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How did God part the Red Sea?

Rebekah Garratt & Rikesh Kunverji
Natural Sciences (Life and Physical Sciences), School of Biological Sciences, University of Leicester
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Abstract
This article will discuss physical methods to explain the Biblical account of Moses parting the Red Sea with the help of God, as told in Exodus. Meteorological phenomena, such as gale force winds and negative surges, as well as tidal mechanisms, such as Rossby waves will be discussed. Due to the relief dependent complex nature of these phenomena, possible locations where the Israelites crossed will be also be theorised.

Keywords: *Scripture; Earth Sciences; Meteorology; Tides; Waves; The Bible*

Introduction

Escaping the enslavement of the Pharaoh of Egypt, the Israelites found themselves stranded off the coast of the Red Sea with the ever-pursing Egyptians behind them. Trapped, terrified and desperate, Moses reached out to God. The following events whether historically true or not are well known, the Red Sea was parted. As described in Exodus, "Then Moses stretched out his hand over the sea and all that night the Lord drove the sea back with a strong east wind and turned it into dry land. The waters were divided, and the Israelites went through the sea on dry ground, with a wall of water on their right and on their left" [1]. The speed of the wind to have parted the Red Sea would need to have been considerable in this Biblical account, especially with the ability and being able to keep the water apart for extended periods of time. The aim of this paper is to discuss feasible ways that this crossing could have taken place, by considering meteorological and tidal phenomena.

Negative Surges

A negative surge is a condition when coastal waters fall to lower levels during an extreme weather event [2]. This occurs most dramatically in inlets and bays, akin to those along the coastline in the northern section of the Red Sea, the Gulf of Suez, as shown in Figure 1. Recent examples of negative surges have been due to Hurricanes Ian and Irma [2, 3]. In the case of Hurricane Irma, parts of the Floridan peninsula experienced a negative storm surge of -2.7 m [3]. The water was pushed from the area, exposing vast areas of the seafloor, similar to a Rossby wave – which will be discussed in a later section of this paper. A hurricane of this type would be abnormal close to the Red Sea, however, Mediterranean tropical-like cyclones, also known as *medicanes* can form in both the Mediterranean and Arabian seas [4]. Tropical cyclones require a sea temperature of at least 27 °C, as well as being in a low pressure region within 30° latitude of the equators low pressure region [5]. Particularly in the Summer months, the Red Sea meets both of these requirements [6] making a *medicane*, and the subsequent negative surge, a possible explanation to allow the Israelites to cross an exposed reef.

Figure 1 – Map of the entire Red Sea (left), and the north section of the Gulf of Suez – highlighted in red (right). Areas of interest are highlighted, where A (orange) represents a reef area that may possibly be exposed by wind setdown via eastern winds, whereas B (red) represents an area that may be exposed by tidal resonance (Adapted from: Wikimedia Commons).

Eastern Winds

A model created by Drews & Han [7] explores the Biblical description of a "strong east wind". Wind setdown is a drop in the water level due to wind incident on a body of water for an extended period. In this model, due to a uniform 28 ms^{-1} wind, this led to an area of exposed terrain , where the Israelites could have crossed. However, this follows another translation of the Hebrew *Yam Suph*, literally 'Sea of Reeds' [8], choosing a coastal lagoon known as the Lake of Tanis and not the Red Sea. For it to have been the Red Sea, the authors theorise that a similar wind speed would have needed to be incident for 12 hours to expose a raised reef in the Suez through a similar mechanism to a negative surge [7]. As discussed in the previous section, whilst unlikely, it is possible for a *medicane* to develop in the area. These have been proven to persist for this length of time [9], as well as reaching these wind speeds [4] making this a possible mechanism to expose the Suez reef. For example, making the highlighted section marked A in Figure 1, a possible location, if a tropical cyclone did arrive from the Mediterranean.

Tidal Resonance

Tides are long period waves that move through the ocean due to gravitational forces exerted by the Moon, as well as the Sun. Due to the greatest fluctuation in sea level [10], the Gulf of Suez represents the best location for Moses to have crossed due to any tidal extremes. As the gulf is a narrow basin, the periodic tide can be modelled as a standing wave [11]. A quarter wavelength would fit in the Gulf of Suez, and the antinodes would cause the variation of tides at the coast. Resonance is a physical phenomenon that leads to a greater amplitude response when systems are driven to oscillate close to their natural frequency [12]. In this case, tidal resonance occurs when a sudden, unexpected external input, such as extreme wind, excites one of the resonant modes of a local region of the Red Sea, leading to a much more extreme low tide, exposing greater areas of the seabed. This has been previously seen in the Bay of Fundy, where the tidal frequency is close to its natural frequency causing the most extreme tides on the planet [11]. Therefore, the highlighted section B in Figure 1 may be a possible place of crossing, if the seabed was exposed due to an abnormal tide.

Rossby Waves

Rossby waves are caused by the rotation of the Earth, and are found in two forms, oceanic and atmospheric. Atmospheric waves are reliant on horizontal atmosphere undulation between polar front jet streams that separate cold and tropical air [12]. As the earth rotates, three different forms of circulation occur, one of which is Ferrel circulation. Ferrel circulation takes place in Ferrel cells, mid-latitude circulation cells where air flows eastward and northward at surface level, and is responsible for the causation of Rossby waves [13]. In Exodus, the wind is described as coming from the east and the north, in particular the Gulf of Suez as shown in Figures 1 & 2 is in a Ferrel cell, therefore, the parting of the sea splitting could have been due to the Rossby wave, fulfilling some of the requirements described in Exodus. The waves are responsible for low pressure cells (cyclones) and high-pressure cells (anticyclones). Oceanic Rossby waves follow the same requirements as they can only occur in barotropic fluids, and it is a by-product of Coriolis effect. The wind strength and direction can also further impact the height of the waves [14]. Rossby waves tend to be slow and can take as long as 10 years to be moved, however, their impact can still be felt as they make the tide higher than usual [15]. The waves move vast amounts of water meaning an occurrence at the Red Sea could have moved vast amounts of water, causing the tide to recede by an unusual amount, leaving shallow or no water for the Israelites to walk through.

Conclusion

Investigating into the methods in which the waters may have receded, allowing Moses to cross safely, may be dependent on having 'perfect' conditions, but are still physically feasible events. Meteorological phenomena are known to be notoriously unpredictable and can lead to chaotic chains of events leading to extreme phenomena, which may have been viewed by bystanders as the 'parting of the sea'. This is also supported by the account of Napoleon's campaign in the Middle East in the 1790's where, most likely due to tidal changes, the Red Sea was traversed [16]. Whether a miraculous act of God or due to some of the unlikely, coincidental phenomena discussed in this paper, the chance of 'parting' is not zero.

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