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WEATHER FORECASTING

Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time. It is a crucial aspect of daily life for countless people globally, as it helps us plan our activities, brace ourselves for unfavorable weather conditions, and alleviate the consequences of severe events. “Predicting Weather" has been in practice for over thousands years, but officially it is called "weather forecasting" since the 19th century. It is believed that the very first weather forecast was published on August 1, 1861, in the English newspaper Times by the English meteorologist Robert Fitzroy” (windy.app). This write-up dives deeper into the science of weather forecasting, outlining the tools and techniques utilized and the challenges confronted by weather forecasters.

The science behind weather forecasting can be very hard and if accurate can be immensely of great benefit (e.g prediction of hurricane, prediction of flooding, helps farmers to know when to plant or not, knowing when a heavy snow storm is imminent..). According to the National weather Service, “Weather forecasts are made by collecting data about the current state of the atmosphere and using an understanding of atmospheric processes to predict how the atmosphere will evolve”. Weather forecasting entails three steps: Observation, analysis, and communication (National Weather Services). Observation is the initial stage of weather forecasting, which involves gathering information about the current weather conditions. A wide range of tools and techniques are employed to collect weather data, such as weather stations, radar, satellites, and weather balloons. These observation tools provide measurements of various weather variables, including temperature, pressure, humidity, wind speed and direction, and precipitation(The Conversation). After collecting the observations, the subsequent step is to process and analyze the data. Weather forecasters employ diverse techniques and tools, including computer models, to generate an accurate picture of the current state of the atmosphere. Analysis involves scrutinizing the collected data, and synthesizing it into a cohesive picture of the prevailing weather conditions (The Conversation). Lastly, in weather forecasting is communication, which involves disseminating the predicted weather information to the public, weather-sensitive organizations, and emergency management agencies. Various channels, such as TV and radio broadcasts, websites, social media, and mobile applications, are utilized to convey weather-related updates. Weather forecasts are often customized to meet the needs of diverse audiences, with the amount of detail provided varying depending on the target audience (The Conversation).

Partial Differential Equation

One instance of a differential equation utilized in weather forecasting is the advection equation, it is a partial differential equation of the first order. This equation explains the motion of fluid and the conveyance of atmospheric factors like moisture and heat. The key variables in weather forecasting are fluid velocity ,V, (with three components: u for eastward, v for northward, and w for upward), pressure (p), density (ρ), temperature (T), and humidity (q). By applying Newton's laws of motion and the principles of conservation of energy and mass, we can derive a system of equations that can be solved using initial conditions. At the heart of this system are the Navier-Stokes equations, which govern fluid motion. These equations are typically written in vector form as:

$$\frac{\partial V}{\partial t} + V \cdot \nabla V + 2\Omega \times V + \frac{1}{\rho}\nabla p = F + g'$$

Here, ∇V and ∇p represent the gradient of the velocity and pressure fields, respectively, and Ω represents the rotation rate of the Earth. The term F represents external forces acting on the fluid, such as gravity and friction, while g' represents the effect of gravity on the horizontal pressure gradient. Partial differential equations (PDEs) are a crucial mathematical tool for meteorologists in weather forecasting. They provide a framework for understanding the intricate behavior of the atmosphere, which is necessary for generating accurate and reliable weather forecasts. Numerical methods and data assimilation techniques are used to solve these equations, allowing meteorologists to make predictions about future weather conditions based on current observations and models.

Here are videos that perfectly explain and go in depth about how Partial Differential Equations are used to determine weather patterns and forecasting weather.

> But what is a partial differential equation? | DE2

> MET-TH502 || Partial Differential Equation || DU Meteorology

Lorenz Equation

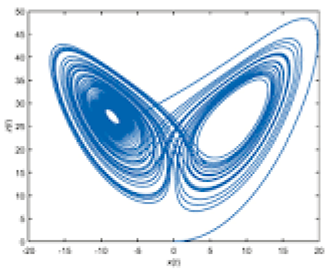
In the 1960s, Edward Lorenz developed the Lorenz equations - a set of three nonlinear differential equations that aimed to model atmospheric convection and the Earth's weather dynamics. The equations comprise variables x, y, and z, which describe the state of the system over time, while parameters σ, ρ, and β determine the system's behavior.

$dx/dt = \sigma(y - x)$ Eqn I

$dy/dt = x(\rho - z) - y$ Eqn II

$dz/dt = xy - \beta z$ Eqn III (Chegg)

The equations are notable for their chaotic behavior, where small changes in initial conditions can lead to significantly different outcomes - known as the "butterfly effect".The Lorenz System oftens comes out in a butterfly shaped plot. The significance of Lorenz's work on these equations lies in its contribution to chaos theory and promoting a novel approach to understanding complex systems. The Lorenz equations have been used to model diverse phenomena such as fluid dynamics, chemical reactions, and stock market behavior, among others.



Source for more detail information :

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MLA Format

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