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Atmosphere dynamic balance model (*ADB*-MODEL) and streamlines of general circulation of the troposphere

Mbane Biouele César

Laboratoire de Physique de l'Atmosphère Terrestre, B.P. 812 Faculté des Sciences de l'Université de Yaoundé I-Cameroun.

ABSTRACT

Given the fact that plots of Troposphere Tricellular Circulation are only based on weather mean conditions measured near the ground (i.e.: pressure and wind fields observed at the surface of the Earth), we want to improve the plots of streamlines of the general circulation of the troposphere, by using the impacts of thermoelastic properties of saturated water vapor on atmosphere vertical motions. Our results are based on Mbanes' equation of Atmosphere dynamic balance which shows precisely that, unlike the dry water vapor that can be assimilated to the ideal gas at all circumstances, the 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 (provided by ground-or space-based observations) lead to the location of the air parcel in which the ideal gas assumption should be banned; hence the appropriate plots of troposphere tricellular circulation streamlines.

Key words: Atmosphere dynamic balance, plots of Tricellular circulation streamlines.

INTRODUCTION

Because of the importance of the sun, particularly in its relationship to the earth, enormous efforts and sums of money are committed to acquire all sorts of information on climate phenomena, such as transfer of mass and heat in the atmosphere. Over the years, these efforts and considerable financial support from the Governments of many countries around the world have set up databases that store:

- 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.

- 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);
- Maps constructed with the images or information provided by cameras installed on satellites and on vehicles (boats, planes or cars).

These efforts have led to important scientific advances on the knowledge of basic meteorological parameters such as surface fields of pressure and winds along a meridian [1, 4]. However, progresses on the general circulation of the atmosphere are very slow, because of measurement errors on the space based data, and the absence of theory that can help to know quantitatively (or qualitatively) what exactly happens in the middle and high layers of troposphere.

In this work, we want to improve the plots of the streamlines of the general circulation of the troposphere by using the impacts of thermoelastic properties of saturated water vapor on atmosphere vertical motions. Our results are based on Mbanes' equation of Atmosphere dynamic balance which shows precisely that, unlike the dry water vapor that can be assimilated to the ideal gas at all circumstances, the 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 (provided by ground-or space-based observations) lead to the location of the air parcel in which the ideal gas assumption should be banned; hence the appropriate plots of streamlines of troposphere tricellular circulation.

2- EQUATION OF ATMOSPHERE DYNAMIC BALANCE

Atmospheric dynamics uses a very precise concept of particle of air [5-9]. 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

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

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

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

Then the ***Mbanes' equation of Atmosphere dynamic balance:***

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

One can also write equation of Atmosphere dynamic balance in terms of partial pressures

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

The Clausius-Clapeyron relations (illustrated by saturation vapor pressure line of Fig.1a) 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.

Mbanes' 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.

Equations (6 and 7) are also prognostic 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 can be reproduced an infinite number of times from an original simple experiment [10] 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 [11, 12].

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)	$e_w < 6.11$	$e_w > 6.11$	$e_w > 6.11$
$(\frac{\partial P}{\partial T})_V$	+	-	+

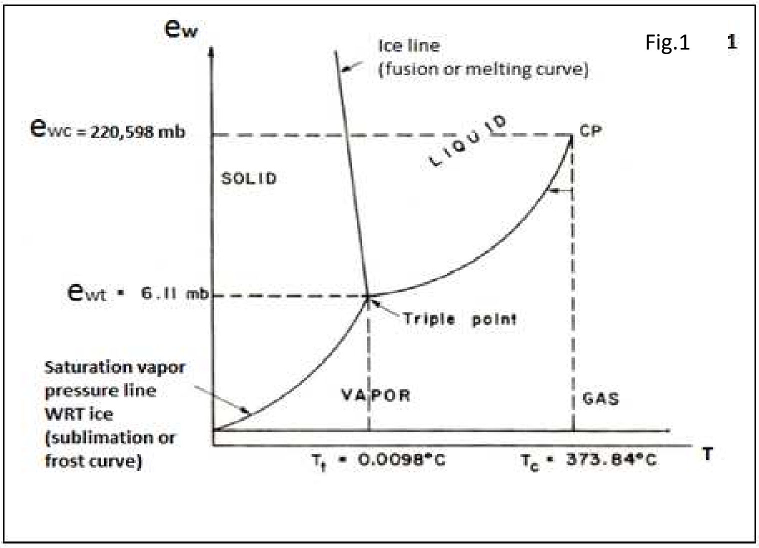
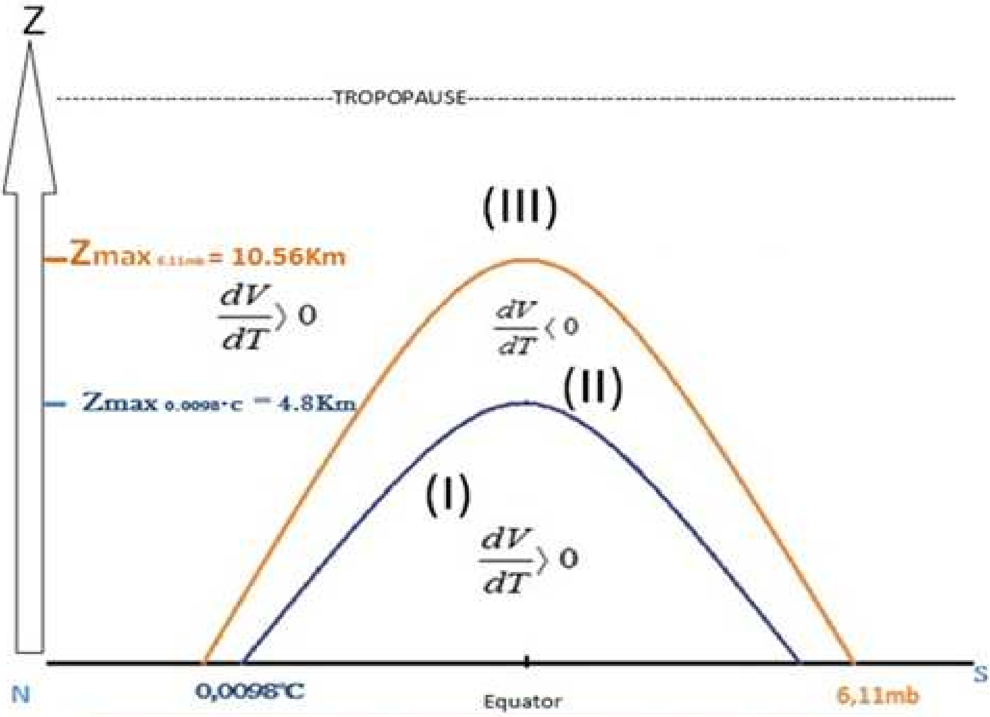


FIG.1. The projection of the $e_w \alpha T$-surface for water substance onto the e_w T-plane

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 or hurricane.

3- SPECIFIC REGIONS OF TROPOSPHERE ACCORDING TO *ADB*-MODEL

The *ADB*-MODEL (Atmosphere Dynamic Balance Model (Table I)) leads to a partition of the troposphere in three specific regions (Fig.2): In regions (I) and (III) one can observe hot advection and cooler subsidence (that looks evident for human common sense). Contrary to what looks evident for our common sense: in region (II), hot subsidence and cooler advection are predicted by *ADB*-MODEL.



Specific regions of the troposphere limited by water vapor critical surfaces.

Fig.2

. V = air parcel volume; T = temperature of air.

. $Z_{max\ 0.0098°C}$ = Maximum elevation (statistic value) of 0.0098°C Isotherm.

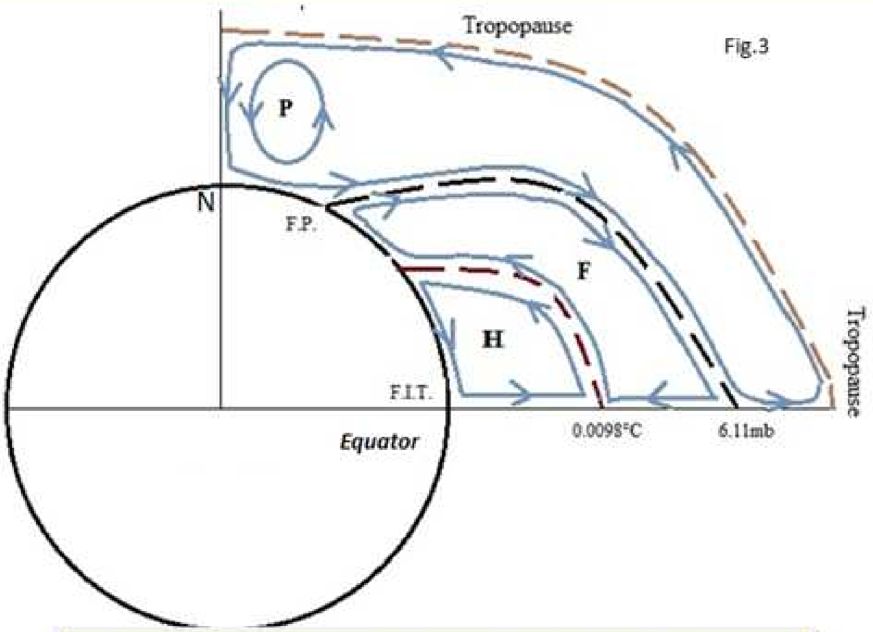
. $Z_{max\ 6.11mb}$ = Maximum elevation (statistic value) of 6.11mb pseudo-isobar

4- STREAMLINES OF TRICELLULAR CIRCULATION SUGGESTED BY *ADB*-MODEL

Given the fact that Kinematic boundaries' conditions of troposphere specific regions are clearly known, we can draw streamlines of meridional transport of mass due to inhomogeneous distribution of heat at the Earths' surface. Before drawing streamlines, we have considered two major assumptions:

- The surface of the Earth is supposed homogenize or uniform;
- The temperature of the Earth surface must decrease gradually and systematically from equator to (northern or southern) poles.

Then applying the *ADB*-MODEL rules (regarding hot or cold advection on one hand, and hot or cold subsidence on other hand) of regions I, II and III; we obtain a realistic plot of troposphere tricellular circulation streamlines (Fig. 3).



Streamlines of Troposphere tricellular circulation

Tropopause

6.11mb Pseudo Isobar

0.0098°C Isotherm

(H) Hadley Cell; (F) Ferrell Cell; (P) Polar Cell with its excrescence

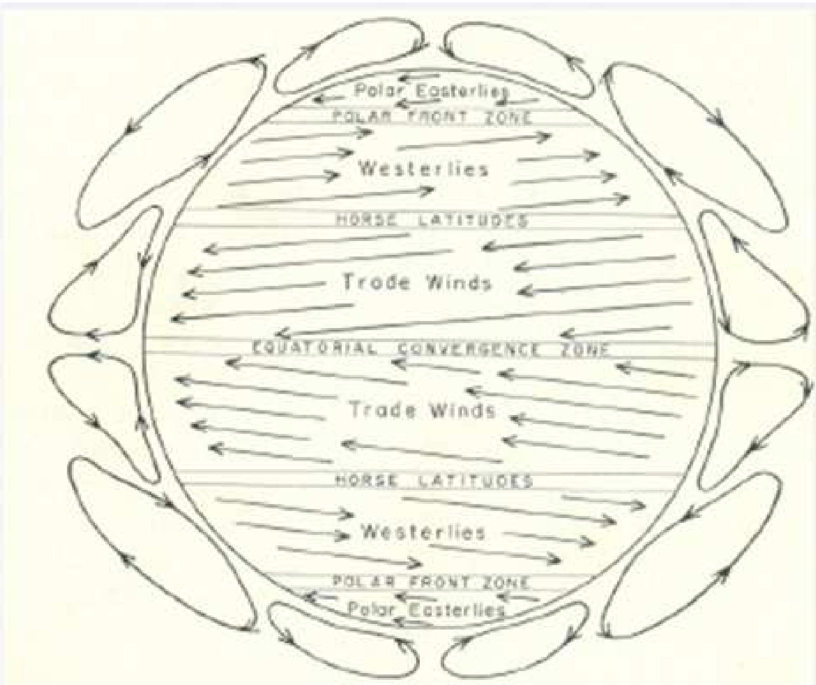


Fig.4. Schematic representation of the general circulation, modified after Bergeron and Rossby (H. R. Byers, 1959)

CONCLUSION

Figure 3, proposed in this work allows knowing how the Hadley, Ferrell and Polar cells, are distributed under the tropopause. The regions in which these cells are deployed are fully identified. Current weather observations can be used to locate the **polar front** (P.F), the **6.11 mb pseudo-isobar** and **0.0098 ° C isotherm** if necessary. In other words, it is now possible to exactly know the geometry of individual cells and their relative positions. All that marks a clear difference between the classical plots (Figure 4) and the plot suggested by ADB-MODEL (Figure 3).

Plot suggested by ADB-MODEL also allows us to accept now that volcanic ash had been transported from the Tropics to the Polar Regions: a phenomenon that until now were incomprehensible.

It is also important to note that the high evaporations in the Tropics, inevitably affect (according to Fig.3) the Polar Regions: while Fig. 4 provides a barrier between the tropics and the Polar Regions.

Finally, everyone can note that the classic representation of the general circulation is older than half a century what enough is.

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