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P2_4 Noah's Ark: The Story Continues…

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Abstract

This paper calculates the timeframes involved in the story of Noah's ark. Specifically, estimates of completely submerging the Earth in water and the subsequent evaporation of this water are obtained as 20.2 years and ~73,000 years respectively.

Introduction

The Noah's ark bible account of Genesis 6 – 9 describes the nautical voyage of a family plus two of every member of the animal kingdom aboard a giant boat. *Youle et al.,* 2013 [1] calculated that Noah's ark possessed the required buoyancy to support the mass of its passengers. This paper will attempt to continue the story and study the timescale of the flood to determine the fate of those on board. According to scripture, 'the windows of heaven were opened and the rain was upon the earth forty days and forty nights' [2]. After this time, the highest mountains were flooded by an excess of 15 cubits (~7m) and the flood persisted for 150 days. God then sent a wind to abate the flood and the ark came to rest upon the mountains of Ararat. However, the water level did not recede back down for Noah to exit the ark until just over a year after the rain stopped. This paper will study the validity of the timescale of the flood by examining the rates of rainfall and evaporation.

Theory

The time taken for the water to flood the Earth, t_f, to an elevation *E* can be calculated with the following:

$$t_f\ (s) = \frac{E}{Rate\ of\ rainfall}. \quad (1)$$

The rate of evaporation from an open water surface depends on many factors and the most widely used model was devised by Howard Penman in 1948 [3]. This equation was then adapted by Jim Shuttleworth [4] to provide the resultant equation

$$E_{mass}\ (mm\ day^{-1}) = \frac{mR_n + 6.43\gamma(1+0.536U)e_a}{\lambda_v(m+\gamma)}, \quad (2)$$

where *U* is the wind speed and R_n is the net irradiance. *m* is the slope of the saturation vapour pressure curve given by

$$m\ (kPa\ K^{-1}) = \frac{711}{{T_a}^2} e^{\left(21.07 - \frac{5336}{T_a}\right)}, \quad (3)$$

where T_a is the air temperature. γ is the psychrometric constant which relates the partial pressure of water in air to the air temperature and is as follows

$$\gamma\ (kPa\ K^{-1}) = 0.0016286 \frac{P}{\lambda_v}, \quad (4)$$

where P is the pressure which can be expressed as

$$P\ (kPa) = 101.3\left[\frac{288 - 0.0065E}{288}\right]^{5.257}, \quad (5)$$

and λ_v is the latent heat of vaporisation

$$\lambda_v\ (MJ\ kg^{-1}) = 2.501 - 0.002361T_a. \quad (6)$$

Finally, e_s is the saturated vapour pressure which is dependent on the temperature and estimated by a polynomial function [5]

$$e_s\,(kPa) = \frac{a_{0+T_a(}a_1+T_a(a_2+T_a\big(a_3+T_a\big(a_4+T_a(a_5+a_6T_a)\big)\big)))}{10}, \quad (7)$$

where the *a* terms are known coefficients of expansion. The pressure and temperature dependence of most of the variables above will need to be taken into account as the sea level decreases with altitude.

Results

To calculate the time taken to completely cover the Earth with water, it will be assumed that the rate of rainfall is a constant 50mm h^{-1} [3], which can be described as 'heavy' rainfall. The elevation, *E*, of the waters will be assumed to be 7m above Mount Everest which totals at 8855m. Calculation of equation (1) with these values determines t_f to be 20.2 years rather than 40 days. The required rate of rainfall to flood the earth in only 40 days is 9.2 m h^{-1} which is much higher than any recorded rate. To calculate E_{mass}, it is assumed that R_n is equal to half the total solar irradiance (59.03 MJ m^{-2} day^{-1}) in order to roughly approximate the day and night cycle of Earth. The wind speed is assumed to be ~24ms^{-1} which is equivalent to a strong gale [7]. The peak of Everest is within the troposphere where temperature decreases with altitude at the lapse rate of 6.5° per km [7]. Assuming the temperature at current sea level is on average 15°, it is possible to calculate the temperature at any elevation. Iterating in 10m intervals of elevation, using the lapse rate to calculate the temperature at this elevation, equations (5), (6), (7), (4) then (3) can be used in this order to calculate all of the variables at a given elevation. The time taken for the water to drop by 10m can be calculated by dividing the 10m by the evaporation rate from equation (2) at that altitude and then all of these times can be summed to give the total time required to reach a certain altitude. This method reveals that it would take ~63,000 years for Noah's ark to first come to rest on Mount Ararat which has a peak elevation of 5137m. Due to the evaporation rate increasing with temperature as altitude decreases, it would take only ~10,000 years more for the sea level to drop back to the elevation prior to the flood.

Discussion and Conclusion

A number of assumptions have been made in the calculations above. Firstly, there would not be enough water to fill the oceans this high so the 'windows of heaven' are taken to be an infinite source. The topology of Earth has also been neglected which results in our calculations providing a lower limit. It is also assumed that half of Earth is illumined by the sun without latitudinal variation in order to simplify calculations. In addition, the relative humidity is assumed to be 0% which means that as soon as the water evaporates it returns to the source. This means that clouds would not form and allow further rain to fall. The results still do suggest the timeframe in the bible is an extreme underestimation of what is physically possible in terms of rainfall and evaporation rates. Although Noah was 600 years old at the start of his journey, it is unlikely the passengers of the ark could survive a total of ~73,000 years on board and as the flood began in 2348 BC, the Earth should still be a waterworld today if the story was physically accurate.

References

[1] O. Youle, K. Raymer, B Jordan, T. Morris, *The animals float two by two, hurrah!*, PST **13**, 2013.

[2] *The Holy Bible,* King James Version, Genesis 5:32-10:1.

[3] Penman, H.L. (1948): *Natural evaporation from open water, bare soil and grass.* Proc. Roy. Soc. London A, S. 120-145.

[4] Shuttleworth, J. (2007), Putting the 'vap' into evaporation, *Hydrol. Earth Syst. Sci.*, **11**, 210–244.

[5] Lowe, P.R. (1977). "An approximating polynomial for the computation of saturation vapor pressure." Journal of Applied Meteorology. 16:1:100-103.

[6] http://www.metoffice.gov.uk/media/pdf/4/4/Fact_Sheet_No._6_-_Beaufort_Scale.pdf (04/11/14)

[7] http://www.britannica.com/EBchecked/topic/330402/lapse-rate (04/11/14)