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*What do you know about Hurricane Forecasting?*

From the creation of the Earth, weather has always been a driving factor of the eco-system within our planet. Every planet throughout the galaxy has some sort of weather pattern due to the moons that orbit them or the sun within their solar system. As humans evolved within Earth, we developed many ways to track the weather from the smell or feel of the wind to the color of the clouds in the morning sky. But as we became technologically advanced we became more accurate with predicting weather not perfect but enough to know if a massive weather event will occur that could affect millions of lives. Scientists are able to do this because of the various weather observatories and known history patterns that are located throughout the world. Through these institutions scientists are able to study on of the most important factors in hurricane forecasting and that is the wind. They are able to use wind patterns from the past and compare them with their readings to predict more exact types of weather we will have. Even though wind patterns are a very important factor in studying weather, scientists also use mathematics which is very important to diagnose the data received from the wind patterns. The most famous scientists to begin researching hurricane forecasting was Vilhelm Bjerknes and Lewis Fry Richardson. These scientists were among the first to apply physical law principles to the atmosphere in order to comprehend how our climate functioned [2]. Many equations would arrive due to weather prediction such as Richards first forecasting method. Still used by many meteorologists, this method divides the atmosphere into small parcels of air through a gridded area. Some other methods used to create weather predictions are the spectral method and finite method but none of them fully solves the primitive equation [1]. Seven physical parameters must be known by meteorologists in order to make a weather forecast: temperature, pressure, density, humidity, and wind velocity, which has three components that account for the three distinct wind directions. Some forecasting algorithms also consider the amount of water and ice on the ground and in clouds. In a perfect world, these values would always be known at every location in the atmosphere. Due to the restricted processing capacity, this is practically impossible, hence the values are computed for each individual air parcel in the atmosphere. The basic rules of thermodynamics and hydrodynamics, often known as the primitive equations, are used by scientists to explain large-scale atmospheric phenomena by treating the Earth's atmosphere as if it were a fluid on a spinning sphere. In essence, these are the motion equations; one for each of the three wind directions; along with the ideal gas law, the continuity equation, and the fundamental law of thermodynamics, which describes the conservation of energy and mass [1]. Therefore, the three main variables for one of each of the three wind directions are,

* Ideal Gas Law
* Law of Thermodynamics
* The Continuity Equation

The equation of motion is very important to consider and is represented by Newton’s second law.

This equation represents the force equals the product of mass and acceleration. Essentially, this equation helps describe how an object reacts or operates under different circumstances [1]. To predict the wind parcel is shown in the equation,

This equation helps predict the wind parcel through the relationship between velocity in respect to time. The is represented through the use of the equation where the change in velocity is in respect to time. Then the equation is then broken down to find the other forces in the atmosphere,

* Pressure Force
* Coriolis Force
* Drag Force
* Gravitational Force

To begin with the first force, known as the pressure force, this is represented as in the equation used to find the wind parcels. The force that transports air from a region of high pressure to an area of low pressure is known as the pressure gradient force. The pressure gradient affects the wind's velocity. The wind speed is high if the pressure gradient is strong. The wind speed is light when there is little pressure gradient [3].

Within this equation the **p** represents the pressure between the two regions. Then the ρ represents the density that is exerted. Lasty, the symbol ∇ represents the Nabla which is the vector differential operator. If the force of the pressure gradient were the sole factor influencing wind flow, the wind would blow at a right angle across isobars of high and low pressure [3]. The equation of state, which links pressure, temperature, and density, may be used to determine the pressure inside an air parcel. The ideal gas rule for perfect gases may be used to calculate atmospheric pressure since air behaves similarly to a perfect gas:

In this equation the ρ represents the density that is exerted just like before, but there are new variables. The T is used to represent the absolute temperature in Kelvin, while the is the gas constant for dry air. This has a constant value of . The gas constant is different for moist air, as water vapor is less dense than dry air. But instead of using a different gas constant, a virtual temperature defining this effect can be used. The second force, known as the Coriolis force, this is represented as may be thought of as the difference between gravity and centrifugal force. Air traveling over the earth is forced to follow a curved route because of the Earth's rotation. Air is deflected to the right of its direction of travel in the Northern Hemisphere and to the left in the Southern Hemisphere. Due to the Earth's almost spherical form, the Coriolis force, which accelerates wind in the horizontal direction, is greatest in the poles and zero at the equator [1].

Within this equation the symbol represents the angular velocity of a rotating planet. This is very important because with a rotating planet there is constant wind moving in one direction. Then the symbol represents the velocity of an object in respect to a moving planet. The next force is the drag force, this is the representation as an act of opposition to an object to slow the object down. This is found within the “air belt” which is around 1 to 2 kilometers above the Earth’s surface. This is represented as , it is very important to note that the drag force is heavily dependent on the wind speed. This is due to the fact that the drag force is a force of opposition, this force will act against the wind to slow it down, therefore as the wind speed increases the drag force will increase. Lastly, there is the gravitational force which is represented through the use of . The gravitational force is just the force need to keep the molecules within Earth’s atmosphere, so that we aren’t floating in space. After, we attained all the formulas needed to find each given force, the equation of motion is revealed:

Once we have attained the Equation of Motion which is used to help scientist predict a hurricane through movement with the use of the four forces, pressure force, gradient force, drag force, and gravitational force. I will incorporate how to attain the three different components needed to find wind velocity.

* Zonal Wind
* Meridional Wind
* Vertical Wind

Zonal winds are those that circulate parallel to the equator at the same latitude and thermalize the atmosphere longitudinally. The Huygens Doppler Wind Experiment, doppler changes in the emission lines of atmospheric components like ethane, and cloud tracking observations are the main sources of their constraints [4]. Zonal winds are used and represented by the equation below:

As provided in the equation above zonal winds is represent with the variable u. The latitude is denoted by ϕ(−π/2<ϕ<π/2) *ϕ*(−*π*/2<*ϕ*<*π*/2), the longitude by λ(−π<λ<π) *λ*(−*π*<*λ*<*π*) and the height above the Earth's surface by z [1]. The meridional wind the wind or a wind component that runs along the local meridian, as opposed to the zonal wind. The meridional wind is positive if it comes from the south and negative if it comes from the north in a horizontal coordinate system that is fixed locally, with the x axis pointing eastward and the y axis pointing north. This is represented in the equation below:

Lastly there is vertical wind that is represented with the formula:

The distance between the air parcel and the geocentre is given by *r*, where r=RE + z (*RE*​ being the Earth's radius). Often, this distance is approximated by the Earth's radius, so r = RE. In the following formula, I will use *r* for better legibility.

The laws of physics such as Newton's Second Law, the Law of Conservation of Mass, and the First Law of Thermodynamics, to mention a few, are employed numerically to predict the weather. When predicting the weather, the Law of Conservation of Mass is used to calculate how much force is being conserved over time. For instance, hurricanes are a kind of natural catastrophe that develops in the water; when the storm's route is forecasted, it is determined that the strongest part of the storm would hit land first. The Law of Conservation of Mass holds that mass cannot be generated or destroyed, therefore as time goes on, the storm becomes less intense. Meaning that hurricanes don't just appear out of thin air; rather, they form when certain conditions are met, such as being surrounded by warm waters and moist, humid air. And after a certain amount of time, hurricanes don't just vanish into thin air; instead, they dissipate back into the atmosphere because they are removed from the source that gave them life. Because the heated air within the storm starts to mix with the surrounding, somewhat colder air as it moves along its course, hurricanes tend to weaken as they move farther from their point of origin.

Citations:

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