Pre-Flood Vapor Canopy Radiative Temperature Profiles

David E. Rush, MS,
c/- Institute for Creation Research, PO Box 2667, El Cajon, California, 92021, USA.

Larry Vardiman, PhD,
Institute for Creation Research, PO Box 2667, El Cajon, California, 92021, USA.

Presented at the Second International Conference on Creationism, Pittsburgh, Pennsylvania, July 30–August 4, 1990 and published in: Proceedings of the Second International Conference on Creationism, *R.E. Walsh & C.L. Brooks (Eds.), pp. 231–240, 1990.*

Abstract

Using a widely accepted radiance program, temperature profiles for various pre-Flood vapor canopies are calculated. The profiles are for pure radiative equilibrium, with no clouds or convective adjustments. This is the first step in answering the question, "Could a vapor canopy have provided a worldwide climate suitable for human habitation?" It is found that water vapor canopies ranging in size from 10 to 1013 mb produce temperatures at the canopy base hot enough to maintain water in the vapor phase, and hence ensure a stable canopy. However, canopies in the range from 50 to 1013 mb, and perhaps even canopies from 10 to 50 mb, also produce inhospitably high surface temperatures. The addition of clouds in future work would appear to hold promise of modifying these conclusions greatly.

Keywords

Temperature Profiles, Pre-Flood Vapor Canopy, Radiative Equilibrium, Radiation Models, Clouds, Heat Balance

Introduction

The idea that the atmosphere of the ancient earth may have been overlain by water in one phase or another was apparently first thought of, at least in modern times, by Isaac Vail (1905), a uniformitarian. For Vail, the canopy that collapsed to contribute to the biblical Flood of Noah's time was merely the last of many canopies that had existed throughout earth's long history. They had formed from outgassing of the earth's interior, and their collapse over geologic time had formed the oceans. But the idea of a vapor canopy in Noah's time appealed to creationists, where it took root and began to be incorporated by them in models of earth history. The modern day revival of creationism is usually dated to 1961, with the publication of *The Genesis Flood* by Whitcomb and Morris. A water vapor canopy played an important part in their model. It continues to have a major role in many creationist models of the ancient earth.

There is no direct support from science for the existence of a water vapor canopy surrounding the earth in the past. However, a survey of the solar system reveals that five of the nine planets, including the one closest to us in distance and size, Venus, have thick cloud canopies. Direct support from Scripture for a canopy comes from Day 2 of creation week.

> And God made the firmament (atmosphere), and divided the waters which were under the firmament from the waters which were above the firmament: and it was so (Genesis 1:7).

An important effect of canopies in the solar system today is to moderate temperatures beneath them. Planets that do not have canopies show a much wider variance in temperature—diurnally, yearly, and latitudinally. Earth is characterized by a fairly large and permanent temperature gradient between its equator and poles. This temperature gradient produces a pressure gradient, which becomes the driving force behind weather systems of the planet. But nearly all creationists and uniformitarians agree that at some time in the past the planet enjoyed a warmer, more uniform climate from pole to pole. Concerning the Cretaceous for example, uniformitarians Barron, Thompson, & Schneider ((1981) say,

> The contrast between the climate of the Cretaceous period (65 million to 140 million years ago) and that of the present epoch is the largest in the history of the earth that has been fairly well documented. A fundamental problem in paleoclimatology is how a globally ice-free climate could be maintained … The Cretaceous climate has been classically described as warm and equable on the basis of "climate sensitive" sedimentary indicators, characteristics of fossil floras and faunas, and oxygen isotope data … The Cretaceous was the acme of exothermic reptiles. As yet, unequivocal evidence of permanent ice is

unknown … Cretaceous polar temperatures have been estimated by various observers to be between 5 and 19°C.

Scripture also offers some evidence that the pre-Flood climate worldwide may have been dramatically different than today's. Genesis 2:5, 6 raise the possibility that there was no rain on the earth from Adam to Noah. During this time vegetation was watered by a mist rather than rain. Genesis 2:25 implies that climatic conditions were warm everywhere on earth because Adam and Eve and their descendants were to populate the earth and be comfortable all year around without clothing. Genesis 8:22 first mentions hot and cold, summer and winter, in connection with seasons. Genesis 9:12–16 establishes the Noahic covenant, with its sign, the rainbow. This is the first time that a rainbow or a cloud is mentioned in Scripture. Clouds are of course necessary for rain, and a rainbow is simply an optical phenomena caused by sunlight on rain drops. As before, however, the Bible does not explicitly state they did not exist before the Flood. For amplification of biblical arguments for a warm pre-Flood climate, see Dillow (1982).

These tantalizing hints from the Bible are certainly compatible with the idea that earth's climate has been very different. Taken together, they are consistent with a warm climate worldwide. A warm, equable climate year-round would be less likely to have any of the atmospheric "natural disasters" that periodically afflict today's world, such as hurricanes, floods, tornadoes, blizzards, hailstorms, etc.

So we see that evidence from geology and the Bible seem to point to a very different global climate in the past. In addition, elements of many ancient legends also tend to support this conclusion (Dillow, 1982, chap. 4).

This paper addresses one traditional tenet of the creation model. A water canopy in some form has been proposed by many creationists to explain biblical and scientific evidence for climatic conditions before the Flood. This paper is a status report of ongoing research to solidify the physical basis for the vapor canopy model.

Possible Causes of a Warm Climate

To warm the earth significantly, at least one of two things must happen: either the earth must receive more radiant energy from the sun, or it must retain more of the heat it does get. We may label the first possibility as processes that affect primarily the incident solar, or shortwave, radiation absorbed at the earth's surface. We may call the second option processes that primarily affect the infrared, or longwave, radiation the earth emits. The first possibility, that of increased shortwave radiation, may be met by a hotter sun, a decreased earth-sun distance, lower albedo (reflectivity) of the atmosphere or the surface, or any other process that increases the net absorbed solar radiation at the surface. Most creationists and uniformitarians say that the shortwave factors may indeed have been contributing causes, but they look to the longwave for the primary cause of ancient warmth. A longwave factor means that the earth somehow retained more of the solar radiation it received. The only way this could be done is with a different atmosphere.

Of key importance to us on earth are only three constituents of the atmosphere: CO_2, H_2O, and O_3. These three species account for about 99% of radiative interplay. The three major components of the atmosphere, nitrogen, oxygen, and argon, are practically transparent to both shortwave and longwave radiation (except for one narrow solar absorption band of oxygen). Today's atmosphere is not primarily heated from above, by the sun, but from below, by the earth. This is because the atmosphere is more transparent to shortwave radiation than longwave. Increasing mixing ratios (concentrations) of those molecules that absorb more longwave than shortwave (as both water vapor and carbon dioxide do) has the net effect of *warming* the atmosphere, which in turn emits more longwave. This warms the surface further—resulting in the so-called "greenhouse effect."

In modeling the ancient climate, uniformitarians usually assume that the total amount of water vapor in the atmosphere has not changed significantly in the past. That is, even though the water vapor concentration (mixing ratio) today varies widely with location and time, the assumption is that the total amount of water vapor in the atmosphere has been essentially unchanging over very long periods of time. Uniformitarians also assume the amount of ozone, which has a fairly minor effect overall compared to the others, has also been constant. So, they normally introduce large amounts of carbon dioxide into their models (for example, Berner, Lasaga, & Garrals, 1983; Budyko, 1988, p. 3; Hunt, 1984). Carbon dioxide is uniformly mixed throughout the atmosphere (unlike water vapor and ozone), and is assumed to have had a much higher concentration in the past. The excess carbon dioxide is now thought to be tied up in rocks of the crust.

The Bible, however, hints at another cause for a worldwide equable climate—"the waters which were above the firmament." The Bible never says the original atmosphere was different than today's (indeed, it can't be much different and support the life it does). What it does say is that the atmosphere ("firmament") was standing between waters beneath it (the oceans) and waters above it. At present there are of course no waters above the atmosphere; but at the beginning of the Flood, God "opened the windows of heaven" and perhaps emptied onto the earth all the waters that had been there. Some creationists have proposed that the antediluvian "waters above" would have been stable (at least for thousands of years) if the water was in its vapor phase. This would have the effect of covering the present atmosphere with a water vapor blanket, or canopy. From the time of Creation until the Flood, a canopy of water in vapor form surrounded and rested upon an atmosphere similar to today's. This canopy, a longwave forcing mechanism, provided an equable worldwide climate until the beginning of the Flood, when its collapse produced 40 days and nights of rain.

A successful vapor canopy will meet two criteria:

- The canopy must be stable. Once in place, it must be kept in place by the laws of physics. (Arguments that appeal to a continuing miracle to maintain the canopy, such as Johnson's (1986) and Udd's (1975), are by this criterion rejected.)
- The surface temperature must be hospitable to human beings.

A one-dimensional radiation balance between the earth-atmosphere-canopy system is the necessary starting point in meeting these criteria. This is so because exchange of radiant energy is the dominant mode of energy exchange in the atmosphere. Dillow (1982) attempted this, but freely admitted (p. 247) that his work was a "*progress report* rather than a complete solution." His handicap was the lack of a sophisticated radiance program with detailed spectral data. Such a program is now available and may be used to construct vertical temperature profiles from radiation balances with a high degree of confidence. Such profiles may not in themselves provide definitive solutions to the two primary criteria of stability and surface temperature, but they are a necessary starting point. The goal of this work therefore is construction of one-dimensional, pure radiative equilibrium temperature profiles of the earth-atmosphere-canopy system.

Development of the Method

A number of simplifying assumptions have been made:

- The problem is addressed in one dimension only. Two and three dimensional analyses, which involve meridional heat and mass transfer, in the atmosphere and preferably the oceans also, are much too complex for the first phase of this study. Such routines require expensive main-frame time, and in any case rely ultimately on a one-dimensional analysis.
- Radiation only will be considered. Other processes active in today's atmosphere are convection, diffusion, conduction, and latent heat release/gain. Of these, only convection and latent heat processes (besides radiation) noticeably modify the temperature profile in the stratosphere and below. However, the radiation calculation must be done first, and its shape will determine whether or not convection can take place. If convection is active, knowledge of water vapor content as a function of altitude may then be used to figure latent heat effects, which will further modify the temperature profile. The addition of these two effects is relatively simple, and could readily be added onto this work if necessary.
- Calculations will be done in a clear sky, with no clouds and no aerosols.

The goal is to obtain one-dimensional, pure radiative temperature profiles for various water vapor canopies covering today's atmosphere. The key element in this whole process is determining radiances. For nearly 20 years scientists at the U.S. Air Force Geophysical Laboratories (AFGL) have worked on a public domain atmospheric radiance (and transmission) program called LOWTRAN. The present version, LOWTRAN 7, is dated 1989, and contains 18,000 source lines of Fortran code (Kneizys, 1988). The spectral data used is from the Laboratories and is generally considered the finest available anywhere. The program is capable of calculating atmospheric absorption and radiance for a wide range of absorber concentrations, pressures, and temperatures. Its primary purpose is not for climate modelling as such, but since it gives radiances it may be used to calculate fluxes, and hence temperature profiles. A number of programs, totaling some 2,200 Fortran lines, were written for this research to manage LOWTRAN 7 for the task.

LOWTRAN 7 has significant improvements over earlier versions. Foremost among these are the addition of multiple scattering, updated water vapor continuum absorption values that now include the region from 0–350 cm^{-1} (∞–28.6 μm^{-1}), and an improved solar source function. For further details, see Kneizys, Shettle, Abreu, Chetwynd, Fenn, Gallery, Selby, & Clough (1983) or Kneizys, Shettle, Abreu, Chetwynd, Anderson, Gallery, Selby, & Clough (in prep.). LOWTRAN 7 is used to compute the integrated radiances at given levels in the atmosphere. Five separate calculations are made: (a) shortwave directly-transmitted solar radiation, (b) shortwave multiple-scattered downward solar radiation, (c) shortwave multiple-scattered upward solar radiation, (d) longwave upward emitted radiation, and (e) longwave downward emitted radiation. Once the integrated radiance over the desired wavelength interval is obtained from LOWTRAN 7, net fluxes are calculated. The total flux leaving a layer is subtracted from that entering, and the result, ΔF, is used to figure the heating.

The atmosphere is divided into 20 or more "atmospheric levels" of specified altitude, pressure, temperature, and absorber concentration. Pressure and absorber concentrations at each level are constant, altitudes and temperatures vary with time. All radiance calculations are taken at constant pressure "flux levels," chosen so that each atmospheric level is exactly halfway between two flux levels. The region between two flux levels is called a layer. The cooling rate of a given layer is then:

$$\frac{dT}{dt} = \frac{g\Delta F}{C_P \Delta P} \tag{1}$$

where dT/dt is the rate of change in temperature of the layer, g is the acceleration due to gravity, C_P is heat capacity at constant pressure, and ΔP is the pressure change across the layer. The heating (cooling) rate is then converted to a new atmospheric level temperature by the equation,

$$T_{n+1} = T_n + \frac{dT}{dt}\Delta t \tag{2}$$

where T_n is the temperature at the nth iteration, and Δt is the time interval. The process is then repeated as often as needed until pre-set criteria for equilibrium are met.

Testing of the Model

As stated earlier, the goal of this study is to construct several one-dimensional pure radiative equilibrium temperature profiles through today's atmosphere with various water vapor canopies overlying. LOWTRAN 7 has been compared with other radiation models, according to AFGL, and is in wide use. But to our knowledge it has not been used in its entirety in this type of theoretical study, though parts of it have been used by others (for example, Chou, 1986; Thompson & Warren, 1982). Professor Pallmann of St. Louis University is in the process of incorporating LOWTRAN 7 into a radiation program (A.J. Pallmann, personal communication, 1989). Accordingly, it was mandatory that our method be compared to known results for today's atmosphere. Manabe & Strickler (1964) constructed a widely accepted pure radiation profile for today's atmosphere (see for example, Liou, 1980, pp. 336–338 this was based on research by Manabe & Möller, 1961). Even though the last 25 years have seen much work on the radiation problem, and many new results on individual aspects of it, the net effect has been simply to confirm the Manabe & Strickler profile. Their curve is still widely honored as a calibration curve, with the exception that their surface temperature is too high, which will be discussed later.

The Manabe & Stickler procedure was followed as closely as possible. To ensure an overall energy balance, two conditions are monitored: (a) the earth's surface is assumed to have zero heat storage capacity; therefore all incoming shortwave and longwave radiation absorbed by the ground is returned upward as longwave radiation. This ensures a surface net flux of zero at all times. (b) As a criterion for equilibrium, the planetary heat balance (the net incoming shortwave less the outgoing longwave, measured at the top of the atmosphere) is expected to approach zero. Other conditions of the Manabe & Strickler modeling are also met. The time interval chosen is eight hours, except that shorter intervals are used as equilibrium is approached. Air temperature of the lowest layer is assumed to be the same as the ground temperature. Variable absorber concentrations (H_2O and O_3) are taken from Manabe & Strickler figures, both for April at 35°N. Constant pressure levels are set the same as theirs. Surface albedo is assumed to be 0.10. Manabe & Strickler do not say how scattering was handled except that Rayleigh scattering was assumed to contribute 7% to the planetary albedo. This assumption was not used. Instead, scattering fluxes (up and down) were obtained by integrating radiances over a hemisphere.

Figure 1 shows the warming of an initially cold isothermal atmosphere. The top of each line represents the "top" of the atmosphere at 2.3 mb. It slowly rises as the atmosphere beneath it warms up. It is apparent from Figure 1 that a pure radiative equilibrium profile does not accurately describe the actual temperature profile in today's atmosphere. The surface is too warm and the upper troposphere too cold. The reason is that convection is not taken into account. When Manabe & Strickler added a convective adjustment, their results were a much better approximation to the actual temperature profile. However, for this study we are interested only in a radiative profile.

Two deviations from Manabe & Strickler's

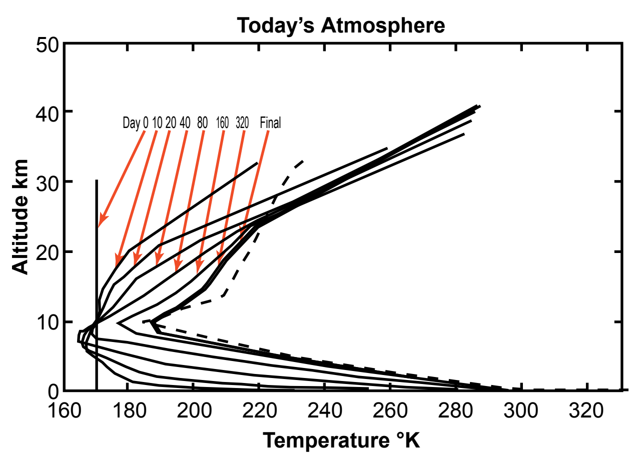

Figure 1. Vertical temperature profile for today's atmosphere starting from an isothermal 170° condition approaching the Manabe & Strickler (1964) result. Solid profiles are model results at indicated days after day 0 and dashed line is Manabe & Strickler profile.

equilibrium are evident. Their surface temperature is 332 K, and ours only 320 K (the original Manabe & Möller, 1961 value was 313 K). However, 332 K is above that of most modeling programs currently im use, which give temperatures in the 320s (Briegleb, 1989; Pallmann, 1989). Both Briegleb and Pallmann say a value of 320 K is acceptable. The precise value depends on exact absorber profiles, absorption coefficients, and a host of minor parameters. The other deviation is in the stratosphere, but this could be caused by slight differences in absorber concentrations. Manabe & Strickler note that "The upper stratospheric equilibrium temperature depends very much on the distribution of water vapor" (though the overall heating of the stratosphere is caused of course by ozone). Also, efforts over the years at AFGL and elsewhere have provided more precise absorption coefficients for all absorbers. In any case, Manabe & Strickler say that the stratospheric temperature profile "… affects the temperature of the earth's surface and troposphere very little (less than 1°) judging from the present results." Therefore, the deviation between their results and ours in the stratosphere is not judged important for this work. We may conclude that our model compares favorably with an accepted standard for today's atmosphere.

In addition to the Manabe & Strickler comparison, a set of flux values were calculated for an atmosphere used by the National Center for Atmospheric Research to test radiance programs (Kiehl, Wolski, Briegleb, & Ramanathan, 1987). Comparison with their results was also favorable (Briegleb, 1989).

Initial Canopy Conditions

Four different canopies were carried to completion. Water vapor amounts in the canopies were 10, 50, 125, and 1013 mb. Unless otherwise noted, characteristics of the atmosphere and other assumptions were the same as in the Manabe & Strickler calibration test. The Manabe & Strickler atmosphere was geared to April, 35 °N, and differed only slightly from the U.S. Standard Atmosphere. The solar zenith angle was set at 60°, and day fraction at 0.5. This approximates average conditions on the earth. A surface albedo of 0.13 was used (Barron , Thompson, & Schneider, 1981), a value midway between today's values of 0.08–0.20 in humid regions (Laval & Picon, 1986). It happens that the ocean albedo at a solar zenith angle of 60° is also 0.13 (Ramanathan, Cess, Harrison, Minnis, Barkstrom, Ahmad, & Hartmann, 1989). This is somewhat less than today's average surface albedo for the earth (including polar regions) of 0.14–0.18 (Ramanathan & Coakley, 1978). The day of the year is 109, a day in mid-April, a time of average earth-sun distance. This gives an average value for the solar constant. Spectral intervals used unless otherwise noted: Solar direct: 3,500–40,000 cm^{-1} (2.86–0.25 μm^{-1}) dv=20 cm^{-1}. Scattering: 8,000–40,000 cm^{-1} (1.25–0.25 μm^{-1}) dv = 1,000 cm^{-1} Longwave: 20–3,500 cm^{-1} (500–2.86 μm^{-1}) dv=20 cm^{-1}. Longwave fluxes were calculated by the formula F=πI. Shortwave scattering fluxes were calculated by numerical integration of radiances over the hemisphere. Shortwave directly transmitted flux is obtained straight from LOWTRAN 7. It was not necessary to calculate each of the solar fluxes at every iteration, as they are only slightly temperature dependent. New solar fluxes were obtained only once every 30 iterations, or less often as equilibrium was approached, saving much computer time.

Discussion of 50 mb Canopy Results

The 50 mb canopy will be described in some detail and the other results summarized. 50 mb of water vapor is equivalent to 20 inches of precipitable water. Figure 2 shows radiative equilibrium approached from a cold isothermal beginning point. The top of each line represents the "top" of the canopy. Thus at Day 0, the atmosphere-canopy is cold and low. By Day 10, the surface is already heated to 296 K, and lower layers of the atmosphere are also rapidly heating. This is due to the intense solar radiation that has been absorbed by the ground and re-emitted as infrared, where it is readily absorbed by the relatively high water content of the lower layers. The middle layers are relatively low in water vapor and ozone (carbon dioxide has the same mixing ratio everywhere) and so they tend to be transparent to both shortwave and longwave. The upper layers constitute the stratosphere in today's atmosphere and therefore are low in water vapor and high in ozone. They are heated by absorption of solar ultraviolet.

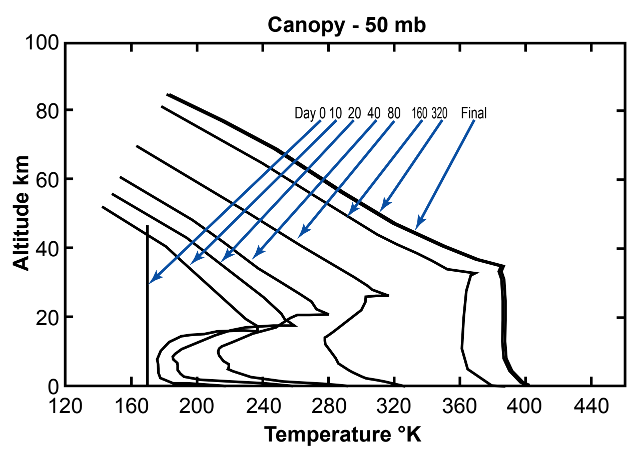

Figure 2. Vertical temperature profiles of a 50 mb canopy above today's atmosphere starting from an isothermal 170° condition approaching equilibrium

The discontinuity at about 18 km in Day 10 represents the top of the atmosphere and base of the canopy. Note that the great majority of the mass of the atmosphere-canopy is below 18 km. The lower portion of the canopy is heated primarily by absorption of longwave from the ground, but also somewhat by solar absorption. From 18 km (pressure=50 mb) to about 52 km (pressure=1.00 mb) the canopy cools as longwave radiation is emitted to space. The top cools so well that it is several months before it again attains its starting point of 170 K. However, additional months of heating do not have much effect, and it ends up at only 189 K, or −84 °C. Since the water vapor pressure at the top of the canopy (1.279 mb; changed from 1.00 during the model run) is much higher than the saturation vapor pressure at 189 K (2×10^{-5} mb), the vapor will turn to ice. At the next level, this is also true. The vapor pressure is 4.615 mb, the saturation pressure (at 246 K) only 0.27 mb, and the vapor will also tend to become ice. At the next level down however, the vapor pressure is 11.597 mb, the saturation pressure (at 284 K) is 13 mb, and the vapor will remain in the vapor form. At all lower levels of the canopy the vapor pressure is lower than the saturation pressure and the water will be in the vapor phase. A temperature of 387 K at the base of the canopy (50 mb) guarantees the vapor phase. In the final profile, the canopy base has risen to 35 km and the top (1.279 mb) to 83 km.

The critical lapse rate for water vapor, if we assume no phase change, is the adiabatic one, which is 5.3°/km. If the observed lapse rate exceeds this, convection will occur as hotter, less dense gas tends to rise and colder, more dense gas tends to sink. If the observed lapse rate is less than the critical one, there is no tendency to overturn and the canopy is stable. The lapse rate in the lowest canopy layer between 50 and 48 mb is 9.6°/km. Therefore, convection will begin. The next layer also shows a tendency to convect. Beyond this, all higher layers have a lapse rate below 5.3°/km, and will be stable. The situation is similar to that of the atmosphere today, where unstable lower layers often send mass and heat up into higher, stable layers. The topmost layers of the canopy involve a phase change, so their critical lapse rate will be different from the adiabatic one. The atmosphere itself is nearly isothermal down to the lower layers, which show slightly higher temperatures. Only in the lowest two (thin) layers is the critical (adiabatic) lapse rate of 10°/km exceeded. There will be a slight convective transport of heat from the surface into the first several hundred meters. This will lower the surface temperature by a degree or two, and raise the temperature just above by a corresponding amount. Overall, the atmosphere will be quite stable. At the surface, the initial rapid heating has slowed so much that the final six months see a rise of only one degree, to 409 K, or 35° above the boiling point of water at 1063 mb.

Figure 3 shows the heat balance of the earth at equilibrium and transmission values for the infrared, all for the 50 mb canopy. Of 100 units of incoming solar, 19 units are absorbed by water vapor in the canopy. (All absorption values include a small amount due to absorption of reflected [outgoing] solar). Eight additional units (of the 100) are absorbed by the atmosphere, and five units reflected by the atmosphere-canopy to space. That leaves 68 units that make it to the surface, most transmitted directly but some scattered. Eight units are reflected at the surface, contributing to the total planetary albedo of 13 units, and leaving 60 units absorbed by the earth. These 60 units are then re-emitted as longwave radiation. Actually, because of the very high surface temperature 478 units total are emitted by the surface, but 418 of these have been received as longwave from the canopy and atmosphere, for a net infrared loss of 60. This balances the net solar gain of 60.

An infrared energy balance of the atmosphere shows 478 units of terrestrial radiation, 349 units of infrared from the canopy entering, 418 units leaving to the ground, and 417 leaving for the canopy, for a net infrared cooling of eight units. This balances the solar absorption of eight units. A balance on the canopy shows it receiving 417 units from below, losing 349 units downward, and 87 upward to space. This is a net infrared cooling of 19 units, which balances the solar absorption of 19 units.

Overall, the 87 longwave units emitted to space plus the 13 shortwave units reflected to space account for the original 100 units received from the sun. It is readily apparent that the canopy is very effective at trapping the earth's radiation. Without the windows to space that exist today, temperatures build until the canopy's emission to space finally equals the net incoming solar. To be more precise, the windows are not totally closed with the 50 mb canopy. Also shown in Figure 3 are transmission data. These percentages show the amount of surface longwave radiation that arrives unimpeded at the canopy base (27%) and at the canopy top (11%). Without the canopy, 27% of the terrestrial radiation would escape straight to space, but with it only 11% does so. This difference may at first seem small, but it means that the entire earth-atmosphere-canopy system must heat up to the point where it radiates enough extra energy to space to make up the difference.

In conclusion, only 50 mb of water vapor added above the present atmosphere would raise the surface temperature as determined by a radiation balance from 320 K to 409 K. A better comparison is to include convection effects. Convection lowered the Manabe & Strickler ground temperature in today's atmosphere (less clouds) from a pure radiational 332 K to 300 K (Manabe & Strickler, 1964), much closer to the observed 288 K. As mentioned in discussion earlier,

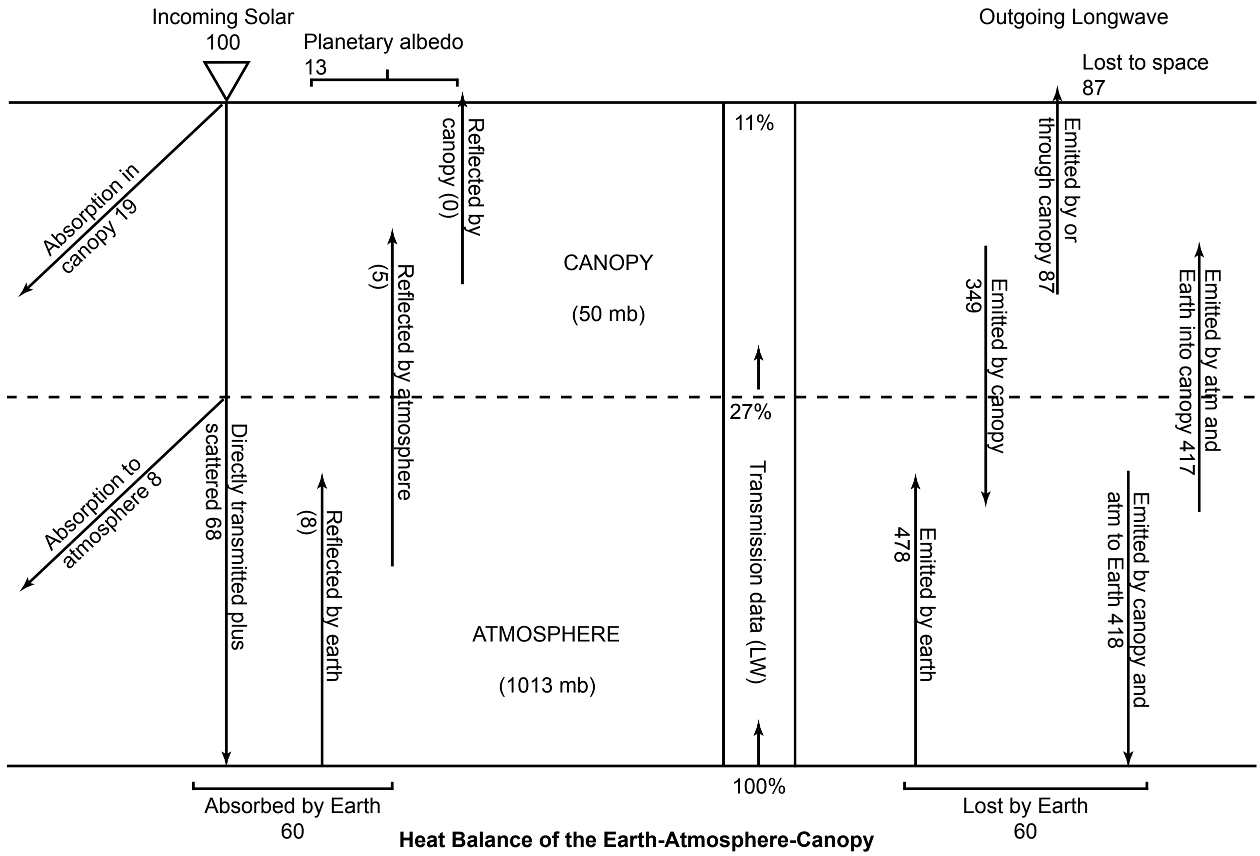

Figure 3. The heat balance of the earth-atmosphere-canopy system for the 50 mb canopy over today's atmosphere. The left portion of the diagram shows the flux of shortwave radiation, the right portion the flux of longwave radiation, and the middle portion the transmission of longwave radiation upward to space. The canopy is above the dashed line and the atmosphere is below the dashed line.

convection in the atmosphere under the 50 mb canopy would probably lower the surface temperature only a degree or two. So it seems that addition of only 50 mb of water vapor above the present atmosphere would raise the surface temperature more than 100°.

Kasting & Ackerman (1986) added 10 *bars* of CO_2 and got a surface temperature of only 400 K, including convection effects, at present solar luminosity. Truly, the water molecule has an amazing ability to absorb radiation. The contrast with CO_2 is all the more marked when it is seen that a large part of the Kasting & Ackerman "CO_2 caused" temperature increase is actually caused by water vapor from increased oceanic and lake evaporation. In the 50 mb canopy, there would certainly be increased tropospheric water content from evaporation, but it has not been considered.

Discussion of Other Canopy Results

Vertical temperature profiles for canopies with 10, 125, and 1013 mb of water vapor show similar distributions as the 50 mb canopy but hotter for thicker canopies and cooler for the thinner canopy. Figure 4 shows the surface temperature as a function of the mass of the canopy. As the mass of the canopy is slowly increased from zero, the surface temperature rapidly increases. At a canopy mass of 125 mb, the longwave windows to space are nearly closed and additional water vapor has little marginal effect. At 1013 mb (1 atm), the windows are totally closed. No longwave terrestrial radiation escapes straight to space.

Surface temperatures are directly related to the mass of the canopy and produce too warm a surface temperature to be hospitable for life under pure radiative equilibrium for all canopies studied. However, for the 10 mb case inclusion of convection would noticeably decrease the surface temperature, perhaps into the suitable 300–310 K range. In each case the temperature at the top of the canopy is below freezing. The cold temperature causes the saturation vapor pressure to fall below the ambient pressure, producing a cirrus cloud layer. Near the surface of the earth and at the base of the canopy thin layers are convectively unstable, based on the temperature lapse rate.

Conclusions

It was stated earlier in this paper that two criteria for the vapor canopy would need to be met: (a) stability, and (b) a surface temperature suitable for habitation. The first criterion was met. For any size canopy considered, at least from radiation analyses of pure water vapor canopies, it was shown that the temperature is always high enough throughout most of the canopy, particularly at the base, to easily ensure the vapor phase. The second criterion is not as straightforward to evaluate. Radiation considerations strongly suggest surface temperatures are not suitable for the 1013, 125, and 50 mb canopies. The canopy blanket is simply so effective that the surface temperature becomes inhospitable. This could also be true for the 10 mb canopy, though convection considerations may alter this conclusion. Inclusion of convection in the denser canopies would not change this verdict.

It does seem reasonable to suppose that somewhere between 0 and 50 mb there exists a value that would lead to a successful canopy. Remarkably, this is the same conclusion reached by Kofahl (1977) with his "sliderule estimates." He suggested a total water vapor content in the atmosphere-canopy of six inches, or five inches (12 mb) more than the atmosphere alone. The chief drawback to a thin canopy is that it would not significantly contribute to the 40 days and nights of rain for the Flood.

Morton (1979) was apparently the first to conclude that the canopy would have made the earth's surface too hot for human habitation (Kofahl did not calculate surface temperatures). Morton made a number of assumptions that greatly simplified the problem, and his surface temperatures are much higher than ours, but the general conclusion is the same: Life as we know it would not have been possible under a canopy of 1013 mb (1 atm), nor even with a canopy of only 50 mb. When other features such as clouds are added to the model, this conclusion could be modified greatly, however. Preliminary explorations with cloud layers at the top of the 50 mb canopy have shown significant radiation effects which lower the surface temperature drastically. Unfortunately, while the surface temperature decreases when clouds are added, so does the temperature of the canopy, reducing its stability.

Recommendations

Recommendations for future work are shown in Table 1. The features which should be added to the canopy model to make it more realistic are arranged in descending order of probable impact, first for cooling, then for heating. The most important feature is the addition of clouds. Clouds in the upper canopy would provide a dramatic increase in the planet's albedo, thereby lowering the net influx of solar radiation to the canopy-atmosphere-earth system. Temperatures at the top of the canopy are cool enough to freeze vapor, even without nuclei. Therefore, we may expect that thin cirrus clouds would form. They could not exist everywhere all the time, as stars need to be visible at night to satisfy biblical criteria. Today such clouds actually heat the earth (Liou & Ou, 1983), because they are more effective at trapping outgoing radiation than reflecting incoming solar. But under canopy conditions they should cool it since the longwave spectrum is already saturated. Although not expected to be as significant as cloud layers, the other suggested features in Table 1 could produce important effects on cooling or heating, particularly in certain regions of the atmosphere. The other features are discussed in detail in Rush (1990).

Table 1. Recommended features which should be added to the canopy model in future work and the likely effects.

Recommended Features to be Added	Likely Effects at the Earth's Surface
Clouds	Cooling
Aerosols	Cooling or Heating
Convection	Cooling
Latitudinal Transport of Heat	Cooling
Ozone	Cooling
Vertical Conduction	Cooling
Constant Relative Humidity	Heating
Minor Absorbers	Heating

Incorporating clouds and constant relative humidity below the canopy should give us a good idea of the temperature profile at an average spot on earth. By running the model at different latitudes, an idea of temperature profiles at various points on earth could be obtained. The difference between these profiles will give an indication of the driving force that will set up circulation patterns.

Beyond this however, different methods exist for constructing what are called general circulation models (GCMs). Different groups around the world have built their own GCMs. The Canadians call theirs the "Canadian Climate Centre Spectral Atmospheric General Circulation Model." Its elements are described by Boer et al, (1984). Ramanathan, Pitcher, Malone, & Blackmon (1983) describe modification to a U.S. National Center for Atmospheric Research GCM. Semtner (1984) considers an atmospheric model coupled to three different ocean models. With the interest in possible climate warming caused by increased CO_2, much research has gone into this area.

Future creationist research could perhaps modify a public domain GCM, or build a new creationist one. Although it would take a great amount of computing power, a GCM could give us exciting glimpses into worldwide climate under a vapor canopy.

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Discussion

It is highly encouraging to derive a canopy model with a temperature profile that allows the vapor to be hot enough to keep from condensing, at least for part of the canopy. Most of Dillow's simulations were too cold everywhere. It is therefore worthwhile to proceed with model refinements.

Adding clouds is the best place to start. Dillow's model kept the earth cool with a stratus cloud below the inversion. Investigating an ice cloud at the top of the canopy appears necessary for both models because the radiative temperature is too cold there. Perhaps there would have been dissociation of water molecules into hydrogen and oxygen at the top of the canopy and then the formation of zone which could keep the top of the canopy hot enough to prevent cloud formation.

Figure 2 could have had the water vapor pressure curve plotted for reference so that the readers might know where the canopy appears cool enough for your canopy and for that of Dillow (1983) and Baumgardner. It was necessary to make a few reasonable assumptions in converting pressures to altitudes.

The Rush and Varidman model profile (curve #5) for 50 mb of vapor in the canopy crosses the condensation curve (curve #2) just a couple of degrees above the melting point (curve #6). They are therefore correct in pointing out that their canopy would have an ice cloud at the top.

The profile presented in Dillow's Figure 3, curve B (curve #1) is typical of most of their simulations. Their special equatorial simulation from their Table 6 is shown (curve #4) for comparison. The condensation profile that applies to their canopy (curve #3) is between the two in the lower canopy and warmer than both simulations for the top of their canopy.

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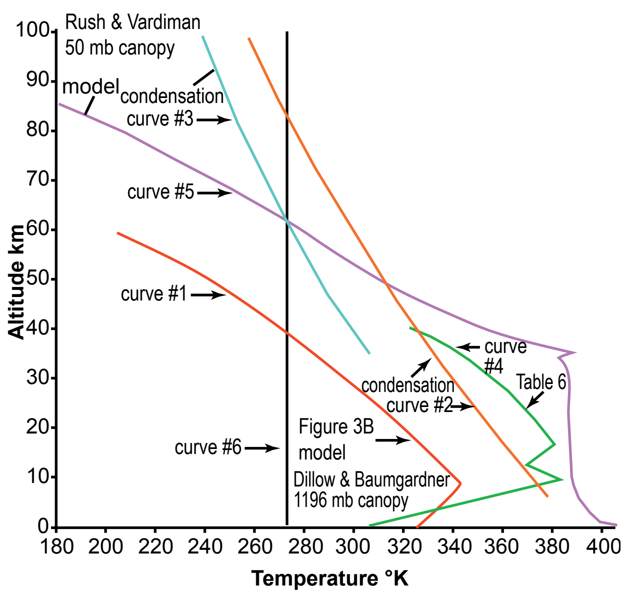
Edmond W. Holroyd III, PhD
Arvada, Colorado.



Canopy Temperature Profiles

I applaud Mr. Rush and Dr. Vardiman for a detailed, scientific analysis of the vapor canopy. Their approach is standard in climate modeling. Unfortunately, for those who believe in a vapor canopy, the article poses some grave challenges. Although the results are only the first step, it seems that two problems are apparent: either the surface is too hot or there isn't enough moisture in the canopy for 40 days and nights of rain. A three-dimensional climate model with convection and clouds would help, but I have my doubts that it will solve the problems, because of the magnitude of the heating. I have several questions: How is the lapse rate in pure water vapor determined? What would relative humidity mean? In convection, clouds form when the relative humidity reaches 100%. When would clouds form? Seems to me the release of latent heat in convection would catastrophically rain out the canopy in the calculated temperature profile. Why wouldn't this happen? One possibility to solve the heat problem are the cirrus clouds at the top. In the canopy model, they would likely be so thick that they may reflect more sunlight than cirrus (especially thin cirrus) in today's climate. Wouldn't this be true, and would it partially solve the problems. The only aerosols that would reach the canopy are extra-terrestrial. Are these CCW? Assuming extra-terrestrial particles are poor CCW, what effect would a lack of CCW have on canopy cloud formation?

Michael J. Oard, MS,
Great Falls, Montana.

Closure

We wish to thank Dr. Holroyd for the extra effort he took in plotting condensation curves for the different models. We certainly agree that the next step in canopy research should be the addition of high-level cirrus clouds.

In reply to Mr. Oard's comments, the lapse rate of pure water vapor is given by the formula g/C_{pv}, where g is the acceleration due to gravity and C_{pv} is the heat capacity at constant pressure of pure water vapor. For water vapor. this is only 5.3°/km, as opposed to 9.8°/km for dry air.

Relative humidity may be defined as the ratio of the amount of water vapor a parcel of air holds to the amount it would hold at saturation. In the canopy therefore, with nothing but water vapor. the term would technically be meaningless. Instead, if we compare the actual pressure at a given level due to the weight of the overlying vapor to the saturation water vapor pressure at the temperature of the same level, we can determine if the vapor will condense. If the saturation vapor pressure of the canopy is less than the actual pressure, then (given the presence of condensation nuclei) additional vapor will condense out as either liquid droplets or ice crystals, depending on temperature, and form clouds. If condensation nuclei were absent before the Flood, the saturation vapor pressure could have been effectively doubled or tripled, allowing more water to be stored in the canopy without condensation.

We have not quantitatively considered convection effects in this work, nor have we considered latent heat effects. It's our feeling that convection would have no significant effect on the final temperature profile. Only a small fraction (less than 10%) of the canopy base, and would slightly lower the base temperature and slightly raise the temperature just above the base. As pointed out in the discussion of the 50 mb results, we would not expect this temperature correction to be more than a degree or two. The temperature at the base is so high (409 K) and the pressure so low

(50 mb) that the vapor phase—and stability—would be easily assured.

At the top of the canopy, the release of latent heat by condensation and freezing would indeed alter the temperature profile, but again, not significantly. The topmost layer is at a low enough temperature (189 K) and pressure (1 mb) to easily ensure the ice phase, and hence cirrus-type clouds.

The chief reason why we cannot allow thick clouds is a biblical one: heavenly objects need to be visible, at least during part of the diurnal cycle.

As Mr. Oard correctly notes, our 50 mb canopy (20 inches of precipitable water) would hardly provide 40 days and nights of heavy rainfall. The collapse of the canopy may not have contributed much water to the Flood, but the canopy in place before the Flood would certainly have had a dramatic effect on climate.

David Rush, MS
Larry Vardiman, PhD.