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INITIAL CONDITIONS FOR A POST-FLOOD RAPID ICE AGE

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KEYWORDS: Climate, Computer Simulation, Ice Age

ABSTRACT

In the early years of the modern creationist movement questions were raised as to the role of ice ages in explaining geological data. Beginning with Whitcomb and Morris (1961) and formalized by Oard (1979), a proposed scenario of warm oceans and volcanic activity would provide the needed conditions to initiate a post-flood ice age. During the 1990's Vardiman used the Community Climate Model (CCM) to study the impact of warm oceans on global air circulation and precipitation patterns. Following Vardiman's lead this study uses the Goddard Institute of Space Studies (GISS) Model E climate model. The first part of the study uses a fixed 30 ºC sea surface temperature to validate against work done by Spelman (1996). The second part of the study incorporates a dynamic ocean as well as increased volcanic aerosol levels to determine the initial conditions needed to provide snowfall rates of significant intensity to initiate accumulation for an ice age.

Given initial sea surface temperatures of 30 ºC, extensive volcanic activity is needed to offset the heat flux provided by warm oceans. The Model E simulations had run times of six years and did not achieve the conditions needed for extensive snowfall at high latitudes. Using a dynamic ocean and volcanic aerosol optical depths of 2.00 give promise of sufficient cooling if the simulation were to extend to several decades. Given the limited run times, these simulations can only provide information about the sensitivity of the climate model and the thermodynamic balance over a limited time scale. Future work using century long runs will provide more conclusive results about the validity of the initial conditions proposed here. Extended runs will also provide valuable information about climate shifts as well as changes in circulation patterns within the ocean, which can then be compared to geological strata associated with the Pleistocene.

INTRODUCTION

Ice Ages

In most geology textbooks the ice age is described as a series of ice sheet advances during the Quarternary period due to extended periods of lower surface temperatures. Ice sheets currently exist over Antarctica and Greenland; however, during the ice age there were advances in current

day glaciers and extensive ice sheets covering the higher latitudes of North America, Europe and Asia. Evidence for multiple ice ages comes from successive layers of glacial debris, erratic boulders, fjords, moraines, etc. Ice cores, lake sediments and tree rings are used as proxy data for global temperatures and atmospheric composition and their data extend through the Holocene into the Pleistocene. From EPICA Dome C ice cores there are indications of correlations between lower temperatures and low CO_2 during the last four ice advances in North America (Nebraskan, Kansan, Illinois and Wisconsin). (Luthi *et al*, 2008) Correlations such as these are used to support cause/effect scenarios of global warming. Regardless of the time scale or the causation, there are multiple sources of evidence for a Quarternary ice age.

Volcanism

During the Quarternary there is evidence of significant volcanic events that have an impact on climate. Rampino and Self (1992) notes that the Toba eruption occurred close to the beginning of the last glacial maximum (Wisconsin) and may have provided the cooling needed to initiate this event. Not only do volcanoes produce large amounts of ash, which causes a short term cooling effect, but also sulfur dioxide (SO_2), which can result in multi-year cooling effects by generating stratospheric aerosols. In an attempt to correlate volcanic events with climate impact several indices have been developed. The Volcanic Explosivity Index (VEI) uses volume, cloud height and duration of eruption to categorize 8000 eruptions. (Newhall and Self, 1982). Since the VEI is restricted to volcanological data, climate impact for similar eruptions may be different due to the amount of sulfate aerosols generated. Proxy data for aerosol load come from sulfate and acidity data from ice cores; however, Robock and Free (1996) conclude that, except for a few eruptions, the climate forcing of explosive eruptions in the Northern Hemisphere before 1200 AD could not be delineated from the current ice core record.

Assuming a correlation between volcanic volume and aerosol generation, the VEI provides a useful first guess on climate impact of volcanoes. The 1991 eruption of Mount Pinatubo had a VEI of six and expelled 10 km^3 of material and 20 Mt of SO_2. (Robock, 2000). The climate impact resulted in reduction in surface temperature by up to 0.7 ºC over the course of three years. (Self *et al*. 1981) The 1815 eruption of Tambora has a VEI of seven, expelled 30 km^3 of material and 100 Mt of SO_2 and resulted in the "Year without a Summer" in the Northern Hemisphere. (Self *et al*. 1984) Using geological dating techniques, the eruption of Toba occurred around 74,000 years before present, had a VEI of eight, released up to 100 times the aerosols of the Mount Pinatubo eruption, and resulted in worldwide temperature declines of up to 5 ºC and declines of 15 ºC at higher latitudes. (Robock *et al*., 2009) Although Robock's research concludes that Toba could not initiate an ice age due to decadal impact of the explosion, he begins his analysis with current day initial conditions. It is clear from volcanic/climate research that massive eruptions can have a significant impact on global temperatures and have even larger local effects due to changes in atmospheric circulation patterns. Although individual events have climatic impact limited to several years, it is found that increases in volcanic activity globally can result in increases in SO_2 and accounts for the most significant increases in stratospheric aerosols during the last decade. (Vernier, J. P. *et al*., 2011)

Ocean Circulation

Ocean circulation also has an impact on climate. As a whole, the ocean consists of a well-mixed warm surface layer overlying a cooler deep layer. The mixed layer interacts strongly with the atmosphere with a thermal adjustment time of 300 days (Marshall and Plumb, 2008) while the deep ocean consists of a slow moving circulation which overturns on the time scale of centuries. Coupling between the ocean and atmosphere can result in significant climate effects. The most common is El Nino/Southern Oscillation which is often abbreviated ENSO. This decadal scale ocean-atmospheric coupling drives the position of a region wide pool of warm ocean water in the tropical pacific. This shift has wide ranging impact from changes in the tropical monsoons and the position of the higher latitude jet stream. One theory for the initiation of the Younger Dryas, a return to glacial conditions after the end of the most recent ice age, involves a modification of the thermohaline circulation of the Northern Atlantic Ocean. Melting ice sheets in the Northern Hemisphere introduce less-dense, fresh water into the North Atlantic, thus cutting off the warming effect of the Gulf Stream. (Manabe and Stouffer, 1997)

The buildup of ice sheets during the ice age reduces the height of sea level. Yokoyama *et al*. (2000) determine that sea level was 130 m lower during the last glacial maximum based on the Bonaparte Depression off Australia. This exposed continental shelves, introduced a land bridge between Asia and North America, connected Great Britain to Europe and many of the Indonesian islands to Asia as illustrated by Figure 1. The increased weight of the ice sheets resulted in a depression of the earth's crust in those regions and is evidenced by an isostatic rebound of at least 55 m for Lake Agassiz since the end of the last ice incursion. (Brevik, 1992)

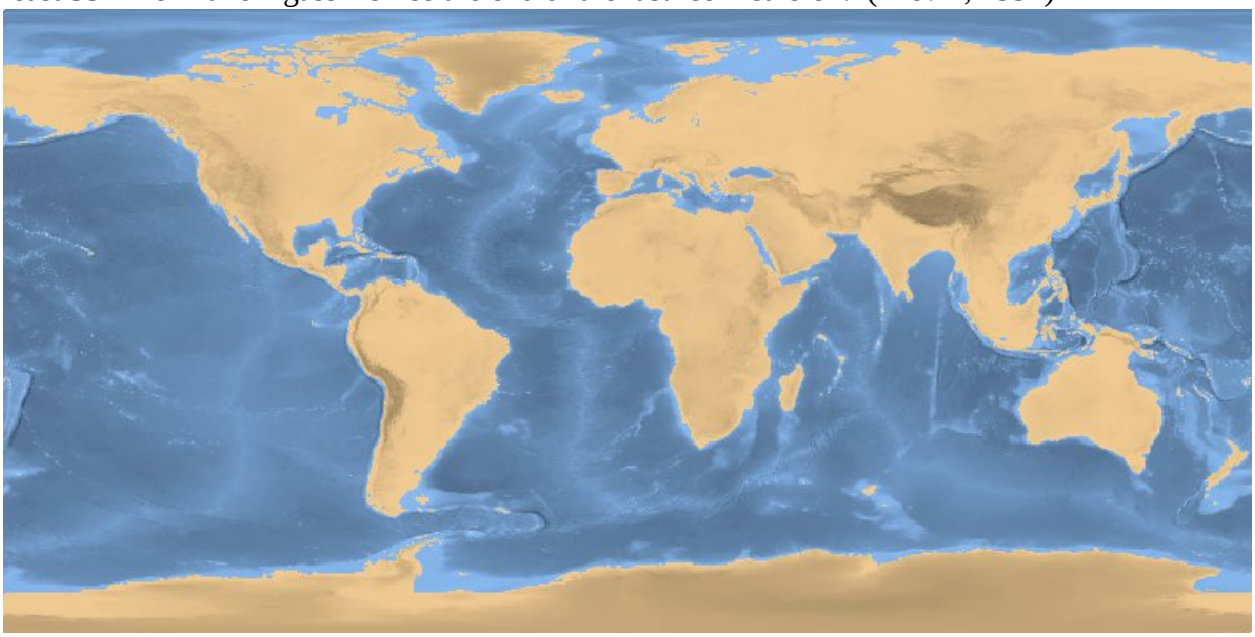

Figure 1 Diagram of the earth's land surface with sea levels 130 m lower than current day values. Image was generated using the Java applet residing at http://merkel.zoneo.net/Topo/Applet/.

Milankovitch Cycles

One explanation as to the origin of the ice ages was proposed by a Serbian, Milutin Milankovitch. Changes in the earth's orbital parameters (eccentricity, inclination, obliquity, and

precession) have cycles of 413, 125, 95, 70, 41, and 26 Ka (Kilo annum). It is assumed that the accumulation of small changes in solar insolation results in a net cooling of the earth thus initiating an ice age. It is found that changes in solar insolation are insufficient to provide the cooling needed for an ice age unless positive feedback mechanisms are present to amplify the effect, such as decreased amounts of CO_2. (Zeng, 2007) Secondly, the predominant 100 Ka cycle found in deep sea and ice cores matches one of the eccentricity periods. However, it is expected that the precession or obliquity would have a larger impact. Spectral analysis performed by Wunsch (2004) indicates that for frequencies between 10,000 and 92,000 cycles/Ka Milankovitch frequency bands contribute less than 10% to the variance in the data and suggests that autocorrelation within a stochastic process could also explain the predominant feature at 100 Ka. Deep sea cores also indicate that there is a transition from a 41 Ka dominant cycle to a 100 Ka dominant cycle. Does this reflect Milankovitch forcing or a change in the dynamic response of the earth system?

Creationist Response

When presented with this causal explanation for the ice ages, a young-earth creationist will reject it due to the implication of millions of years. Ice ages are particularly problematic because sediments associated with this geological era also correspond to fossils of Homo sapiens. In response creationists have evaluated glacial evidence, the deep sea and ice cores as well as proposed their own causal explanations for the ice ages.

Denying a Pleistocene ice age Cox (1979) attributes glacial features to rapid uplift of the earth's surface and disintegration due to a pressure decrease. With regard to pre-Pleistocene ice ages, Molen (1990) made comparisons between gravity flows and ice age deposits. He concluded that these deposits were different from the Pleistocene deposits, but all ice ages may be the result of gravity flows. Oard (1997) likewise concluded that striated bedrocks and tillites can be explained as submarine landslides during the flood. Evaluation of core data was primarily carried out by Vardiman. Assuming sedimentation rates in the deep ocean decreased exponentially in the wake of the flood, Vardiman (1996a) compresses the time span of sea cores to 2000 years. With regard to ice cores, compression effects at the base of the ice sheet make it impossible to identify annual layers of deposition. Using a modified ice flow model, Vardiman (1996b) interprets Greenland ice cores as extending back 4500 years. This model when applied to ice core Oxygen-18 ratios has a minimum occurring 200-300 years after the flood, which may correspond to the maximum ice accumulation during a post-flood ice age. (Vardiman, 1996b, p. 47) Reinterpreting deep sea and ice core data in this manner erases connections between patterns in the cores and the Milankovitch cycles. Not abandoning the significance of these patterns, Woolley (2009) proposes they are the result of coupled oscillations in the earth system and can be modeled with a Duffing equation.

Deluvial as well as other explanations for the data attributed to ice ages are documented in Howorth (1892). Early theories with regard to the initiation of the global flood as well as the ice ages have a pedigree heavily influenced by the work of Vail (1912) where he proposes a water canopy. Although not holding to an ice age in a traditional sense, Dillow's (1981) explanation for sudden freezing at high latitudes and expansion of glaciers in the tropics is due to a combination of significant volcanic events and the collapse of a water vapor canopy. Holding to

a two canopy model Johnson (1986) concludes that collapse of a water canopy could have initiated the flood, but a later collapse of an ice canopy may be the source of the ice age. An alternate view for the ice age is provided by Daly (1973) where an arctic ice mass moves southward during the flood event. Vardiman's (1998) conclusion, that the vapor canopy could at most hold one meter of precipitable water, unless albedo effects are added to reduce the amount of solar radiation, made room for alternate explanations for the flood waters and for the cause of the ice ages.

In Whitcomb and Morris' seminal book *The Genesis Flood* the following comment was made with regard to the initiating of a post-flood ice age:

> "An abundant supply of moisture, strong polar winds, lowered polar temperatures due both to removal of the thermal vapor blanket and probable dense accumulation of volcanic dust particles in the atmosphere, newly uplifted mountains, essentially barren topography of the denuded lands: all these and possibly other factors could have contributed to the rapid accumulation and growth of the ice sheets." (Whitcomb and Morris, 1961, p. 294)

Building off of these ideas, Oard (1979) proposed an ice age due to the presence of warm post-flood oceans and volcanism. This proposed ice age has a duration of 500 years and would achieve ice thicknesses of 400+ meters rather than the accepted value of 2000+ meter for the Laurentide ice sheet during the last glacial maxima. This ice age is a single event rather than multiple cyclic events. Support for a rapid, single ice age event is presented in Springstead (1971), Oard (1990a) and Molen (2008). Ice sheet modeling performed by Horstemeyer and Gullett (2003) support a rapid ice age by estimating ice sheet flow rates. This work along with Sherbern, Horstemeyer and Solanki (2008) propose that evidence interpreted as multiple ice ages may be the result of multiple surges during a single ice age event.

The ice age is a reconstruction or scenario used to explain evidence collected around the globe. One's confidence in the explanatory power of the scenario leads to a confidence in the historicity of the event. Although accepted by the scientific community as well established, many details of the ice age such as initiation and environmental impact are open for discussion and revision. With advancements in computer technology the global climate model (GCM) provides a powerful tool for evaluating ice age scenarios. GCMs use similar techniques as weather forecasting models to study global relationships of the earth environment. Being able to model physical relationships, which can be validated against measurements around the globe, give confidence that the past and future climate can be explored. In Cane *et al*. (2006) it is stated that advancements in GCMs over the past decades have improved simulations of paleoclimates and provide improved confidence in predictions of future climate.

Among creationists a significantly different view of paleoclimate exists and, therefore, implies a different view of the future. Several scenarios of post-flood recovery have been proposed by the creationist community, which have implications as to the stability of the earth's environment to change. Assuming God works through lawful, physical action during the post-flood era on the global scale, GCMs should prove a useful tool for validating creationist scenarios of flood recovery. This paper takes the first step in exploring Oard's scenario of a rapid post-flood ice age. In Section I general information about GCMs is provided along with details about the specific GCM used for this research. In Section II past simulations of warm oceans are

compared to simulations with the current model. Incorporating volcanic aerosols are discussed in Section III followed by concluding remarks about relevance of this work to creation research and future GCM research.

SECTION I – GLOBAL CLIMATE MODELS

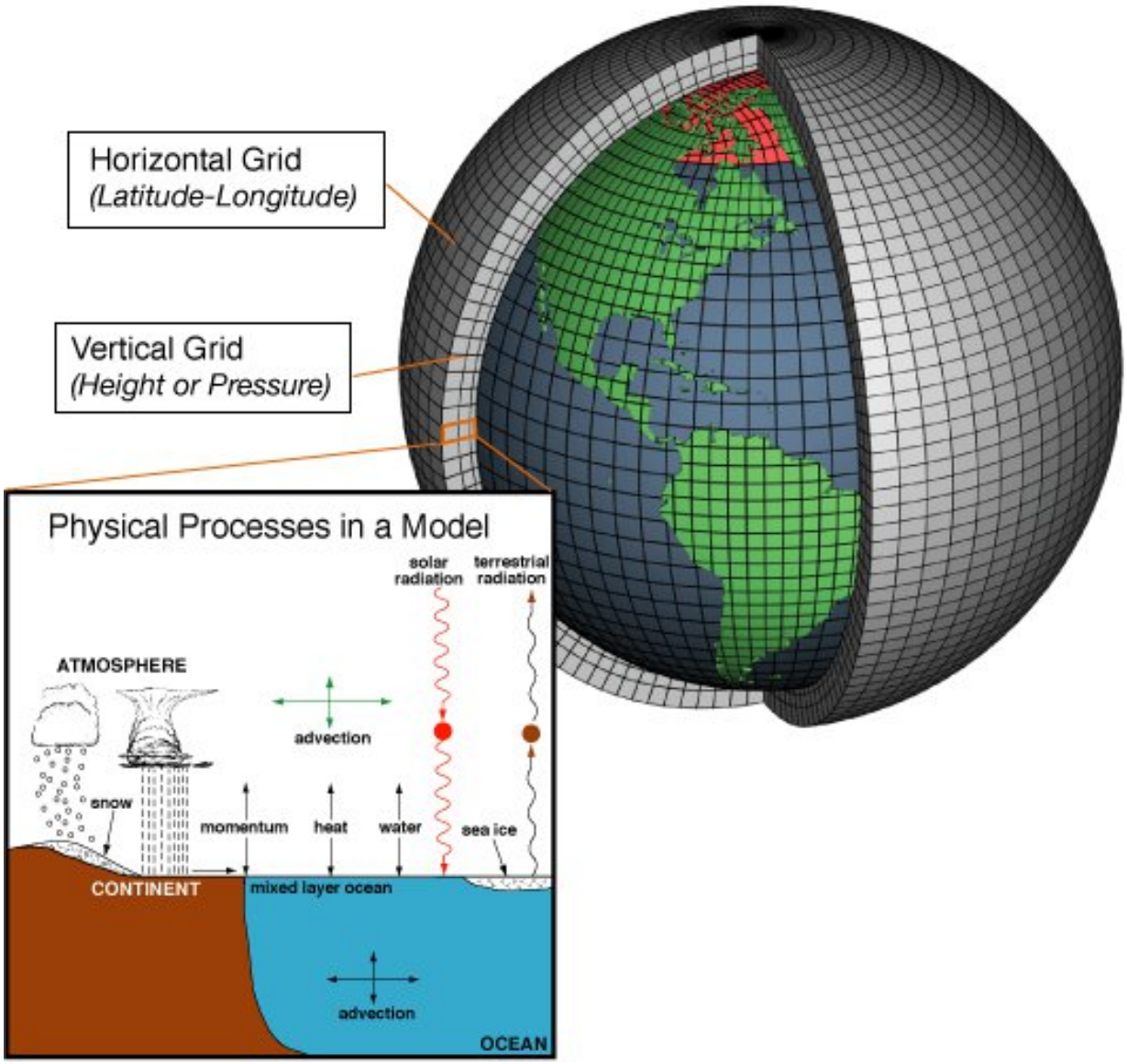

Figure 2 Representation of the earth system for use in climate modeling. The surface is divided into a two-dimensional grid and the atmosphere is represented as multiple layers. Physical interactions of radiation, latent and sensible heat transfer, and exchange processes at the surface are simulated. (Image source: NOAA)

GCMs are similar to weather models, where motion of the atmosphere is simulated using mathematical relationships between physical properties of momentum, temperature, pressure, density and water vapor. Instead of modeling a portion of a continent over the course of a week, the global weather is simulated over the course of years. As illustrated in Figure 2, the earth's

surface is broken into a regular array based on latitude and longitude. The atmosphere is broken into a number of layers. Since topography near the surface changes significantly, altitude makes a poor vertical coordinate. Alternate vertical coordinates are employed to improve stability of calculations. Sigma coordinates are often used where a sigma surface is a constant fraction between the surface pressure and the pressure at the top of the atmosphere. As GCMs improve, more refined equations are used to update physical values at each grid point in the atmosphere. Ideally each calculation is based on fundamental physics principles; however, this is computationally impossible. In many cases a look-up table is incorporated to minimize the computation of variables based on invariant properties. In other cases fundamental physics is not well understood and is replaced with conceptual parameterizations. The most common parameterizations deal with sub-grid processes. Turbulent mixing in the ocean as well as the propagation of radiation through non-uniform clouds are two such examples.

To ensure that parameterizations are reasonable, output from model simulations is compared to observed atmospheric and oceanic quantities. This is an ongoing focus of research and provides a basis for increased confidence in model results. One limitation to climate models is that they are "tuned" to current climatological conditions. Although they can simulate the interconnection between a large number of physical properties, their results are plausible outcomes, not reality. When simulations use initial conditions or boundary conditions that extend well beyond current day values, the output must be approached with more caution. The new conditions may push the model into an unstable mode (subroutines are usually incorporated to catch these) or a regime where parameterizations are no longer valid. Also, it may be possible that the new conditions entail a situation where the physical world responds with a process that is not incorporated into the climate model. Therefore, when extrapolating climate effects far removed from current conditions, discernment should be exercised to distinguish between science and personal bias. Extrapolation does not invalidate climate modeling, but it does move its predictions from being likely to being plausible or possible.

Current GCMs not only model the atmosphere, but also include ocean circulation, sea ice interactions, land processes and biological/ecological response. As each system is added, subtle feedback loops are introduced which manifest themselves as observed physical phenomena. A good example of this effect is El Nino, where the position of a warm pool of water in the tropical pacific has an impact on atmospheric circulation. The atmospheric response in turn can influence warming and cooling of the ocean surface, which can intensify or weaken the El Nino effect. As GCMs increase in complexity, they require more computational resources to simulate similar time intervals. As a result, there is a trade-off between the resolution, time span, and physical detail of a GCM.

The models used for this study are the Goddard Institute of Space Studies (GISS) Model II (Hansen *et al*., 1983) and Model E (Schmidt *et al*., 2006). Model II consists of a 36 by 22 horizontal grid giving a 10º longitude and 8º latitude resolution. The atmosphere is divided into 9 layers extending from the surface to a pressure level of 10 mb. Although restricted to modeling the atmosphere, it is the core model for EdGCM, a project intended to bring climate simulations to the desktop environment for educational purposes. With this model a century long simulation can be performed in 18 hours on a 3 GHz WinXP system. This model was used for rapid iterations to test the feasibility of different scenarios. Model E is a more mature version

of the GISS Model II with options to more effectively model the stratosphere and to include a dynamic ocean. The configuration used for this paper has a horizontal grid of 72 by 46 (5º longitude and 4º latitude) and 20 atmospheric layers extending to 0.1 mb, which is well above the stratopause. This model also has the option of using a 13 layer dynamic ocean extending to a depth of 4650 meters. (Russell, 1995) Although the AR5 version model is available, it is under current development. Therefore, the AR4 version of the model, which was used as part of the Intergovernmental Panel on Climate Change (IPCC) data repository, was used for this work.

SECTION II – WARM OCEAN SIMULATIONS

Fixed Sea Surface Temperature

The first assumption for a rapid post-flood ice age is warm oceans. Oard (1990b) proposes a uniform sea surface temperature of 30 ºC at the end of the flood and polar oceans cooling to 10 ºC at glacial maximum. Estimating the heat flux leaving the warm ocean, reducing horizontal heat transport by 12.5%, and reducing solar radiation by 25% due to volcanic aerosols and increased albedo, Oard estimates an ice age lasting 500 years. Focusing on just warm oceans, Spelman (1996) ran sensitivity studies relating precipitation to ocean temperatures using the National Center for Atmospheric Research (NCAR) Community Climate Model 1 (CCM1). This model has a horizontal gird of 48 by 40 using 12 atmospheric layers with fixed sea surface temperatures. Fixing sea surface temperatures to a uniform value of 30 ºC and solar irradiance to January conditions for 360 days, he observed an enhanced precipitation along the edge of the Antarctic continent and over the Arctic and North Atlantic Oceans. As seen in Figure 3a, a peak precipitation rate of 40 mm/day occurs near the North Pole. The area of this precipitation region is exaggerated due to the distortion of the equirectangular projection. Vardiman (1998) used the CCM1 to model response of the atmosphere to ocean hot spots over spreading sea floor ridges. He concluded that there was enhanced precipitation downstream of the ridge and were shifts in the atmospheric circulation pattern.

To verify compatibility between simulations with the CCM1 and current work with the GISS Model II and Model E, simulations using uniform 30 ºC sea surface temperatures were performed. Using ice free oceans, a similar precipitation pattern is observed (Figure 3b); however, with half the magnitude of precipitation as reported by Spelman. The reason for the difference is two-fold. First, the simulation was ice free. If ice is included, the temperature gradient between land and ocean increases and precipitation is enhanced as illustrated in Figure 3c, which maintains sea ice in 30 ºC oceans. Second, Figures 3b and 3c are multi-year averages over the month of January, while Figure 3a is for the last day of the perpetual January simulation. Using similar conditions as Figure 3c, but with increased resolution, the GISS Model E gives higher precipitation rates (Figure 3d) although they are still averaged over the month. Averages hide the significance of individual weather events, which can have sub-grid effects not captured by GCMs. To better capture the impact of post-flood weather events, mesoscale or weather forecasting models (resolution of 30 km rather than 600 km) should be used. These models not only provide a better prediction of precipitation, but also capture shifts in weather patterns due to warm oceans as demonstrated in Vardiman (2003), Vardiman and Brewer (2010a, 2010b, 2010c), and Vardiman and Brewer (2011).

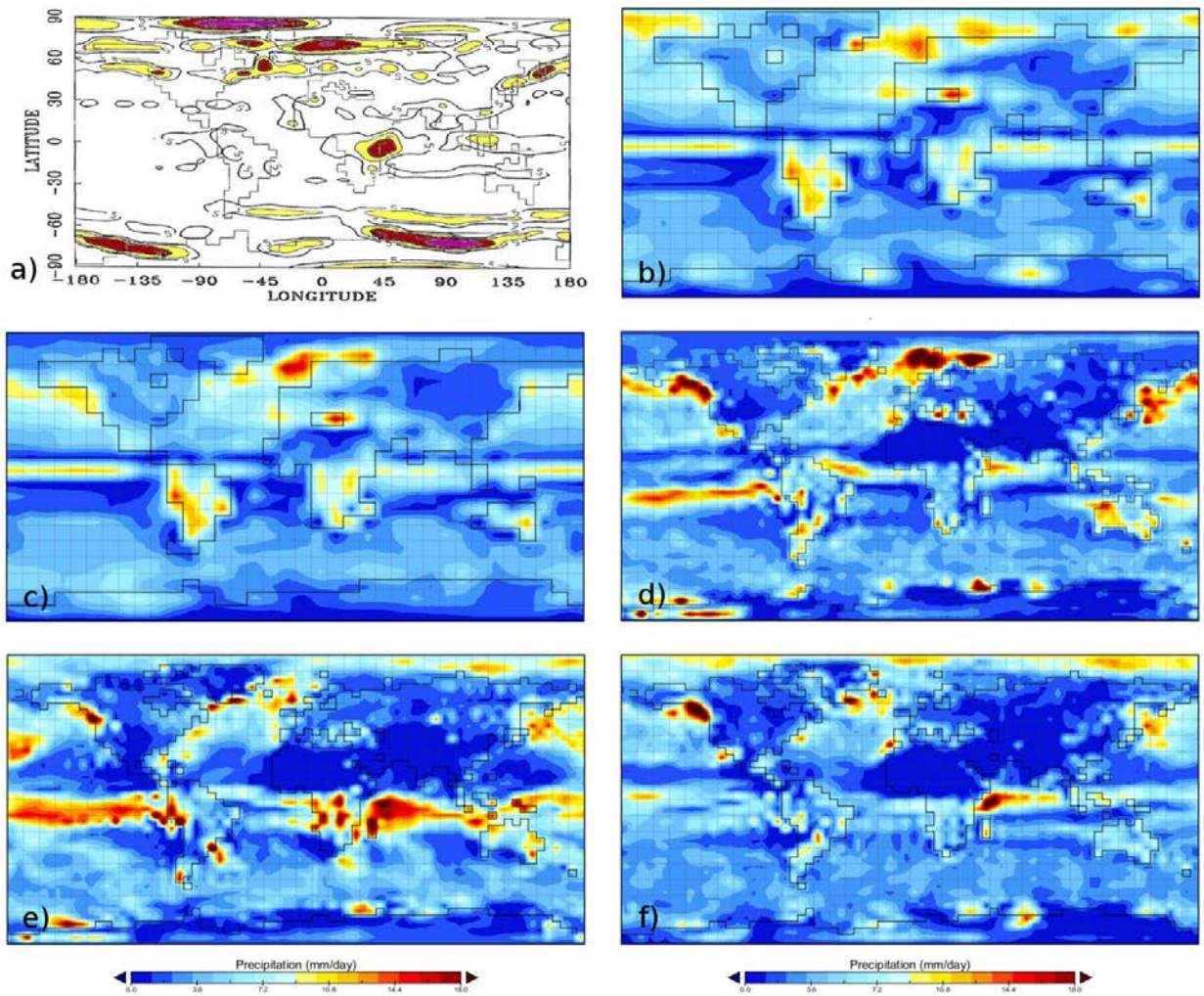

Figure 3 Comparison of precipitation rates between different models with 30 ºC sea surface temperatures. a) CCM1 perpetual January with sea ice (Max precipitation 40 mm/day) b) GISS Model II multi-year January average without sea ice (Max precipitation 17 mm/day) c) GISS Model II multi-year January average with sea ice (Max precipitation 18 mm/day) d) GISS Model E January with sea ice (Max precipitation 28 mm/day) e) GISS Model E January with dynamic oceans (Max 29 mm/day) f) GISS Model E January with dynamic oceans and τ=2 stratospheric aerosols (Max 25 mm/day)

Dynamic Ocean Model

GCMs have an advantage over weather models by incorporating boundary conditions that change during the simulation by coupling in ocean, land process, and sea ice models. To make use of this advantage, simulations with the GISS Model E were implement using a dynamic warm ocean. Instead of setting sea surface temperatures to a uniform value of 30 ºC, the entire depth of the ocean was set at 30 ºC and allowed to circulate and cool based on the laws of physics incorporated in the ocean model. Running for five years of model time the final January was analyzed. During those five years, oceans in the high latitudes begin to cool. Sea and land ice also melt back substantially. As a result, the land/sea temperature contrast is weakened, thus reducing the amount of precipitation in the Arctic and Antarctic as seen in Figure 3e. As a result of all water being 30 ºC at the beginning of the simulation, polarward transport of heat by the

ocean is cut off resulting in enhanced equatorial sea surface temperatures. This in turn increases precipitation in these regions.

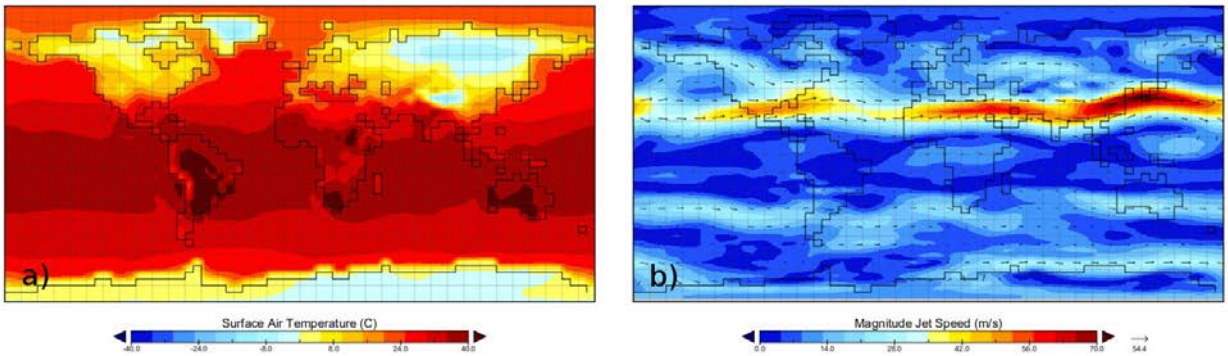

Figure 4 a) Surface air temperature and b) jet stream vectors for simulation with 30 ºC dynamic oceans.

The dynamic ocean demonstrates more significant effects than shifts in precipitation patterns. As seen in Figure 4a, surface air temperatures increase dramatically. Heat trapped in the equatorial regions causes air temperatures above the ocean to reach 38 ºC and temperatures of up to 53 ºC over some continents. After five years of simulation time, the average global air temperature in January reaches 29 ºC, 15 ºC above current day values. January snowfall is still possible over Northern Asia, Greenland and Antarctica, but these cooler temperatures are possible due to the albedo of the initial ice sheets, which are rapidly melting back. The jet stream position is similar to the current day; however, the magnitude is greatly enhanced reaching speeds of more than 70 m/s.

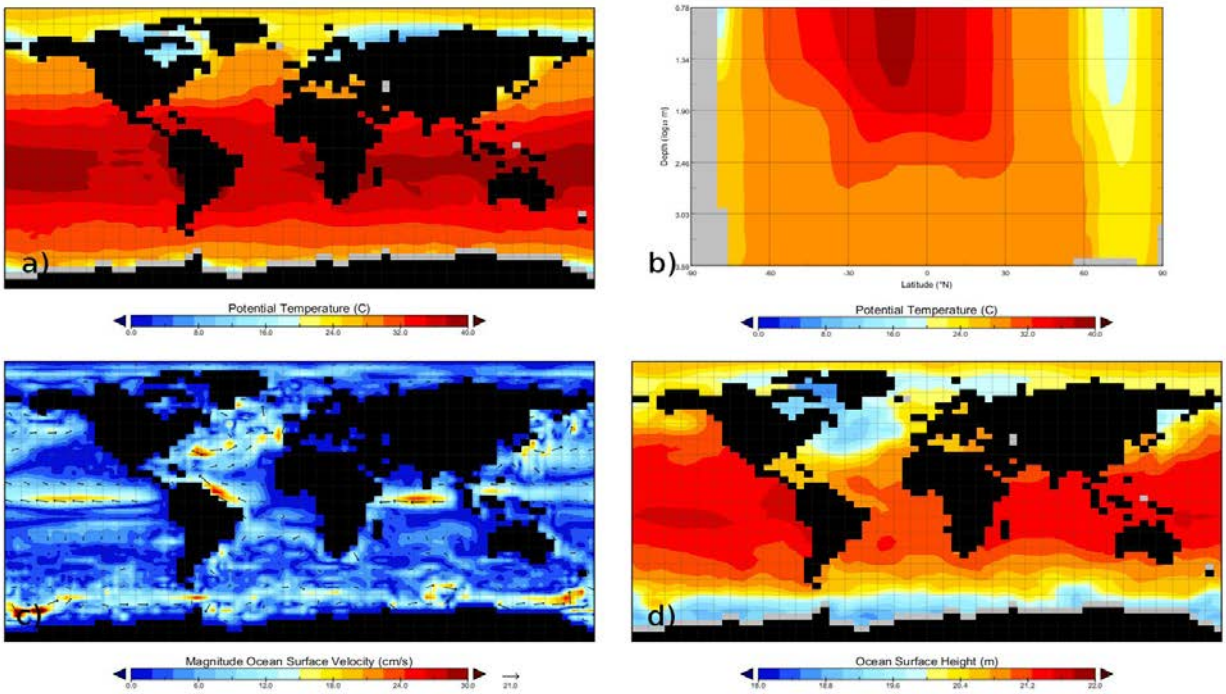

Figure 5 30 ºC dynamic ocean after five years. a) Sea surface temperatures, b) Latitudinal average of sea temperature plotted against the log value of the depth, c) Surface currents and d) Ocean surface height compared to current day average height.

The surface air temperatures make sense when compared to the sea surface temperatures (Figure 5a). Although the ocean begins at a uniform temperature, the average equatorial temperature increases to 38 ºC with pools of water at 42 ºC. Figure 5b shows a vertical cross-section of the ocean by plotting the latitudinal average against the depth. To accentuate the surface waters, the vertical is plotted as a log of the depth. Cool water at the poles sinks causing warm water to rise at the equator forming a single, large convective pattern. Unlike modern day conditions, circulation is not primarily restricted to the surface. According to Marshall and Plumb (2008) a fully mixed ocean has a time constant of 40 years. If this mode of circulation persists, then after five time constants (200 years) the ocean would be within one percent of its equilibrium value of 4 ºC. At some time in the ocean cooling, there will be a transition to a decoupled surface and deep ocean, which will change the time constant for the mixed surface layer and increase the circulation time for the deep ocean. Figure 5c shows the surface ocean currents. The most interesting feature is the convergence of currents in the North Atlantic. This is consistent with a strong down-welling of polar water. An alternate way of illustrating this is with the ocean surface height (Figure 5d). The lowest heights of the ocean surface are in the North Atlantic. Therefore, surface water from the Equator flows downhill into this region. Notice that all of the surface heights are above current day values by a range of 18.6 and 21.6 meters. This is due to warm water occupying a larger volume. Although these increased heights would change the coastline, this effect is not incorporated into the simulation.

SECTION III – VOLCANIC AEROSOLS

Warm oceans have a significant impact on surface air temperatures and must be offset by a cooling mechanism. Using Model E with a fixed sea surface temperature of 30 ºC, the globally averaged surface air temperature during the first January of the simulation reaches 23.7 ºC. Current day values are 14 ºC. In the dynamic ocean simulation the global average is 25.1 ºC and by the fifth year the January average increases to 29.1 ºC due to the increased heat flux from the cooling ocean. At these temperatures accumulation of snowfall needed for ice sheet formation is not possible. Therefore, the increased heating of the atmosphere from the ocean must be offset by the cooling mechanism of volcanic aerosols as proposed by Oard.

Aerosols have a two-fold effect on radiation in the atmosphere. The primary effect is cooling due to the reflection of solar radiation. The secondary effect is heating as a result of re-radiated terrestrial radiation back to the surface. As reported earlier in this paper, Mount Pinatubo resulted in a 0.7 ºC reduction of worldwide temperatures while Tambora resulted in a 5 ºC reduction. To offset ocean heating, eruptions of greater magnitude than Tambora are necessary. Computer models use the concept of optical depth to represent the impact of aerosols. Some call it an extinction factor whereby one optical depth results in a transmission of $e^{-1} = 0.368$ of the sunlight. The remaining 63.2 % of the radiation is either forward scattered, absorbed or reflected back into space. Mount Pinatubo has an extinction factor around 0.1 while Tambora has an extinction factor of 0.333 (Robertson *et al*., 2001; Sato *et al*., 1993). These values are from either direct measurement or estimations based on observed effects or deposits in ice cores. The distribution of aerosols is not uniform and is concentrated near the latitude of the eruption. Over time the aerosols reach high latitudes, but with a reduced effect.

An initial set of simulations with Model E were performed to study the impact of a Tambora scale volcanic eruption. To eliminate the impact of aerosol distribution on atmospheric circulation, a uniform optical depth of 0.333 was applied to all latitudes. With fixed 30 ºC sea surface temperatures, the initial January surface air temperature was only reduced by 0.1 ºC compared to the similar run without aerosols. Applying the same aerosol levels to the dynamic ocean, surface air temperatures were reduced by 0.35 ºC. Running the model for two months is not enough time to demonstrate the long term impact of this level of aerosols; however, it is clear that this level is inadequate to offset the increased heat flux from the ocean.

Another set of simulations were performed using an optical depth of 2.0. This is a significant increase in volcanic activity and may be the result of a single Toba scale event or multiple Pinatubo or Tambora events across the globe. The fixed sea surface simulation resulted in a 0.58 ºC reduction during the first January and the dynamic ocean simulation resulted in a 0.97 ºC reduction. Although these values do not offset the 11 ºC increase of global surface air temperatures compared to current day values, the cooling impact is significantly greater and will drive the warm ocean environment to current day values at a quicker rate.

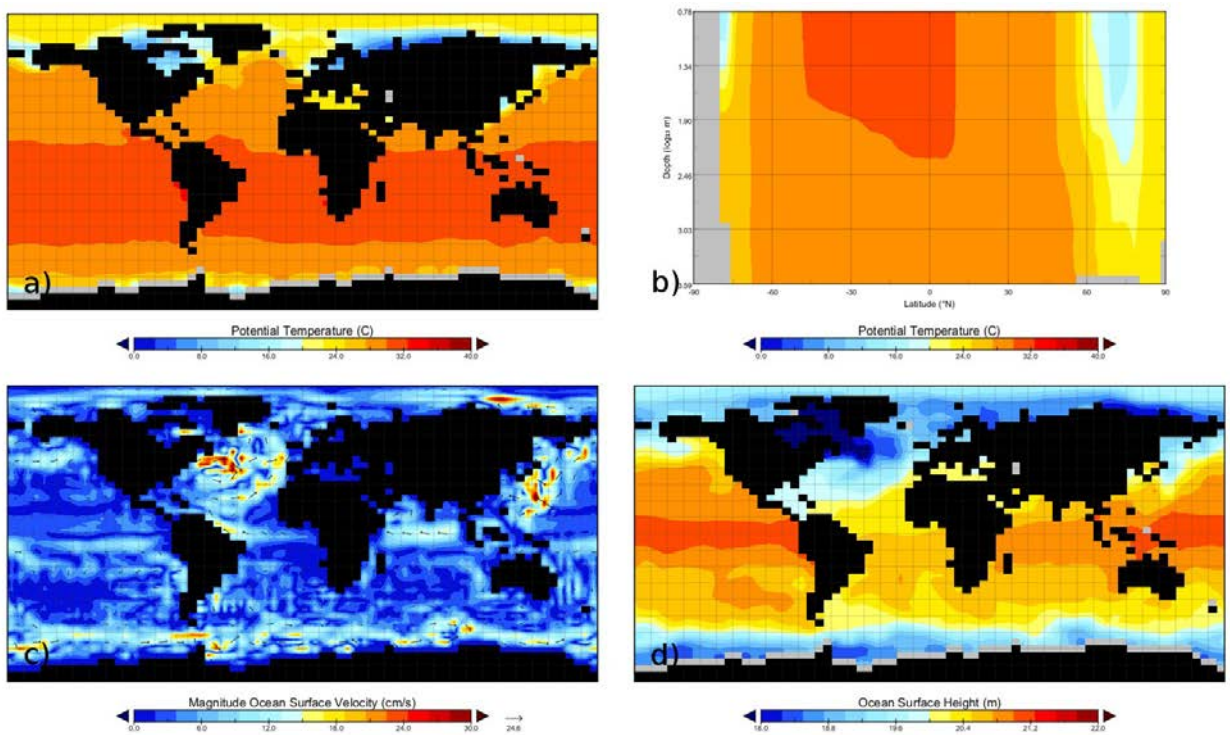

Figure 6 Dynamic ocean after five years using an aerosol optical depth of 2.00. a) Sea surface temperatures, b) Latitudinal average of sea temperature plotted against the log value of the depth, c) Surface currents and d) Ocean surface height compared to current day average height.

Comparing Figure 5 to Figure 6 shows the impact of an aerosol optical depth of 2.00 after five years of simulation time. Although ocean temperatures reach 42 ºC in the aerosol free simulation, the maximum ocean temperatures are 34 ºC for aerosol depth of 2.00. This has an impact on the global average surface air temperature by bringing it down from 29 ºC to 24 ºC. It is also evident that cooling of ocean water at the high latitudes is greater as seen in Figure 6a. Figure 6b demonstrates how cooler water is penetrating deeper into the ocean over the same time

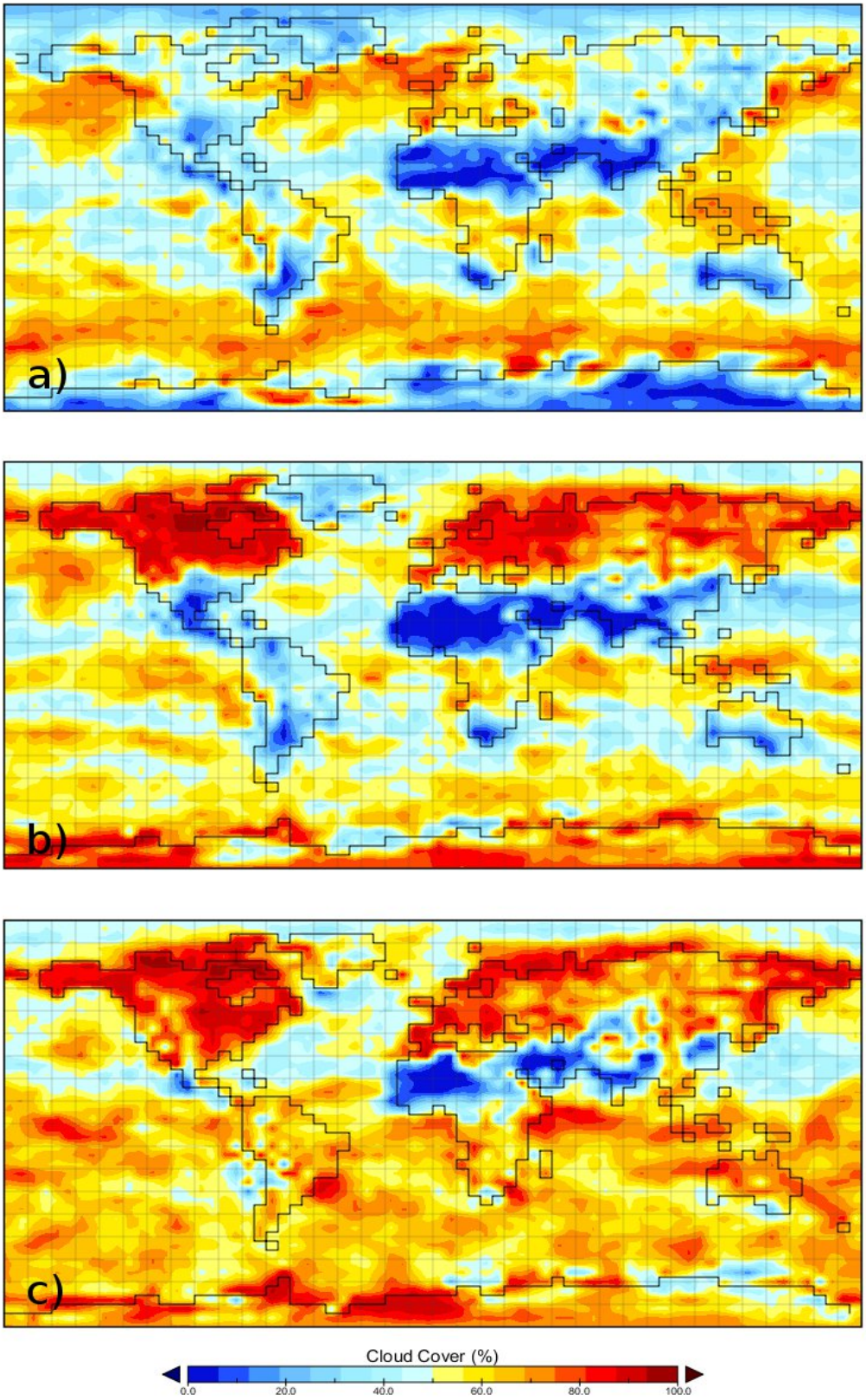

Figure 7 Comparison of January cloud cover between the a) Reference run at current day values, b) Dynamic oceans set at 30 ºC and c) Dynamic ocean at 30 ºC with aerosol optical depth of 2.00.

period and the pool of hot equatorial waters is decreased. Increasing the cooling of the ocean does not change the time constant of the ocean, but does change the equilibrium temperature to a colder temperature, thus allowing the ocean to reach current day values sooner. If the large aerosol effect is not removed, the final global average of sea level temperature will be well below 14 ºC. The height of the ocean in the North Atlantic is reduced by over one meter (Figure 6d) and results in an increased convergence of ocean currents in the same region (Figure 6c).

Increasing the aerosols also has an impact on cloud cover over the earth's surface. Compared to a reference run at current day values (Figure 7a), the dynamic ocean at 30 ºC (Figure 7b) has a larger percentage of clouds which are shifted over the high latitude continents. Figure 7c shows the effect of adding an aerosol optical depth of 2.00. The continents are still heavily cloud covered, but there is also a noticeable increase of cloud cover over the Southern Hemisphere oceans. The cloud cover plots in Figure 7 are for clouds of significant thickness ($\tau > 1$). This ignores the presence of thin cirrus over the arctic, which can have a warming effect. However, the clouds plotted have an impact on the earth's albedo, which can enhance cooling beyond what the aerosols can do alone.

CONCLUSION – RELEVANCE AND FUTURE RESEARCH

This research compares simulations using the GISS Model II and Model E with work done by Spelman and Vardiman on the NCAR CCM1. Although the resolution of the models is different, the precipitation patterns are qualitatively similar. The magnitude of precipitation differs; however, this is most likely due to the smoothing effect of statistical averages. It does seem that the higher resolution model gives larger precipitation amounts near the land/sea boundaries of the models. This amount is deceptive because it is due to the presence of land and sea ice, which would melt away in the presence of 30 ºC oceans.

The most significant impact of warm oceans is an enhanced surface air temperature. Although these temperatures are bearable at higher latitudes, equatorial temperatures of over 40 ºC (104 ºF) seem unbearable. This begs the necessity of a cooling mechanism or the need for early post-diluvian residents to remain at high altitudes to take advantage of cooler mountainous weather. The benefit of recent climate models is the ability to simulate dynamic oceans and incorporate the impact of volcanic aerosols. The dynamic ocean simulations demonstrate that 30 ºC oceans do not remain at 30 ºC. Cutting off polar transport of heat and adding equatorial heating results in ocean temperatures of more than 38 ºC. This increases the surface air temperature even more, which would impact residents of equatorial regions. Cooling at the poles results in a convective circulation pattern and this extends over the depth of the whole ocean. This circulation mode of the ocean will affect sediment deposits differently than the current day mode, which has a decoupled surface mixed layer and deep ocean. The transition between these two modes may explain the shift between the 41 Ka and 100 Ka cycles found in ice cores.

Volcanic aerosols seem to be a reasonable cooling mechanism; however, they can lessen arctic cooling due to the greenhouse effect on terrestrial infra-red radiation. The cooling effect of aerosols is most prominent in equatorial regions. Although simulations performed with uniformly distributed aerosols did not impact atmospheric circulation patterns, simulations with aerosols restricted to equatorial regions enhance the polar/equatorial temperature contrast, thus

shifting the jet stream. Aerosol optical thickness of 2.00 also seems large. This implies that direct sunlight is reduced to 13% of its current value. Under these conditions the sun would appear indistinct and not generate a rainbow, which would increase the significance of the sign to Noah, if indeed these are the post-flood conditions.

There are a number of unresolved issues and one substantial project suggested by this paper. 30 ºC oceans at the end of the flood may be necessary for an ice age of the extent and duration suggested by Oard; however, by reducing initial sea surface temperatures it is possible to improve the habitability of equatorial regions immediately after the flood. Since onset of an ice age, must wait until oceans reach an acceptable temperature, there is no reason to maintain them at such a high temperatures unless they generate the ocean dynamics needed for the onset of a rapid ice age. If the ocean fails to cool to acceptable levels within the first decades after the flood, the onset of the ice age will be delayed and, therefore, reduce the magnitude of the ice age. It is estimated that the average ocean temperature will fall below 15 ºC within 40 years. To truly test out Oard's model a multi-century simulation with appropriate initial conditions must be run. There is value in performing shorter simulation runs. It is still necessary to characterize the ocean temperature and aerosol levels needed to initiate heavy snow fall over high latitude continents. It is desirable to determine the lowest aerosol rates needed since heavy, post-flood vulcanization will inhibit recover of a catastrophically impacted environment. Reduced sunlight levels will limit growth rates of plants and the presence of mercury, acid rain and other pollutants will affect the health of plant and animal populations.

The value of GCMs in modeling the post-flood environment is an underused tool, which can provide useful insights for creation scientists. Estimation of first-order ocean/atmospheric effects as done by Oard are an import first step; however, higher-order effects from feedback loops in the earth system are not easily anticipated. Once a plausible multi-century, post-flood simulation is generated, it will be possible to study erosion, bio-productivity and successions of ecosystems. God's creation is marvelously robust and current GCMs are limited by our current understanding of the earth's interoperating systems. The differences between simulations and geological data may give insight into earth systems that are currently dormant, but active during catastrophic events. It is only through continued research that these advancements in creation science will be realized.

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