend toward lower values of $\delta^{18}\text{O}$ for the first segment of the core from the bottom upward with our alternative conceptual model, with or without a large temperature change. But, what about the sudden change in the more recent portions of Figs. 11 and 12?

I propose that once the ocean cooled sufficiently and the ice sheets on the continents and ice shelves on the oceans stopped growing, the ice shelves began to retreat rapidly. Once the accumulation of snow decreased, the surging of ice off the continents and direct formation of shelves by precipitation on the oceans probably ceased, which led to a breakup of the shelves. As the shelves broke up, a positive radiational feedback occurred whereby the decreased albedo led to more surface heating and more destruction of the ice shelves. Ice shelves around Antarctica and in the North Sea are observed to break up very quickly in the spring today, much more rapidly than they form.

The sudden retreat of the ice shelves would cause the distance between the source and deposition site to diminish, increasing the $\delta^{18}\text{O}$ rapidly. This retreat would also be associated with less precipitation on the ocean surface beyond the ice shelves as the oceans cooled and increased mixing of surface waters because of melting of the ice, thereby increasing the $\delta^{18}\text{O}$ at the source. The cooler type of precipitation process is likely to revert somewhat to a warmer type and contribute to a slight increase in $\delta^{18}\text{O}$ as the shelves retreated. However, the change in distance between source and deposition site and change in concentration of $\delta^{18}\text{O}$ at the source alone could easily explain the increase the $\delta^{18}\text{O}$ of the snow falling at Camp Century.

CONCLUSIONS AND RECOMMENDATIONS

It seems likely that major convective activity would have occurred near the North and South poles because of warm oceans and radiational cooling aloft following the Flood. This would likely have led to the development of hurricane-like circulations over both poles which transitioned into the global circulation we observe today. The cooling near the poles would have resulted in the rapid accumulation of snow on the continents and, later, the formation of ice shelves on the polar oceans. Numerical simulation experiments with the CCM1 model show that extremely high precipitation rates occur in the polar regions and along the boundaries of the continents of the northern hemisphere when uniformly warm sea-surface temperatures are used as input. This heavy precipitation would have produced large accumulations of snow in the polar regions. Studies from ice cores in Greenland show a slow decline in $\delta^{18}\text{O}$ with time, followed by a sudden increase at the end of the "Ice Age". These changes can be explained by fractionation of the oxygen isotopes as water is evaporated and transported from the mid-latitude oceans in the polar regions. The trends observed in ice cores are due to changes in temperature, distance from the source of evaporation, and the type of precipitation processes as the oceans cooled and the general circulation of the atmosphere responded.

It is recommended that (1) more numerical experiments be conducted on the development of hurricane-like circulations in polar regions using hurricane and global circulation models, (2) the variation of $\delta^{18}\text{O}$ in snow be quantified as a function of distance from an evaporative source and the type of precipitation process, and (3) the formation of extensive ice shelves by direct accumulation of precipitating snow be investigated.

ACKNOWLEDGEMENTS

The Climate and Global Dynamics Division of the National Center for Atmospheric Research is gratefully acknowledged for providing a copy of the Community Climate Model (CCM1) used in this study. Mr. Steve Low and his colleagues at Hewlett Packard donated the personal computer. Mr. Herman Daily donated his time and expertise to modify the model, originally designed to run on a CRAY. It now runs on a personal computer with an OS-2 operating system, albeit at about 1/100th the speed.

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