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Full Length Research Paper

Vertical profiles of winds and electric fields triggered by tropical storms - under the hydrodynamic concept of air particle

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Contrary to popular understanding, tropical storms are not just weather events that can easily be described by ground - or space - based observations. Instead the phenomena are a combination of complex physical processes that occur under the accuracy of temperature and humidity conditions. The water vapour originally produced by high temperatures, serves as a source of energy that maintains tropical storms, since this water vapour have managed to reach to the 0.0098°C isotherm level which is located about 4.5 km in tropical latitudes. The electrical capacitors and particle accelerators are sources of acceleration and electric fields similar to those triggered by tropical storms. Both devices (mechanical and electrical) provide a good opportunity to better understand the nature of winds and electric fields that triggers the cold front as it passes over a region.

Key words: Tropical storms, troposphere electricity, lightening.

INTRODUCTION

The complexity of the physics behind the tropical storms is not easy one and in order to understand them, a more realistic assumption provided by the hydrodynamic concept of particle of air shall be considered. The popular ideal gas assumption, which has been used since 1735 by George Hadley (David, 1991), may not be a preferable approach to understand these complexities. The algebraic interpretation of the necessary equality between the pressure of the air particle and its environment, provide a relationship between changes in its volume (V) depending on the temperature (T) and coefficients of expansion of its gaseous constituents at constant volume and temperature.

Base on this important relationship, it is possible to divide the troposphere into three regions: two regions where the volume (V) and temperature (T) vary in the same direction and one region where the volume (V) and temperature (T) vary in the opposite direction.

Taking into account the fact that the exchange of matter between the particle of air and the surroundings environment is very slow, any increase in volume (V) leads to a depletion in density (ρ) which triggers the movement of the particle of air to higher altitudes. On the other hand, any decrease in volume (V) leads to an increase in density which triggers the movement of the particle to lower altitudes.

Knowing how (V) depends on (T) across the troposphere, helps to build the vertical profile of the winds observed in a portion of atmosphere that is disturbed by the passage of a cold front. The positive electrical charges contained in stratus trigged by spontaneous cooling process of air masses of moist low levels, create two electric fields directed downward and upward.

The vertical profiles of wind and electrical fields, triggered by tropical storms, correspond to those of two physical devices (capacitors and accelerators of particles of air). Their modus operandi justified:

- The violence of winds received on the ground.
- The mechanisms of auto maintenance of cyclones.
- The appearance of positive charges within the stratus produced by storms.
- The creation of an electric current when electric fields reach critical values.

Intensity of electric current produced by thunderstorms is

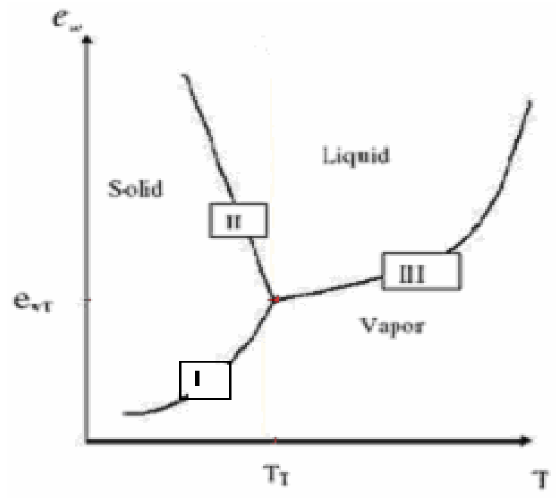

Figure 1. Saturation curves for water substance onto the e_wT-plane (e_{wT} and T_T are called triple-point data): e_{wT} = 6.11 mb ; T_T= 0.0098°C

so high that it burns (by joule effect) everything it finds in its way, producing lightning and thunder. In addition, a particle of pure water, maintain its position in the atmosphere until it has been inseminated by constituents soluble in water such as fine dust particles or gases (CO_2), which increases its density. This helps to understand why stratus, triggered by tropical storms, produces heavy rainfall. Stratus forms at an altitude where the concentration of dust particles and CO_2 is high.

FACTORS LIMITING THE USE OF THE IDEAL GAS HYPOTHESIS IN THE TROPOSPHERE

The equation that connects the volume (V), pressure (P) and the absolute temperature (T) of an ideal gas is expressed:

$$P.V = N.k.T \qquad (1)$$

Where N is the number of molecules and k is Boltzmann constant. This formula can be used to define the virtual temperature, but only for the case of a fixed number (N) of molecules. However, in the troposphere, changes in the water phase modify constantly and in every place, the number (N) of molecules. Therefore, the state equation (1), which led to the definition of virtual temperature, is inadequate for the troposphere.

On the other hand, the various saturation curves of the pT-plane for water substance (Figure 1) shows that: for temperatures less than 0.0098°C and the humidity higher than 6.11 mb, water vapour decreases when temperature increases and increases when the temperature decreases. In the tropical troposphere, there are areas where these conditions of temperature and humidity are combined. In these regions, water vapour has thermo elastic properties opposite to those of ideal gas. Ultimately, to understand the tropical weather, the assumption of ideal gas may not be appropriate.

DEFINITION OF THE CONCEPT OF PARTICLE OF AIR

Atmospheric dynamics uses a very precise concept of particle of air (Byers, 1959; Arakawa, 1966; Batchelor, 1967; Riegel, 1992). Namely:

(a) Few exchanges on a molecular scale: One can follow a quantity of air which preserves certain properties.
(b) Quasi-static: There is at any moment dynamic balance, the particle has the same pressure as its environment (P = Pext).
(c) No thermal balance: The heat transfers by conduction are very slow and are neglected. One can have T ≠ Text.
(d) The size of the particle can go from a few cm to 100 km according to the applications.

CHANGES IN VOLUME OF THE MOIST AIR PARTICLE DEPENDING ON THE TEMPERATURE

The atmosphere is mainly composed of dry air and water vapour. The Dalton law connects the pressure (P) with partial pressure of dry air (Pa) and water vapour (e_w).

$$P = \sum_i P_i = P_a + e_w \qquad (2)$$

In deriving (P) with respect to the temperature, one has

$$\frac{dP}{dT} = \left(\frac{\partial P}{\partial T}\right)_V + \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{dV}{dT}\right) \qquad (3)$$

The pressure of the particle of air must be the same as that of the ambient air, including during sudden changes in phases by water it contains. In other words, the pressure (P) of the particle of air is constant during isolated transformations. Hence

$$dP = 0 \qquad (4)$$

Equations (3) and (4) lead to the derivative of V compared to T

$$\frac{dV}{dT} = -\frac{\left(\frac{\partial P}{\partial T}\right)_V}{\left(\frac{\partial P}{\partial V}\right)_T} \qquad (5)$$

Introducing the coefficient of thermal expansion of moist air at constant temperature

Table 1. Changes in volume of the moist air particle depending on temperature within a specific range of temperature and humidity.

Range of temperature and humidity	T < 0.0098℃ e_w < 6.11 mb	T < 0.0098℃ e_w > 6.11 mb	T > 0.0098℃ e_w > 6.11 mb
$(\frac{\partial P}{\partial T})_V$	+	-	+
$\frac{dV}{dT} = \frac{1}{\chi . P}(\frac{\partial P}{\partial T})_V$	+	-	+

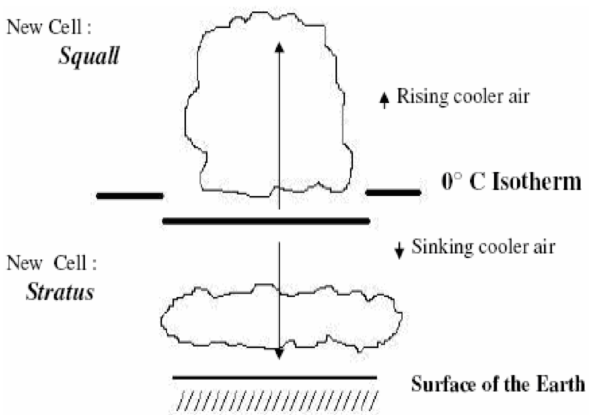

Figure 2a. Intrinsic vertical velocity field of a cooler tropical cyclone. The 0℃ isotherm is broken down surrounding the source.

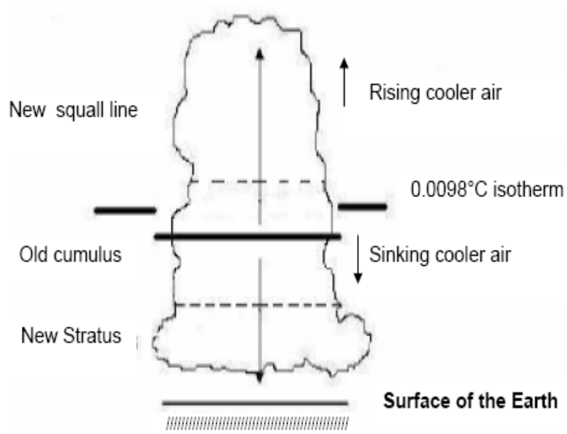

Figure 2b. Vertical distribution of cloud formations in a cumulonimbus.

$$\chi = -\frac{1}{P}(\frac{\partial P}{\partial V})_T ,$$

The equation (5) becomes

$$\frac{dV}{dT} = \frac{1}{\chi . P}(\frac{\partial P}{\partial T})_V \quad (6)$$

Equation (6) is fundamental to the dynamics of the atmosphere because it helps to know the sign of (dV/dT). The rate of increase in volume depends on the elastic properties of gaseous constituents of the particle. Table 1 is obtained from a simple laboratory experiment during which we realize the pressure variations of a volume of moist air locked in a half bottle of mineral water. The device that we used for our experiment was exposed as a first step to solar radiation, and then placed in a refrigerator. The ranges of temperature and humidity are those used by Clapeyron on Figure 1 (Riegel, 1992).

The results of our experiment are in good agreement with the slopes of the various saturation curves obtained in the case of water substance thermodynamics (Figure 1). The existence of cold upward and hot subsidence above the 0.0098℃ isotherm surface of tropical regions is established in Table 1.

VERTICAL PROFILES OF WINDS AND ELECTRIC FIELDS

The results of Table 1 lead us to extract the vertical profile of the winds triggered in a column of air, disturbed by the passage of a cold front. The updrafts of cold front appears on the Figures 2 (a-c).

Figure 2a indicates positions in altitude of cold (updrafts and downdrafts). The squall line finds its energy from the reservoir formed by a branch of the 0℃ isotherm, which breaks down and then trap water vapour that manage to reach near the 0℃ isotherm surface (Mbane, 2005, 2007).

The spontaneous cooling of the moist air masses of low levels triggers the formation of a dark and very spread cloud: the stratus. This cloud spreads from East to West as the cold front. Figure 2b begins to show the complexity of the phenomenon. The recent cells form generally in an area already occupied by old cells. The cloud that results is in which observers describe as cumulonimbus (or cloud announcing the storms). The origin of updrafts of cumulonimbus is well known. The superposition of recent cloud cells with those oldest, led to a long standing thought the existence of an ascendant current, from ground to the tropical tropopause located at about 12 km in altitude.

The cold downdrafts snack in passing, the valence

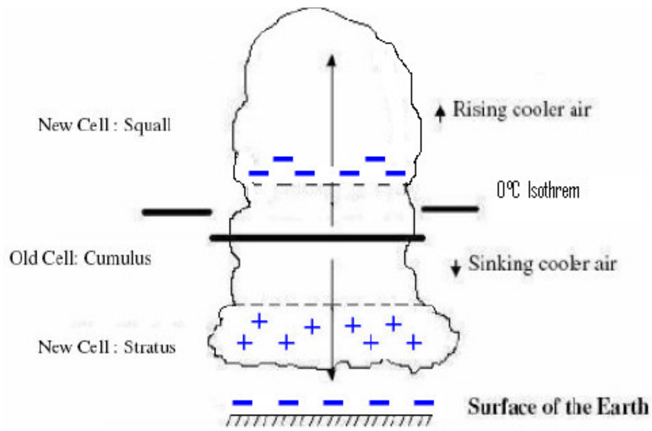

Figure 2c. Vertical distribution of electrical charges within a cumulonimbus.

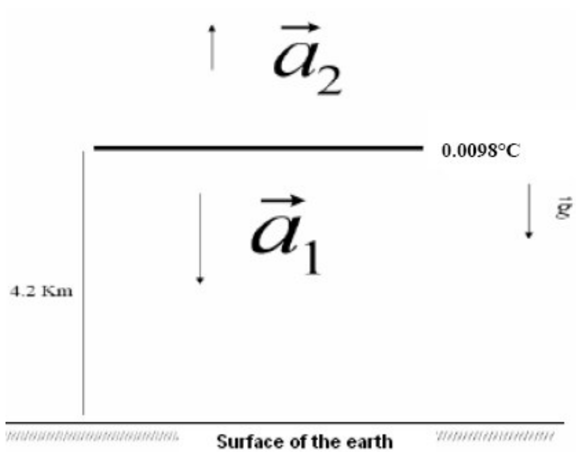

Figure 4a. Kinematical equivalent device of tropical storms.

electrons in water molecules that form the stratus. These electrons populate just at the surface of the ground, while the base of the squall charged, as a result of induction, negatively (Figure 2c). The Cold Fronts generate electrical charges in the columns of air they pass through. Figure 3 shows that the thunderstorms cells do not result from warm advection. These cells, unlike what we see on figure 3, are deployed at high altitudes above gusts of wind that hit the ground.

The reversal of direction of vertical current, established in our work is confirmed by the storm disturbances. Thunderstorm cells are propagated under the action of the Coriolis force with a propagation speed proportional to the cosine of their latitude and the intensity of vertical currents (Mbane, 2005).

KINEMATICAL AND ELECTRICAL EQUIVALENT DEVICES

Figure 2c shows that a tropical storm behaves like a particle accelerator and a capacitor. The modus operandi of

Figure 3. Vertical structure of a cloud formation produced by high heat.

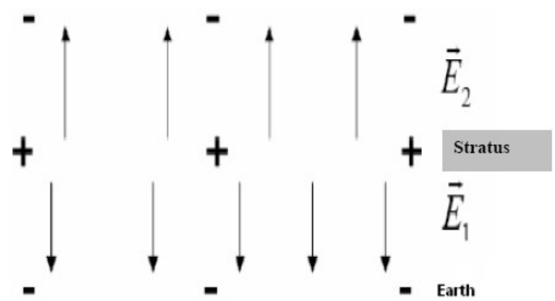

Figure 4b. Electrical equivalent device of tropical storms

each of these two devices allows a better understanding of tropical storms.

Kinematical equivalent device

In both sides of the 0.0098°C isotherm, the air particles are accelerated towards the tropopause and the surface of the ground. Regarding the movement towards the earth's surface, the depression carved by the passage of the cold front generates an acceleration which combines favourably with the acceleration of gravity (g = 9.8 ms^{-2}). The air particles approaching the ground, having travelled almost 4.5 km, acquires a vertiginous vertical velocity. Their kinetic energy increases with distance travelled. Hence the disturb winds at the surface or at the height of waves arising from downdrafts that crashed into the ocean (Figure 4a).

Electrical equivalent device

Between two frames of the capacitor, the electric field is inversely proportional to the square of the distance between these frames. When an electric field reached its critical value depends on the dielectric (moist air), an electric current (I) is triggered between the frames of the capacitor. The intensity of this current is so high that it can burns (by joule effect) objects that it crosses including fine dust particles in the air. The hole opened into the atmosphere by electric shock closes quickly, producing a shock wave (thunders) (Figure 4b).

Conclusion and Comments

The physical mechanisms pertaining to the formation of tropical storms are very complex. However, as shown in this work, there are realistic assumptions on the atmosphere leading to a number of results. Convinced that the assumption of ideal gas is unsuitable for the tropical troposphere, we consider more realistic assumption provided by the hydrodynamic concept of particle of air to study the vertical profiles of winds and electrical fields triggered by tropical storms.

Hydrodynamic assumptions are used very little today and the results obtained in this work demonstrate their effectiveness:

(i) We now know how the volume of the particle varies when air temperature increases or de-creases, in any part of the atmosphere. The vertical movement that results can be predicted.
(ii) We now have a precise idea of the vertical distribution of cloud formations and vertical winds in a cumulonimbus.
(iii) The appearance of positive charges within the stratus produced by storms can be justified.
(iv) We have a better view of the vertical distribution of electrical charges (or electrical fields) within a cumulonimbus.

These results can be placed side by side with ground - or space - based observations, to develop a solid theory on physical mechanisms pertaining to the formation of tropical storms.

REFERENCES

Arakawa A (1966). Computational Design for Long-Term Numerical Integrations of the Equations of Atmospheric Motion. Journal of Computational Physics, 1: 119-143.

Batchelor GK (1967). An Introduction to Fluid Dynamics. Cambridge University Press.

Byers HR (1959). General Meteorology. McGRAW-HILL BOOK COMPANY, INC, P. 540.

Laing D (1991). The Earth System: An introduction to Earth Science. Wm. C. Brown ISBN 0-697-07952-X.

Mbane BC (2005). La Convection Naturelle et ses Manifestations dans une Atmosphère Humide (fundamentals of the thermo-convective flows of the moist air areas). Doctoral Thesis, Dec. 2005, 116pp.

Mbane BC, Pemha E, Gatchouessi KE (2007). Flows thermo-Convective of the Raileigh-Benard-Marangoni, 6th Ebasi International Conference on Physics & Technology for Sustainable Development in Africa. Held in South Africa 24-26th of January 2007.

Mbane BC (2007). Troposphere Climatology, IHY-AFRICA Space Weather Science and Education Workshop, Addis Ababa, Ethiopia, November 12-16.

Riegel CA (1992). Fundamentals of Atmospheric Dynamics and Thermodynamics. World Scientific Publishing Co. Pte. Ltd. P. 496.