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A3_1 How Great is the Great Red Spot?

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Abstract

In this paper we calculated the energy contained within a storm on Earth with equal size and wind speed to the Great Red Spot on Jupiter. We then compared the wind speed of the storm to other hurricanes on Earth and the destructive effect of the storm was evaluated. We estimated the storm would have an energy of 1.4×10^{24} J, which is approximately 10^9 times larger than the total energy produced by 1 megaton of TNT.

Introduction

The planet Jupiter is the largest, and one of the most interesting planets within our Solar System. One of its most defining features is the Great Red Spot, a storm so large and so powerful that it has been present for at least 300 years [1]. In this paper we have calculated the energy the Great Red Spot would have if it were a storm on Earth, compared this to the most powerful storms that occur on Earth, and finally assessed the effect the storm would have on Earth.

Method

To find the energy of the storm, we first calculated its volume, so we could find out the mass of the air particles in the storm. The Great Red Spot does not have one consistent size, hence multiple approximations have been made to calculate its size and therefore volume. We assumed the storm is the shape of an elliptic cylinder, with the Great Red Spot being an oval base that we observe. The area of the oval shape, A, was calculated using the oval's semi-major axis, a, and its semi-minor axis, b, as seen in equation (1).

$$A = \pi \times \frac{ab}{4}, \quad (1)$$

We then calculated the volume, V, using equation (2), where A is the area of the oval and h is the height of the cylinder.

$$V = Ah \quad (2)$$

Using the volume of the cylinder it was possible to calculate how many moles of air, n, are in the storm. This was completed by using equation (3), where V is the volume of the cylinder, and V_{gas} is the volume taken up by one mole of gas.

$$n = \frac{V}{V_{gas}} \quad (3)$$

Using the number of moles calculated in equation (3), the total mass, m, was calculated by multiplying the number of moles, n, by the molar mass of air, m_r, as seen in equation (4).

$$m = m_r n \quad (4)$$

Once the total mass had been calculated we were able to find the energy, E, generated in the

Great Red Spot due to the force from the wind. This was completed by using equation (5), which is simply the equation for kinetic energy.

$$E = \frac{1}{2}mv^2 \tag{5}$$

Findings

The storm has a semi-major axis of approximately 24,000 km and semi-minor axis of 13,000 km [2]. Thus, the observable area of the storm was calculated to be 2.5×10^{14} m^2. We calculated the volume as 7.4×10^{19} m^3, as the depth of the storm is roughly 300km [3].

Using equation (3) the number of moles of air in the storm was calculated to be approximately 3.1×10^{21}. It was only possible to calculate this by researching the volume required for one mole of gas, 0.024 m^3 [4]. This value assumes standard room temperature and pressure for the gas, however this is not strictly true in this situation. The required surface temperature of water for a hurricane to form is 26 degrees Celsius. Therefore 0.024 m^3 was a viable volume in this scenario [5]. After multiplying 3.1×10^{21} by the molar mass of air, 29 g/mol [6], the total mass of the storm was found to be 8.9×10^{19} kg. Given this, the energy generated due to wind was calculated, as the average wind speed in the Great Red Spot is 180 ms^{-1} [1]. The energy was calculated to be 1.4×10^{24} J.

Conclusion

To conclude, if this giant storm were to be on Earth, it would be the largest storm that has been recorded. The fastest wind speed ever recorded on Earth was during Cyclone Olivia, at speeds of 110 ms^{-1} for 1 minute [7]. Cyclone Olivia would hence, at its maximum, have 10^5 to 10^6 times less energy than a Great Red Spot like storm. The Great Red Spot like storm would be incredibly destructive and cause catastrophic damage to anywhere it hits. The most damaging storm in US history is Hurricane Katrina, which caused $160 billion of damage and resulted in almost 2000 deaths [8]. The Great Red Spot is a much more powerful storm than Hurricane Katrina, and would cover a much larger area if on Earth, resulting in greater levels of destruction. Fortunately, the Great Red Spot would dissipate on Earth rapidly, due to its need for a constant heat source which it has on Jupiter.

There are assumptions made during this investigation that would change our calculations. We have assumed that the storm is made purely of air, without water or debris. However, if water or debris were involved in the storm the total energy would be even greater due to an increase in the mass. The energy calculated in our approximations, 1.4×10^{24} J, is a low estimate but it is still an immense amount of energy. This amount of energy is approximately 10^9 larger than the total energy produced by 1 megaton of TNT.

References

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