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Impacts of thermoelastic properties of saturated water vapor on tropical depressions thermodynamics and dynamics

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ABSTRACT

Despite important scientific advances on the knowledge of weather phenomena, research on cyclones, hurricanes and thunderstorms continues intensively to determine physical laws that govern their thermodynamics and dynamics. Given the fact that saturated water vapor is known as the birthplace of meteorological events such as clouds and electrical or thermodynamic processes related, we want to make a contribution to a better understanding of tropical depressions by revealing the impacts of thermoelastic properties of this birthplace on major tropical disturbances kinematics. Our results are based on Clausius-Clapeyrons' formulas which show precisely that, unlike dry water vapor that can be assimilated to the ideal gas at all circumstances, saturated water vapor has, in an air parcel at the same time very cold (temperatures below 0.0098° C) and rich in moisture (vapor pressure above 6.11 mb), thermoelastic properties diametrically opposed to those of ideal gas (including dry water vapor). Vertical profiles of temperature and water vapor in the troposphere leads to localization of the air parcel in which the ideal gas assumption should be banned, hence the appropriate kinematics of cyclones and hurricanes.

Key words: Saturated water vapor, thermoelastic properties, kinematics of cyclones and hurricanes.

INTRODUCTION

Regardless of the manner in which the Tropical depressions are considered, these atmospheric events with high destructive power leave no one indifferent [1-11]. This is one of the reasons; enormous sums of money are committed to acquire all sorts of information on climate phenomena, such as cyclones, hurricanes and thunderstorms. Over the years, these efforts and considerable financial support from the Governments of many countries around the world have set up databases that store:

- Routine meteorological measurements (pressure, temperature of dry and wet thermometers, relative humidity, amount of precipitation, evaporation, sunshine duration, wind, etc..) collected at weather stations (Main or secondary) from different countries, members of World Meteorological Organization (WMO).
- Very precise measurements of basic meteorological parameters (pressure, temperature, humidity, solar radiation and wind), performed during international "campaigns", "Programs" or "Projects" (WAMEX 1979, COPT 1981, AMMA, GEOSS, SECAO, TACE, etc.) on micrometeorological observations, appropriately organized to track tropical depressions.
- Maps constructed with the images or information provided by cameras installed on satellites and on vehicles (boats, planes or cars) arranged to allow to better approach and observe tropical depressions during all phases characterizing their existence (birth, maturity and decline).
- This effort has led to important scientific advances on the knowledge of tropical depressions. Knowledge store inside an extensive literature devoted to the major tropical disturbances. However, research on tropical depressions continues intensively to determine the physical laws that govern:
- Turbulent and violent winds that trigger the Cyclones;
- Updrafts constantly present in thunderclouds, while the assumption of ideal gas, used by all weather models (without exception), only allows the presence of cold downdrafts;
- Spread from East to West (both in the northern hemisphere than in the southern hemisphere) of tropical cyclones, while gaining in intensity, and the change of trajectory (spread from west to east) that occurs when intensity decreases or when moving away toward the poles (North or South);
- The appearance of electric charges and fields in thunderclouds;
- Increased cyclone activity as they pass over the ocean with a surface temperature (Ts) greater than 25 ° C.

Namely five of the many concerns of meteorologists on the major tropical disturbances.

In this work, we want to make a contribution to a better understanding of tropical depressions. We obtain these results having seen happily that in tropical regions, saturated water vapor occupies the middle and top of the troposphere to more than 90% (remember here that saturated water vapor is known as the birthplace, home or bed of weather events such as clouds and (electrical or thermodynamic) processes related. From that moment, it was necessary to resort the thermodynamic properties of saturated water vapor to understand tropical depressions thermodynamics and dynamics. The Clausius-Clapeyron's formulas show precisely that, unlike the dry water vapor that can be assimilated to the ideal gas at all times, saturated water vapor at low temperatures (temperatures below 0.0098 ° C) in the presence of high humidity (vapor pressure above 6.11 mb) of air, has thermoelastic properties diametrically opposed to those of ideal gases (including dry water vapor). Once considered all this valuable information on thermoelastic properties of saturated water vapor, we end up with a major revelation about tropical meteorology:

Winds generated by tropical disturbances such as cyclones or hurricanes, are composed of vertical currents (triggered by passive convection) and horizontal geostrophic currents (triggered by the deep groove of low pressure that generates tropical depression, and whose center is materialized by "eye" of the disturbance).

2- Changes in volume of the moist air particle depending on the temperature

Atmospheric dynamics uses a very precise concept of **particle of air** [12-13]. Namely:

(a) Few exchanges on molecular scale: one can follow a quantity of air which preserves certain properties.

(b) Quasi-static equilibrium: there is at any moment dynamic balance, the particle has the same pressure as its environment ($P=P_{ext}$).

(c) No thermal balance: the heat transfers by conduction are very slow and are neglected. One can have $T \neq T_{ext}$.

(d) The size of the particle can go from a few cm to 100 km according to the applications.

Taking into account the fact that the atmosphere is mainly composed of dry air and water vapor, the Dalton's law connects the pressure (P) with the partial pressure of dry air (P_a) and water vapor (e_w)

$$P=P_a+e_w \qquad (1)$$

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

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

According to the Quasi-static equilibrium (or dynamic balance) the pressure of the parcel 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 parcel of air remains constant during changes in phases. Hence

$$dP = 0 \qquad (3)$$

Equations (2) and (3) lead to the derivative of V compared to T

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

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

$$\chi=-\frac{1}{P}\left(\frac{\partial P}{\partial V}\right)_T.$$

The equation (4) becomes

$$\frac{dV}{dT}=\frac{1}{\chi}\bullet\frac{1}{P}\left(\frac{\partial P}{\partial T}\right)_V.$$

Then

$$\frac{dV}{dT}=\frac{1}{\chi}\bullet\frac{1}{P}\left[\left(\frac{\partial P_a}{\partial T}\right)_V+\left(\frac{\partial e_w}{\partial T}\right)_V\right]$$

The Clausius-Clapeyron relations (illustrated by saturation vapor pressure line of Fig.1) show that the derivative of the pressure (P) compared to T and the derivative of water vapor (ew) compared to T have the same sign, given their current values in the troposphere.

Equations (6-7) are fundamental to the dynamics of atmosphere because they help to know the sign of $\frac{dV}{dT}$ the derivative of the volume (V) of a parcel of moist air, compared to T) under all conditions of temperature and vapor pressure possible in the atmosphere.

They are also prognostic equations because they predict in which direction the air parcel will move (up or down) if temperature increases or decreases. Table I provides an overview of possible situations in the atmosphere.

Table I. Pressure variation of a constant volume of moist air, depending on the temperature T: in specific regions of the troposphere, delimited by 0.0098°C and 6.11 mb characteristic surfaces.

Range of Temperature (°C)	T < 0.0098	T < 0.0098	T > 0.0098
Range of Vapor pressure (mb)	$e_w < 6.11$	$e_w > 6.11$	$e_w > 6.11$
$(\frac{\partial P}{\partial T})_V$	+	-	+

Table I can be reproduced an infinite number of times from an original simple experiment [14] during which the students realize the pressure variations of a constant volume of moist air locked in a half bottle of mineral water. The device that they used for this experiment is 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 Fig.1 [15, 16].

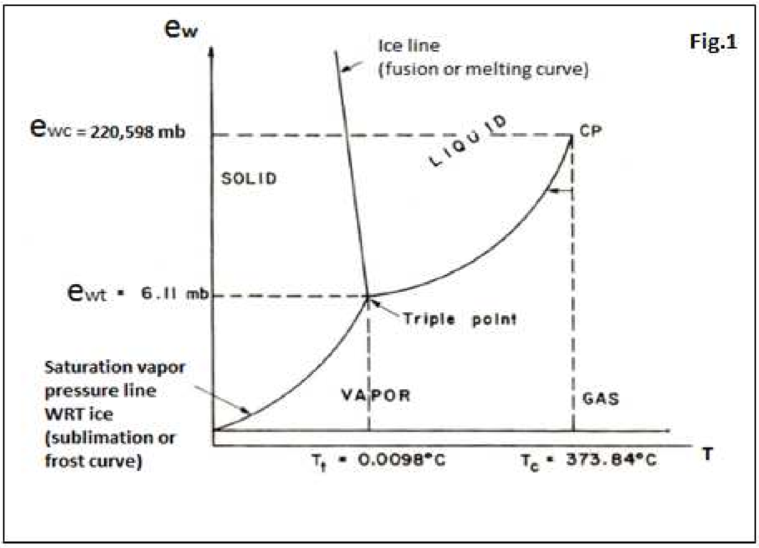


FIG.1. the projection of the $e_w\alpha$T-surface for water substance onto the e_w T-plane

The results of our experiment are always in good agreement with the slopes of the various saturation curves obtained in the case of water substance thermodynamics (Fig.1). These slopes confirm the existence of cold advection and hot subsidence, in regions where temperatures are less than **0.0098°C** and at the same time, vapor pressures greater than **6.11 mb**. The presence in the troposphere of **0.0098 ° C isotherm** and **6.11 mb pseudo-isobar** is necessary for the formation of Cyclones.

3- Vertical profiles of winds triggered by tropical depressions and electrical or thermodynamic phenomena that result

Base on the results of Table I and under the relation (6) linking $(\frac{dV}{dT})$ with $(\frac{\partial P}{\partial T})_V$, it is now possible to divide the Atmosphere into three regions: two regions where the volume (V) and temperature (T) of particles of air vary in the same direction (i.e.: $\frac{dV}{dT} > 0$) and one region where the volume (V) and temperature (T) of particles of air vary in the opposite direction (i.e.: $\frac{dV}{dT} < 0$). Taking into account the fact that the exchange of matter between the particles of air and the surroundings environment is very slow (according to part (a) of Atmospheric dynamics concept of particle of air), any increase in volume (V) leads to a depletion in density (ρ) which triggers the movement of the parcel 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 parcel to lower altitudes.

Essentially the **tropical depressions** are heat engines, which imply the existence of a heat source or a cold source. Knowing how (V) depends on (T) across the troposphere, helps to built the vertical profile of the winds observed in Hurricanes (Figs.2(a-d)) which interior is warmer than its environment; or vertical profile of the winds observed in Cyclones (Fig.3(a-d)) which interior is cooler than its environment. Thunderclouds, electric fields and charges, lightning are related phenomena triggered by the perturbation according to thermodynamic properties of moist air (Figures 4).

Fig. 2.
(2a): Intrinsic vertical velocity fields of Hurricane. The 0.0098°C isotherm is located above the hot source (itself located on the ground surface).
(2b): Vertical distribution of cloud formations triggered by Hurricanes.
2(c-d): Images depicting Hurricanes

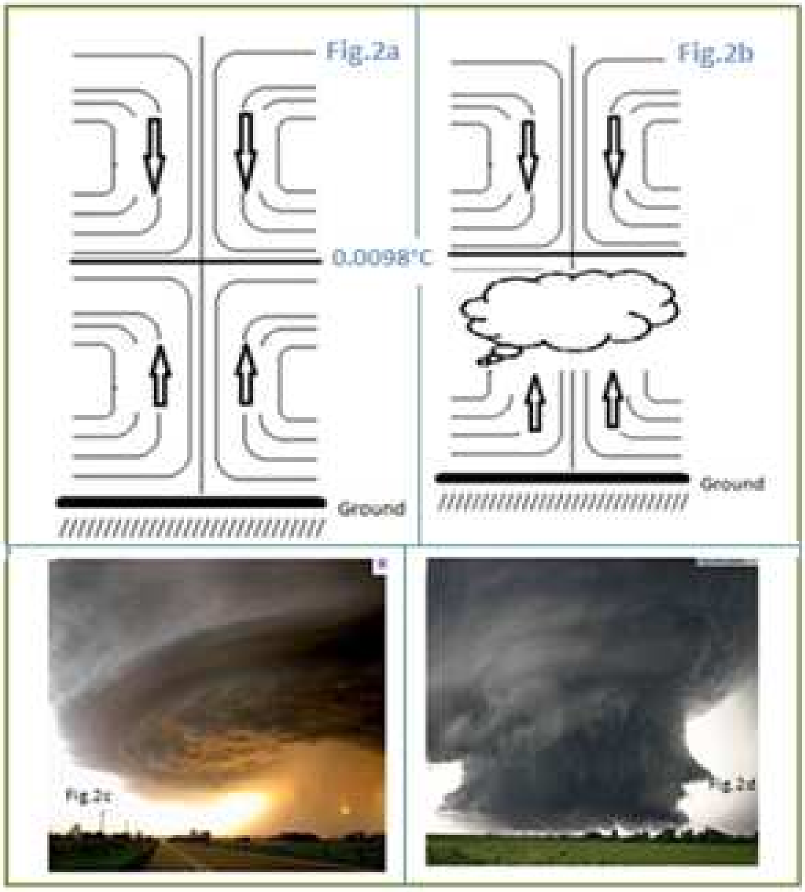
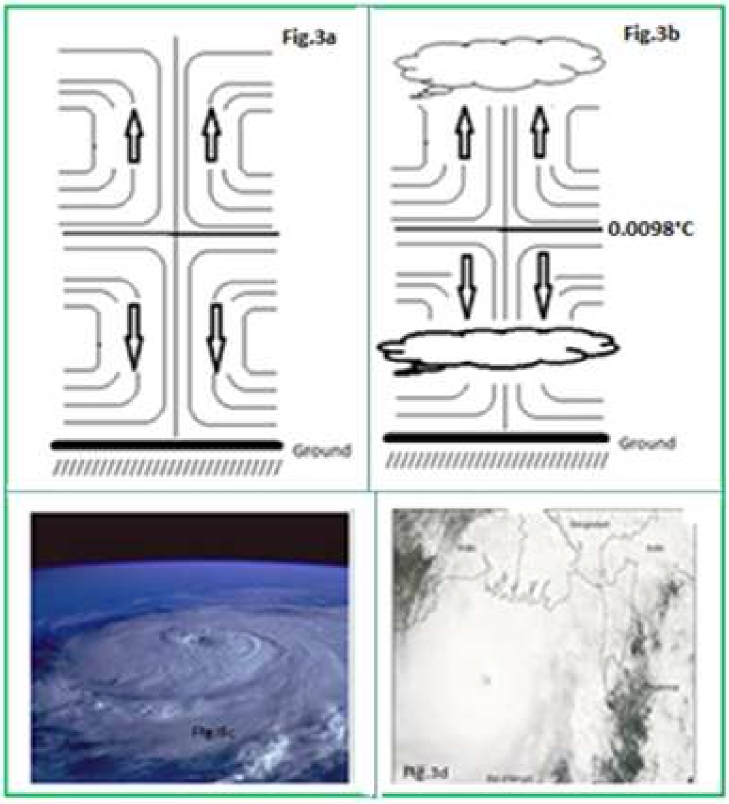


Fig.3.
(3a): Intrinsic vertical velocity fields of cyclones. The 0.0098°C isotherm is located under the cold source (i.e. squall).

(3b): Vertical distribution of cloud formations triggered by cyclones.

3(c-d): Images depicting eyes of the cyclones



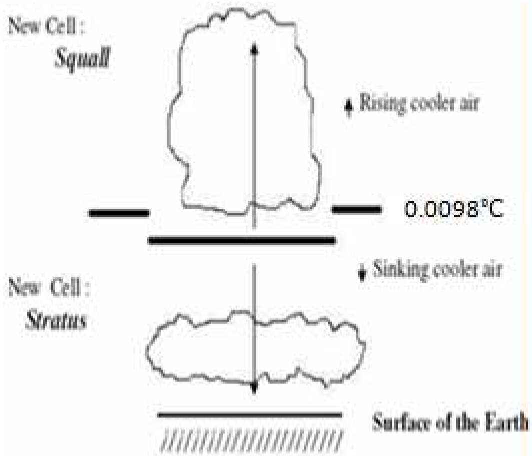


Figure 4a. Intrinsic vertical velocity field of cooler tropical depressions (cyclones). The 0.0098°C isotherm is broken down surrounding the source.

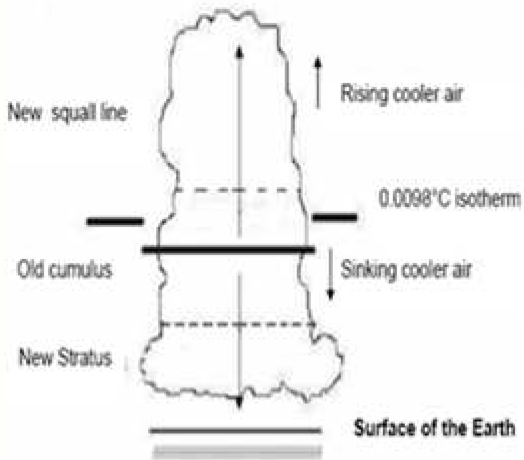


Figure 4b. Vertical distribution of cloud formations within a cumulonimbus

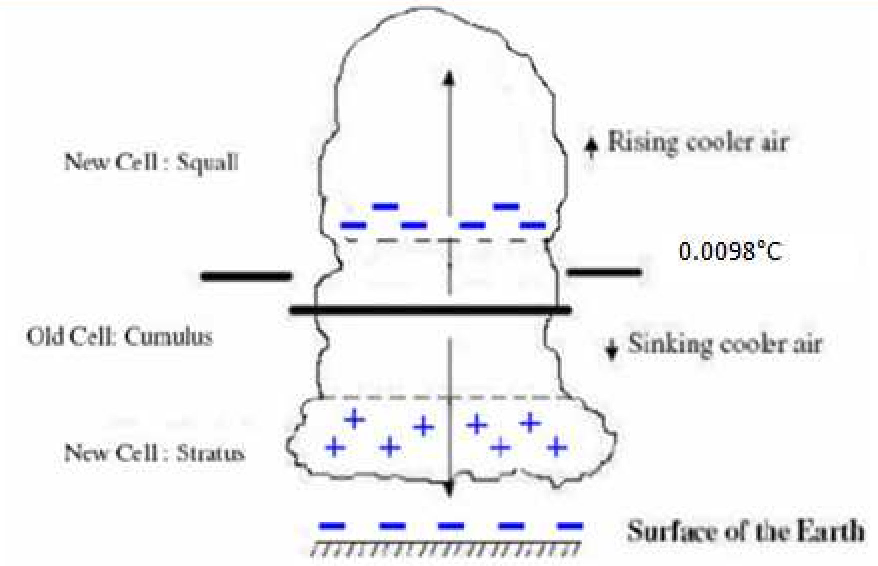


Figure 4c. vertical distribution of electrical charges within a Cumulonimbus.

Downdrafts perforate the newly formed stratus and ionize the molecules of water, pulling their valence electrons, hence the appearance of positive ions and the positive polarity of stratus. The underside of the squall located above the stratus, reacts to the influence of positive electrical charges surrounding by crouching negative charges. The surface of ground below, is also influenced by the positive electrical charges of stratus, and acquires a negative polarity. The storm cloud is really a junction of two capacitors within which lightning can arise and trigger thunder.

4- HORIZONTAL WINDS TRIGGERED BY THE TROPICAL DEPRESSIONS EYES

According to Newton's law of motion, atmospheric flow is a balance between two or more forces of which the following are the most important

$$\frac{d\vec{p}}{dt} = -2\vec{\Omega}\Lambda\vec{p} + \rho\vec{g} + \vec{\xi} - \vec{\nabla}P + \vec{F}$$

Coriolis force, gravity force, frictional forces, pressure-gradient force and tidal force.

Within the tropical depression, the vertical and horizontal flows are laminar. All air particles move in the same direction. Therefore, the particles that slow the movement are very few and the viscous friction near zero.

$$\vec{\xi} = \vec{0} \qquad (9)$$

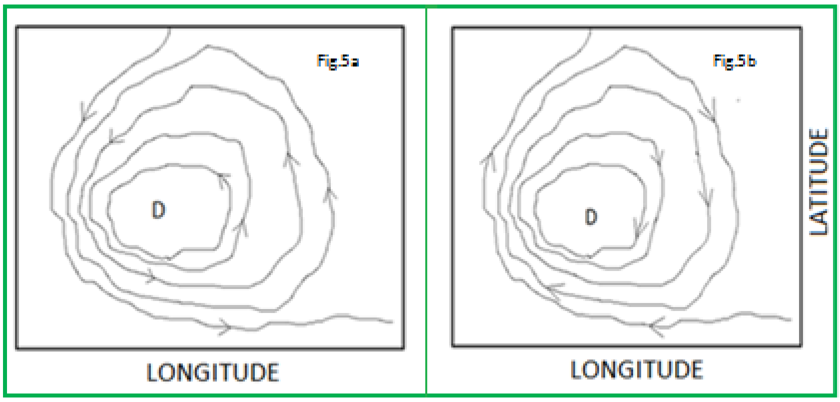
- The size of the perturbations is moderate compared to the distance (d) that separates them from the sun, which exerts an attraction on its particles. The tidal force (proportional to $1/d^2$) is also zero

$$\vec{F} = \vec{0} \qquad (10)$$

It is now clear that strong winds, such as those that exist around the centre depressions, can exist only in regions with strong pressure gradients. The pressure at the centre of cyclones or hurricanes must be very low in order to concentrate a rapid decrease in pressure in a short distance. Deal with such a requirement; the momentum of particles of air, the frictional force and the tidal force are negligible compared to the Coriolis and the pressure-gradient forces. When the pressure gradient and Coriolis forces are the only two factors acting:

$$\vec{0} = -2\rho\vec{\Omega}\Lambda\vec{V} - \vec{\nabla}P \qquad (11)$$

The horizontal wind would blow in a straight path (Figs.5 (a-b)) parallel to the isobars: such a flow is called the **geostrophic wind**.



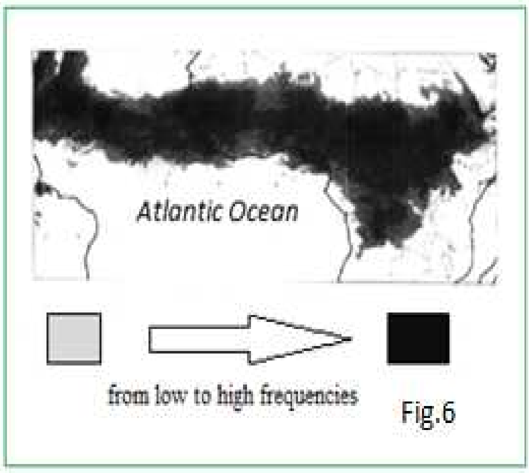
Figs 5. horizontal winds of Cyclones or Hurricanes blow in a straight path Parallel to the isobars. Streamlines in the Northern hemisphere (5a) and the southern hemisphere (5b)

In the Hurricanes cases, geostrophic winds occur from the ground surface to the top of the disturbance: this vortex is visually evidenced by a dark cloud which starts at low levels and peaks at 0.0098 ° C isotherm (Figs.2 (b-d)). In the cyclones cases, geostrophic winds also occur from the ground surface to the top of the disturbance: their vortexes are visually evidenced by a white cloud which occurs at the higher troposphere (Figs.3 (b-d)). The white cloud related to cyclones eyes is often obscured by thick stratus (Fig.3b) that prevents one to see it from the ground. No flow is radial in the tropical disturbances [17] and the centre of the depression evidenced by its eye is a front for the vertical currents associated with passive convection. In the eye of the disturbances, vertical and horizontal currents are necessarily evanescent. Because it is emptied of its particles by the vertical flow (No radial flow): i.e. no particles, no amount of movement due to their presence. Figures5 show the streamlines of the geostrophic wind in the Northern Hemisphere (Fig. 5a) and the Southern Hemisphere (Fig.5b) for the same family of isobars. Geostrophic wind is more intense in areas where the isobars are tightened.

CONCLUSION

For now, the starting points of Hurricanes are not formally identified. However, unlike Cyclones, they reach their maturity on the mainland, destroying lives and whole cities on their way. The energy source is hot lower layers particularly rich in water vapor of the troposphere (i.e. FIG.2(c-d)). Cyclones originate over the continent, precisely over the intertropical convergence zone. Under cover of night pronounced cooling, the “cold cloud” (squall lines) are formed and spread westward (Fig.6) through the action of the Coriolis force. Cyclones reach maturity over the oceans particularly hot (surface temperature above 25 ° C). Their eye is then wrapped in a thick white cloud (Fig. 7). The water vapor originally produced by high temperatures, serves as source of energy that maintains cyclones, since this water vapor have managed to reach to the 0.0098°C isotherm level [13] which is located about 4.5 km in tropical latitudes.

Fig.7



View of the eyewall of Hurricane Katrina taken on August 28, 2005, as seen from a NOAA WP-3D hurricane hunter aircraft before the storm made landfall on the United States Gulf Coast.

The thermodynamics of saturated water vapor is ignored by meteorologists and rarely used in climate models. However, the results presented in this work, demonstrate its effectiveness. To attract the attention of each other on the importance of temperature and winds profiles attributed by us to cyclones and hurricanes, we offer the following views:

(i) Speculation on the origin of electric charges and the events that result must stop and allow each of us to seek ways of preventing the propagation of cyclones or hurricanes: as is done already to contain forest fires. A reflection on the subject is engaged in our research team.
(ii) Now we know how the volume of the particle of air varies when its temperature increases or decreases, in any part of the atmosphere. Vertical movement that results can be predicted.
(iii) Now we distinguish perfectly warm depression (Hurricanes) compared to cold depression (Cyclones).
(iv) It is now possible for all of us to use our common sense, to seek ways of preventing the extent of damage caused by the tropical depression.
(v) We can predict obvious consequence of **global warming**: the frequency of occurrence of tropical depression will be higher and many more areas affected, including those that are spared at this time.
(vi) Airline pilots will be better informed when approaching the turbulence generated by the warm or cold depression.
(vii) According to Mbane [14]: the updrafts are the drivers of tropical depressions. Their fuel is water vapor and they are subject to the Coriolis force ($\mathbf{F}=-2\square\times\mathbf{V}_{updrafts}$) that deviates systematically these disturbances to the west, both in the northern than in the southern hemisphere. The base currents of the atmospheric general circulation inhibit or promote this movement.

To summarize, these results can be placed side by side with ground-or space- based observations, to develop a solid theory on physical mechanism pertaining to the lifecycle of **cyclones or hurricanes**.

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REFERENCES

[1] G. O. P. Obasi, Intertropical meteorology meeting, Nairoby, Kenya (**1974**).
[2] Norquist et al, *MWR*, **1977**,***105***, pp. 334-342.
[3] T.D. Keenan, Quart. J. Roy. Met. Soc., **1992**, 118, pp. 283-326.
[4] P. de Felice, CEPADUES, **1992**, pp. 59-68.
[5] H. Riehl, *Tropical meteorology*, Mc Graw-Hill, New York, **1954**, 392.
[6] C. G. Rossby, Yearbook of Agriculture, U.S. Department of Agriculture, **1941**, pp. 599-655.
[7] P. Bradshaw, *Introduction to turbulence and its measurement*, Pergamon Press, **1971**.
[8] L. Rosenhead, *Laminar boundary layers*, Oxford University Press , **1963**, 242.
[9] H. R. Byers, *General Meteorology*, McGraw-Hill Book Company Inc, **1959**, 540.
[10] A. Arakawa, Journal of Computations Physics, **1966**, **1,** pp. 119-143.
[11] G. K. Batchelor, *An Introduction to Fluids Dynamics*, Cambridge University Press, **1967**, 468.
[12] C. A. Riegel, *Fundamentals of Atmospheric Dynamics and Thermodynamics*, World Scientific Publishing Co. Pte. Ltd, **1992**, 496.
[13] C. B. Mbane, International Journal of Physical Sciences (IJPS), **2009**, **4**, pp. 242-246.
[14] C. B. Mbane, *Doctoral thesis (thèse d'Etat), Univ. of Yaounde I, Yaounde, Cameroun,* **2005**.
[15] H. Lumbroso, *Thermodynamique-100 exercices et Problèmes résolues*, Math Sup. Ediscience/McGraw-Hill, **1973**, 360.
[16] R. Comolet and J. Bonnin, *Mécanique Expérimentale des Fluides (Tome III-Recueil d'Exercices)*, Masson 5^{e} ed., **1992**, 264.
[17] G. T. Csanady, *Theory of Turbomachines*, McGraw-Hill, **1964**.