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Atmosphere dynamic balance model (*ADB*-model) and related troposphere general circulations' cells behind the formation of tropical monsoons

COUANANG SIEBATCHEU Béatrice, MBANE BIOUELE César* and EYEBE FOUDA Armand Jean Sire

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

ABSTRACT

Tropical monsoons, occasionally also known as tropical wet climates or tropical and trade-wind littoral climates, are found in regions where there is a complete seasonal reversal of winds. Given the fact that our understanding of physical processes behind the formation of tropical monsoons is very incomplete and only based on weather mean conditions measured or observed near the ground (i.e.: pressure, precipitations and wind fields), we want to make a contribution to a better description of physic processes behind complete seasonal reversal of easterly (or westerly) winds in regions where tropical monsoons are observed by using the impacts of thermoelastic properties of saturated water vapor on atmosphere passive convection. Our results are based on Mbanes' fundamental relationship of Atmosphere dynamic balance which leads to ADB-model and appropriate plots of both troposphere general circulations' cells and related easterly (or westerly) winds generated by Coriolis force near the surface of the earth.

Key words: *ADB*-model, General Circulations' cells, seasonal reversal of winds, tropical monsoons.

INTRODUCTION

Tropical monsoons, known occasionally as tropical wet climates (Fig.1a) or tropical and trade-wind littoral climates, are found in thoses regions where there is a complete seasonal reversal of easterly (or westerly) winds (fig.1b).

Given the fact that major knowledge on tropical monsoons are only based on ground-or-space-observations of weather mean conditions (i.e.: pressure, persistent heavy rains, flooding and destruction of crops and habitat, Trade-wind fields etc.), we want to make a contribution to a better understanding of physic processes behind these exceptional tropical phenomena, by using the impacts of thermoelastic properties of saturated water vapor on atmosphere passive convection [3-8]. Our results are based on Mbanes' fundamental relationship of Atmosphere dynamic balance which shows precisely that, unlike dry water vapor that can be assimilated to 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, provided by ground-or space-based observations, lead to the location of air parcel in which ideal gas assumption should be banned; hence the appropriate plots of troposphere tricellular circulations' cells that leads to a better understanding of Indian, Southeast Asia, Vietnam or West African Monsoons.

2- Mbanes' fundamental relationships of Atmosphere Dynamic Balance

Atmospheric dynamics uses a very precise concept of particle of air [9-13]. 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.

Fig.1a. Monsoons' Precipitations [1]

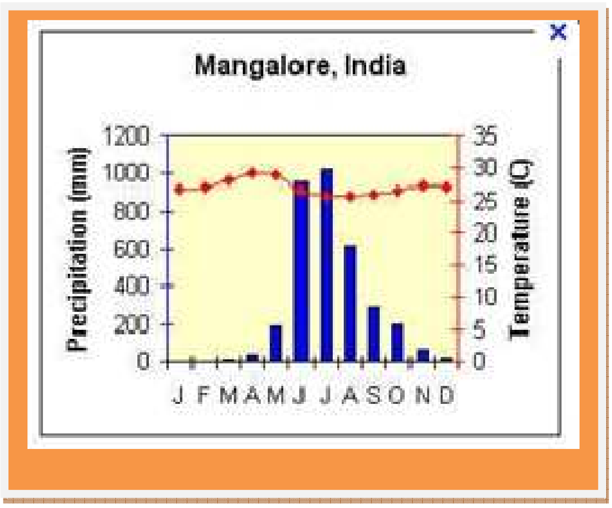
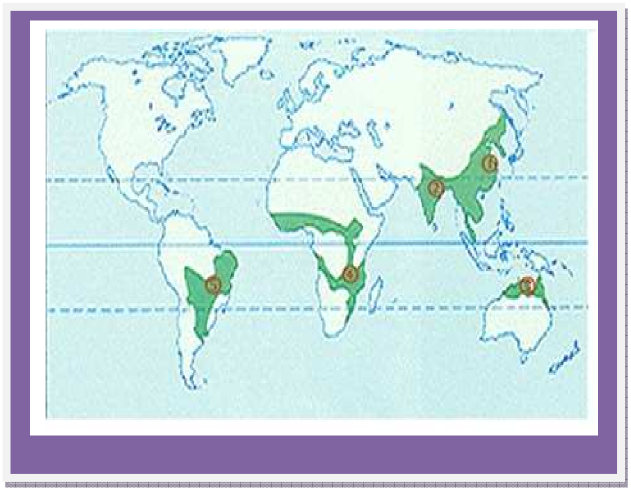


Fig.1b. Monsoons' areas around the word [2]



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

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

According to the Quasi-static equilibrium (or dynamic balance), pressure of a parcel of air must be the same as that of ambient air, including during sudden changes in phases by water it contains. In other words, pressure (P) of 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 Mbanes' Fundamental Relationship 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

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

Or,

$$\frac{dV}{dT} \cong \frac{1}{\chi} \bullet \frac{1}{P} [(\frac{\partial e_w}{\partial T})_V]$$

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 (e_w) compared to T have (8) the same sign, given their current values in the troposphere.

Mbanes' relationships (6-8) are fundamental to the dynamics of atmosphere because they help to know the sign of $\frac{dV}{dT}$ derivative of parcel of moist air volume compared to temperature) under all conditions of temperature and vapor pressure possible in the atmosphere.

Relationships (6-8) 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. 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)	$e_w < 6.11$	$e_w > 6.11$	$e_w > 6.11$
$(\frac{\partial P}{\partial T})_V$	+	-	+

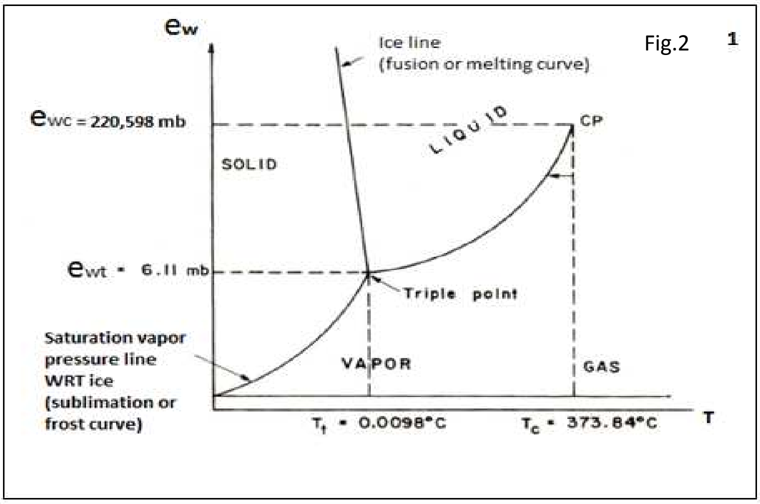


FIG.2. the projection of the e_w αT-surface for water substance onto the e_w T-plane

Table I can be reproduced an infinite number of times from an original simple experiment [3] during which students realize the pressure variations of a constant volume of moist air locked in a half bottle of mineral water. The device 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.2 [14, 15].

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.2). 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**.

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.3): 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.

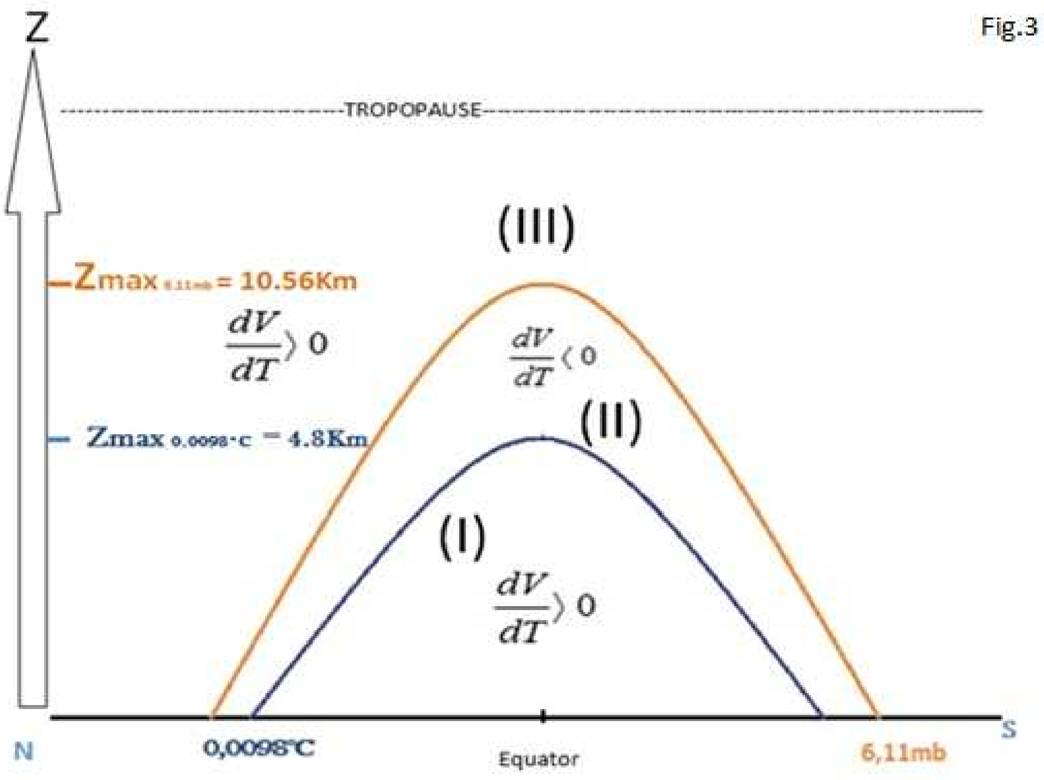


Fig.3. Specific regions of the Troposphere limited by water vapor critical surfaces

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

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

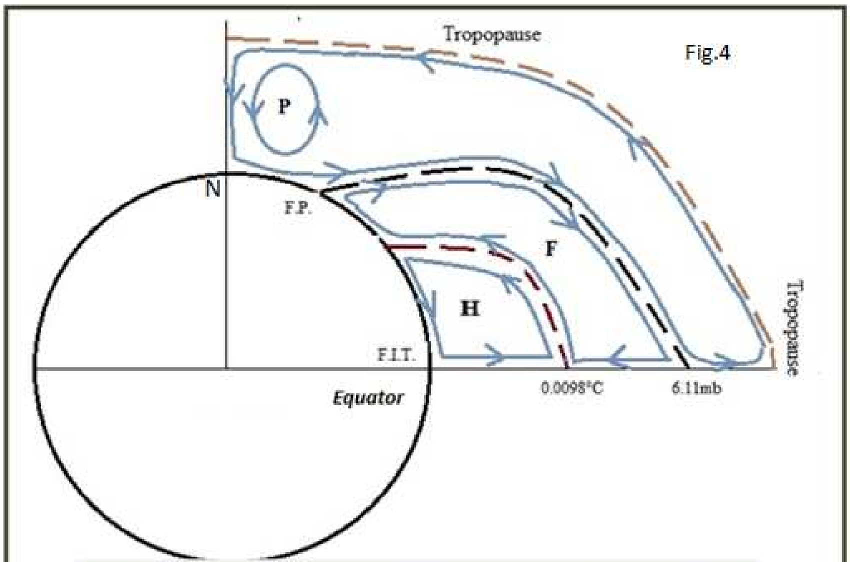
- $Z_{max\ 6.11\ mb}$ = maximum elevation (statistic value) of 6.11mb pseudo-Isobar

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 [7] a realistic plot of troposphere tricellular circulation streamlines (Fig. 4).



Mbanes' Streamlines of Troposphere tricellular circulation

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

5- Troposphere Tricellular Circulation and Coriolis force

Coriolis force is everywhere perpendicular to the velocity $\vec{V}_R$ (since: $\vec{F}_C = -2\vec{\Omega}\Lambda\vec{V}_R$ in Meteorology Rectangular Coordinates System), and it acts to the right (left) in the northern (southern) hemisphere. Therefore: each cell of Fig.4 is behind a couple of easterly and westerly winds (like Hadley cell on Figure 5a).

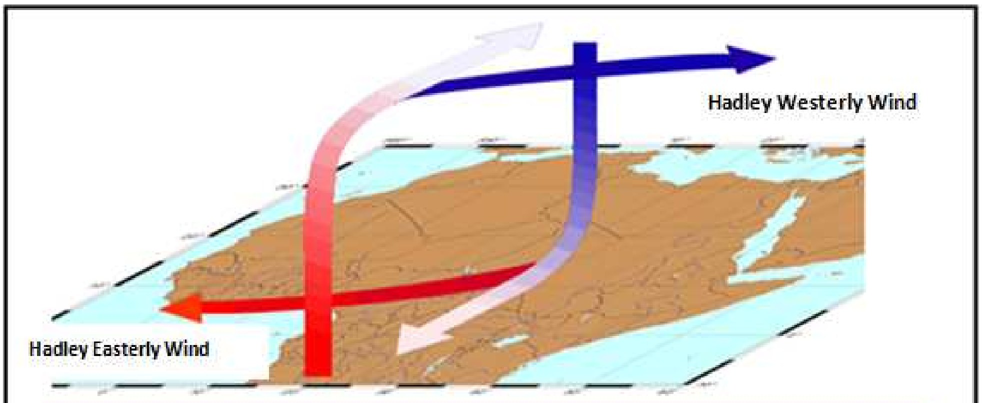
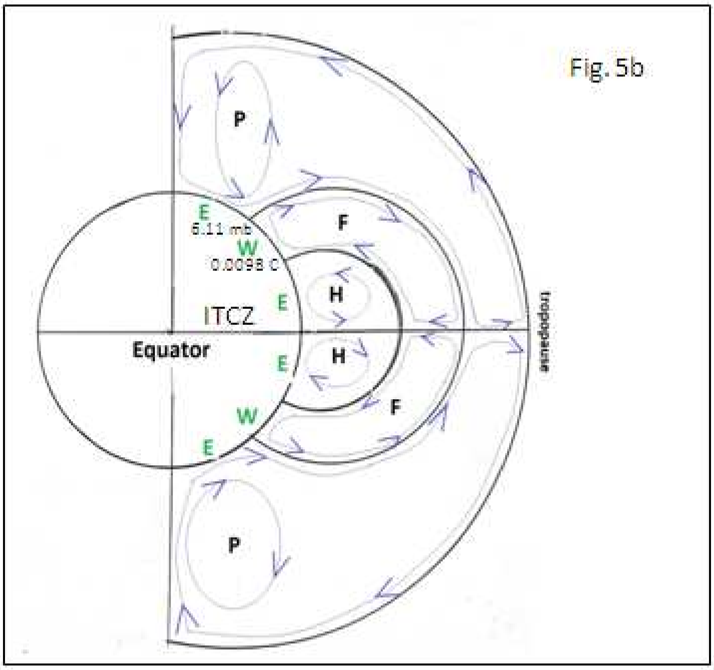


Fig.5a. Easterly and westerly winds triggered by Coriolis Force acting on the Hadley Cell

When the ITCZ is positioned along the equator: the lower troposphere (near the ground) is occupied by the easterly winds triggered by Coriolis force which acts on Polar and Hadley cells. While at the same time and same level (near the ground) of the troposphere, Ferrell cell generates westerly winds as stated on our plot (Fig.5b) and those commonly used (Fig.5c).

Fig. 5b. Troposphere General Circulation when ITCZ and Equator are parallel. Related surface winds:

E: easterly winds
W: westerly winds



In our work, we seek to understand what happens when the ITCZ (or FIT) moves in the northern hemisphere and then Hadley Cell below the ITCZ crosses the equator: Coriolis force acts on Hadley cell below the ITCZ and generates westerly winds (Fig.5d) in the northern hemisphere regions originally occupied by easterly winds (Fig.5b). ***One can remember that: Tropical monsoons are found in regions where there is a complete seasonal reversal of winds (i.e.: countries or regions shown on Fig.1b)***.

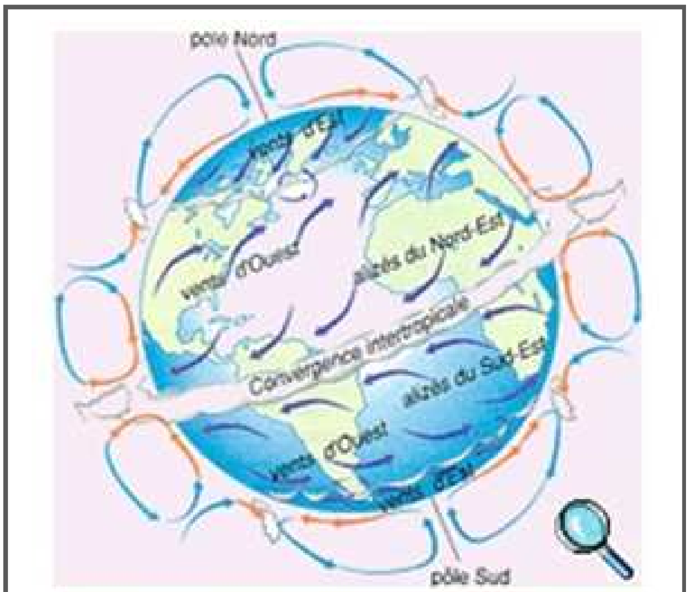


Fig.5c. General Circulation

During the winter for the Northern Hemisphere, the ITCZ is located in the Southern Hemisphere. The Hadley cell over the ITCZ crosses the equator and gives rise to surface westerly winds in the region located between the equator and the ITCZ: one can remember that this place was initially occupied by the easterly winds in summer for the Northern Hemisphere.

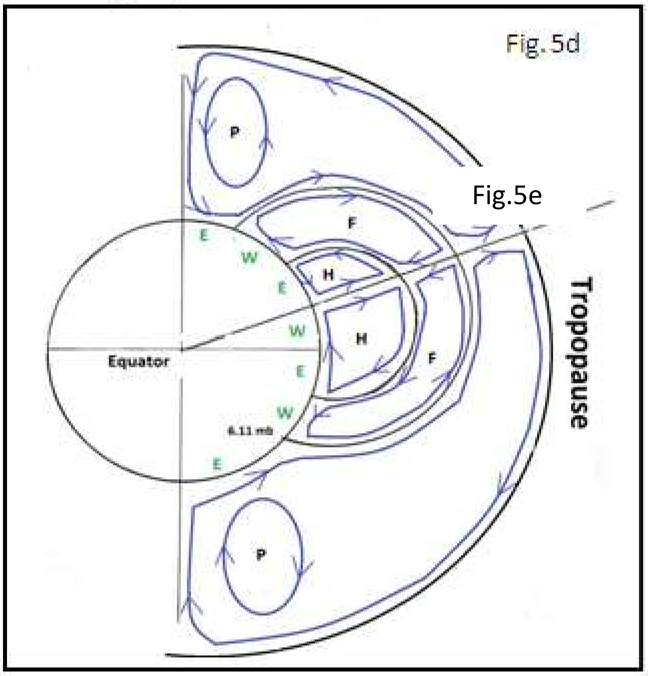


Fig.5d. Troposphere general Circulation (during Northern Hemisphere's summer) and related surface winds:

E: easterly winds

W: westerly winds

Finally, tropical monsoons regions are located between ITCZ's maximum and minimum positions in latitude as shown on figure 6.

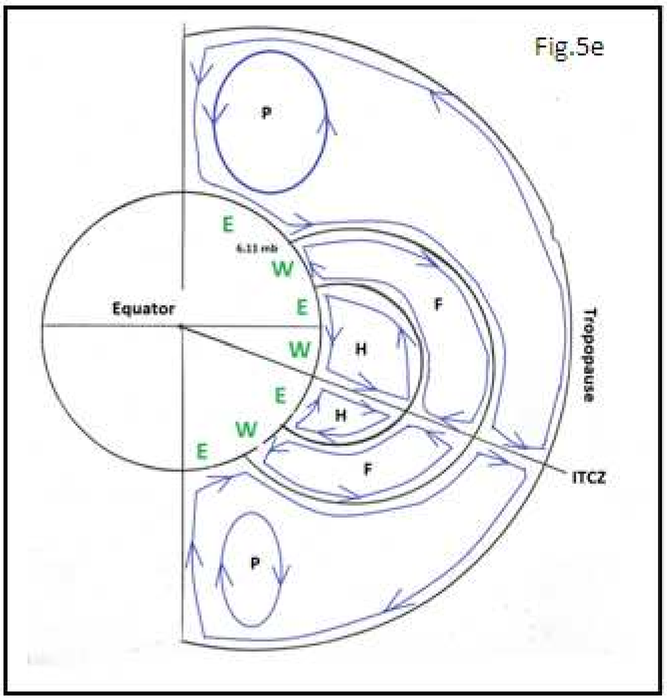


Fig.5e. Troposphere general circulation (during Northern Hemisphere's winter) and related surface winds:

E: easterly winds

W: westerly winds

CONCLUSION

In the northern hemisphere, the declination of the sun (Fig. 7) reaches its extreme values in the months of June and July: it is precisely during this period that the monsoon rains are most abundant (Fig.1). This is proof that there is a relationship of cause and effect between the two climatic parameters that are the declination of the sun (which is aligned on the ITCZ, with a slight phase delay) and rainfall of the monsoon. Whether the Northern Hemisphere or Southern Hemisphere, monsoons are phenomena associated with general circulation of the atmosphere (through the oscillations of the Hadley cell from both sides of the equator) and Coriolis force (resulting from the effects of earths' rotation).

The intensity of the monsoon rainfall depends on the proximity of moisture sources such as ocean surfaces that evaporate better than land areas, and relief that is favorable to the formation of orographic precipitation. The differences between thermal inertia of the ocean surface and land surface play a secondary role in the formation of monsoon rainfall (these differences rather participate in the creation of sea breezes "by sunny Time" or land breezes "when the night falls".

REFERENCES

[1] P. Carriere et al, *Mousson definition et explication*.mht, **2012.**
[2] R. Chabout et al, *Mousson-Encyclopedie Universalis*.mht*, **2012**.*
[3] C. B. Mbane, *La Convection Naturelle et ses Manifestations dans une Atmosphère Humide (Fundamentals of the thermo-convective flows of the moist air areas)*, Doctoral thesis (thèse d'Etat), Univ. of Yaoundé I, Cameroun, **2005**, 116 pp.
[4] C. B. Mbane, *Troposphere Climatology*, IHY-AFRICA Space Weather Science and Educational Workshop, Addis Ababa- Ethiopia, November 12-16, **2007**.
[5] C. B. Mbane, *International Journal of Physical Sciences* (IJPS), **2009**, **4**, pp. 242-246.
[6] C.B. Mbane et al, *Archives of Physics Research*, **2011**, 2(4), pp. 24-33.
[7] C.B. Mbane, *Archives of Physics Research*, **2012**, 3(1):47-53.
[8] C.B. Mbane, *Geosciences*, **2012**, 2(1), pp. 6-10.
[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] P. Bradshaw, *Introduction to turbulence and its measurement*, Pergamon Press, **1971**.
[13] L. Rosenhead, *Laminar boundary layers*, Oxford University Press , **1963**, 242.
[14] H. Lumbroso, *Thermodynamique-100 exercices et Problèmes résolues*, Math Sup. Ediscience/McGraw-Hill, **1973**, 360.
[15] R. Comolet and J. Bonnin, *Mécanique Expérimentale des Fluides (Tome III-Recueil d'Exercices)*, Masson 5^{e} ed., **1992**, 264.