academicJournals

Vol. 8(23), pp. 1284-1290, 23 June, 2013
DOI: 10.5897/IJPS2013.3936
ISSN 1992 - 1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

Hurricanes and cyclones kinematics and thermodynamics based on Clausius-Clapeyron relation derived in 1832

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Accepted 10 June, 2013

Juxtaposing Clausius-Clapeyron relation derived in 1832 with Hydrodynamic concept of atmosphere parcel of air leads to the discovery of an essential property of the troposphere that will deeply ameliorates information contained in literature and audiovisual productions on tropical weather. It is indeed a rectification of the use of an ideal gas principle which enshrined the idea that, hot air is lighter than cold air throughout the atmosphere. In other words, contrary to what has been taught in schools and universities of the world, hot air is not lighter than cold air in all parts of the troposphere. Taking into account this troposphere thermodynamics reality improves our understanding of complex weather phenomena such as cyclones and hurricanes. The two equal level surfaces of water vapor and temperature rating respectively at 6.11 mb and 0.0098°C separate without any ambiguity parts of the troposphere where ideal gas assumption can be applied to parts of the troposphere where this assumption is banned.

Key words: Clausius-Clapeyron relation, Hydrodynamic concept of air parcel, equal level surfaces, rating at 6.11 mb and 0.0098°C.

INTRODUCTION

A number of questions regarding Kinematics and thermodynamics of hurricanes and cyclones remain unanswered despite the quality and quantity of ground-or space-based observations. Instead these weather phenomena are combinations of complex troposphere physical processes that occur under the accuracy of temperature and humidity conditions. In this study, regardless of the manner in which hurricanes and cyclones are consider (Arakawa and Suda, 1953; Ballenzweig,1957; Bangs, 1929; Beerbower, 1926; Cline, 1926; Conner et al., 1957; Duane, 1935; Dunn, 1956; Fassig, 1913; Fletcher, 1955; Gentry, 1955; Haurwitz, 1935; Hoover, 1957; Hughes, 1952; Jordan, 1952; Klein and Winston, 1947; Malkin and Galwaym, 1953; Malkus, 1958; McDonald, 1942; Miller, 1958; Riehl and Palmen, 1957; Rossby, 1949; Schoner and Molansk, 1956; Tannehill, 1936), we want to make a contribution to a better understanding of kinematics, and thermodynamics governing these weather events with high destructive power. Our results are obtained from effectiveness of Clausius-Clapeyron equation that leads to the slope of the equilibrium curves in the *pT*-plane (Figure 1) whose

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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 (temperature below 0.0098°C) in the presence of high humidity of air (vapor pressure above 6.11 mb), has thermoelastic properties diametrically opposed to those of ideal gases (including dry water vapor). In tropical regions, saturated water vapor occupies the middle and top of the troposphere to more than 90% (it should be noted that, saturated water vapor is known as the birth place, home or bed of weather events such as hurricanes and cyclones or clouds related). Therefore, it was necessary to take account of this characteristic property of the saturated water thermodynamics to successfully draw new and unique profiles of hurricanes and cyclones.

Names assigned to tropical disturbances and related precipitating systems vary from one community to another. "*Tornade"* in French is used to refer to *cold-disturbances* while "*Tornado"* in Anglo-Saxon community is used to refer to *hot-disturbances*. In the translation of literature and audiovisual productions, this distinction is not often made and leads to inconsistencies and confusion. Indeed, vertical profiles of cold disturbances are diametrically opposite directions vertical profiles of hot disturbances. Hurricanes or tornadoes will be referred to hot-disturbances while cyclones will be referred to cold-disturbances in this work.

TROPOSPHERE DYNAMIC BALANCE

Atmosphere dynamics uses precise concept of air particle (Batchelor, 1967; Riegel, 1992). Especially:

a) Few exchanges on molecular scale: it is easy to follow quantity of air which preserves certain properties.
b) Quasi-static equilibrium: at any moment there is dynamic balance, that is, the particle has the same pressure as its environment ($P = P_{ext}$).
c) No thermal balance: heat transfers by conduction are very slow and neglected. One can have $T \neq T_{ext}$.
d) The horizontal sizes of the air 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):

$$P = P_a + e \tag{1}$$

In deriving P with respect to the temperature, one has

$$\frac{dP}{dT} = \left(\frac{\partial P}{\partial T}\right)_V + \left(\frac{\partial P}{\partial V}\right)_T . \left(\frac{dV}{dT}\right) \tag{2}$$

According to the quasi-static equilibrium (or dynamic balance), the pressure in the air particle must be the same as that of the air around, including during its water contains changes in phases. In other words, P in the air particle remains constant during individual changes in phases. Hence:

$$\frac{dP}{dT} = 0 \tag{3}$$

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

$$\frac{dV}{dT} = -\frac{(\frac{\partial P}{\partial T})_V}{(\frac{\partial P}{\partial V})_T} \tag{4}$$

Introducing (χ) the coefficient of thermal expansion of moist air at constant temperature:

$$\chi = -\frac{1}{P}(\frac{\partial P}{\partial V})_T \tag{5}$$

Then the equation of atmosphere dynamic balance:

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

Using Clausius-Clapeyron estimations of $(\frac{\partial P_a}{\partial T})_V$ and $(\frac{\partial e_w}{\partial T})_V$, Equation 6 of troposphere *(*or birth place of weather events) dynamic balance become:

$$\frac{dV}{dT} = \frac{1}{\chi} \bullet \frac{1}{P}(\frac{\partial e_w}{\partial T})_V \tag{7}$$

Equations 6 and 7 lead to a very important atmosphere dynamics statement; at any moment and throughout the atmosphere, one can use Equations 6 or 7 and Clausius-Clapeyron slope of the equilibrium curves in the pT-plane (Figure1) to predict in which direction the air parcel will move (up or down) if its temperature increases or decreases. Table 1 and Figure 2 provide an overview of possible situations in the troposphere.

BASIC KINEMATICS AND THERMODYNAMICS OF HURRICANES AND CYCLONES

Vertical profiles of hurricanes

Hurricanes are triggered by passive deep convection generated by a hot source located at the surface of the

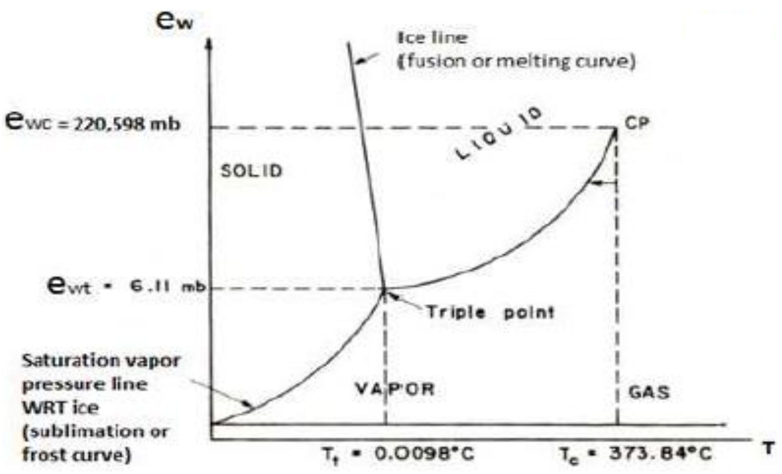

Figure 1. Saturation curves for water substance onto the p_T-plane. (p_T and T_T are called triple-point data): $e_{WT} = 6.11$ mb; $T_T = 0.0098$°C.

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

Range of temperature coupled with range of humidity	**T < 0.0098°C** **e_W < 6.11 mb**	**T < 0.0098°C** **e_W > 6.11 mb**	**T > 0.0098°C** **e_W > 6.11 mb**
$(\frac{\partial P}{\partial T})_V$	+	-	+
$\frac{dV}{dT}$	+	-	+

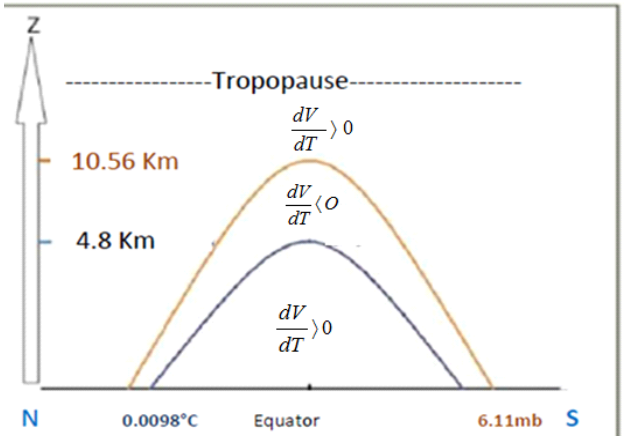

Figure 2. Troposphere specific regions depending on the manner in which V changes with T (V and T are respectively volume and temperature of an air parcel): $\frac{dV}{dT} > 0$; the particle swells when its temperature increases (so it becomes lighter). $\frac{dV}{dT} < 0$; the particle shrinks when its temperature increases (so it becomes less light). -10.56 Km = maximum elevation (statistic value) of 6.11 mb pseudo-isobar, -4.8 Km = maximum elevation (statistic value) of 0.0098°C isotherm, -V (air percel volume), T (air parcel temperature).

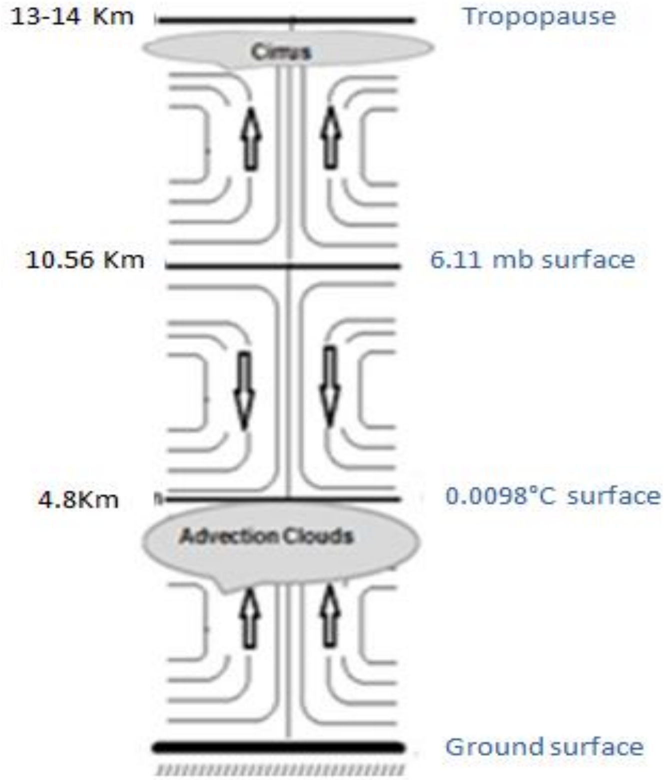

Figure 3. Hurricanes are triggered by passive deep convection generated by a heat hot source located at the surface of the Ground. They appear as high towers consisting of three floors: warm updrafts occupying floors 1 and 3 while warm downdrafts occupy floor 2.

Figure 4 (a-d). Hurricanes or tornadoes trigger dust clouds whose base is thin compared to the peak which is very broad. Hurricanes (or Tornadoes) can also electrify (Mbane, 2012) the troposphere column in which it is formed (Figure 4c). Its broadest peak indicates the presence of hot downdrafts that prevent the progression of warm updrafts.

earth and appear (Figure 3) as very high towers (from 0 to about 9 km) consisting of 3 floors: warm updrafts occupying the first and third while warm downdrafts occupies the second floor. According to ground based observations of Figure 4(a to d), over-land hurricanes (or tornadoes) trigger clouds whose base is thin compared to the peak which is very broad. Hurricanes vertical drafts can also produce electrical charges (Mbane, 2009) in the troposphere colum in which it is formed (Figure 4c). The broadest peaks of the related clouds indicate the presence of the second floor warm downdrafts that prevent the progression of the first floor warm updrafts (Figure 3). Considering the molecular scale, our model (Figure 4e) based on Clausius-Clapeyron's relation (1832) suggests, unlike ideal gas cumulonimbus model (Figure 4f), blocking of hot updrafts by hot down drafts which means installation of an additional greenhouse effect, which causes the accumulation of cloud formation latent heat with earth's surface radiate heat R_T ($R_T = \varepsilon_S \sigma T_S^4$) at the ground surface. This is consistent with based observations and explains high surface temperatures that accompany the formation of clouds in the sunny sky.

Vertical profiles of cylones

Cyclones are triggerd by very deep and passive convection generated by a cold source (squall-line) located at the summit of the troposphere and appear (Figure 5) as very high towers (from 0 to about 14 km) consisting of 3 floors: cooler downdrafts occupying 1^{st} and 3^{rd} while cooler updrafts occupy the 2^{nd} floor. There is good agreement between aircraft-based observations and related cyclones second floor updrafts convective clouds whose base has to be located above 0.0098°C isotherm surface. Cyclones vertical drafts can also produce electrical charges (Mbane, 2012) in the troposphere colum in which it is formed.

Horizontal profiles of hurricane and cyclone

Observed pressure near the eyes of cyclones (or hurricane) is very low and concentrates a rapid decrease in a short distance so that the momentum of particles of air, the frictional force and the tidal force are (from surface of the earth to tropopause) negligible compared to the coriolis and pressure-gradient forces. When pressure gradient and coriolis forces are the only two factors acting, geostrophic winds (rotative in the Northern hemisphere and contra-rotative in the Southern hemisphere) immediately take place (Figures 6) within deep and passive convections. The impact of hurricanes footprint (less than a dozen kilometers in diameter) is much lower than that of cyclones (several tens of kilometers in diameter).

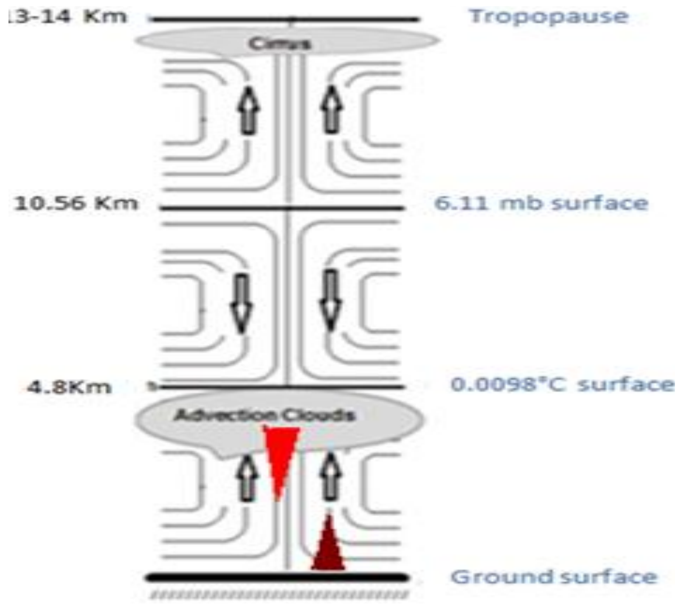

Figure 4e. Our model based on Clausius-Clapeyron's relation (1832) suggests blocking of hot updrafts by hot down drafts: then install an additional greenhouse which triggers the superposition of cloud formation latent heat (red color) with earth's surface radiate heat $\varepsilon_s\sigma$ T^4 (brown color). This is consistent with observations and explains higher temperature and humidity of atmosphere lower layers and tropical regions moderate climate.

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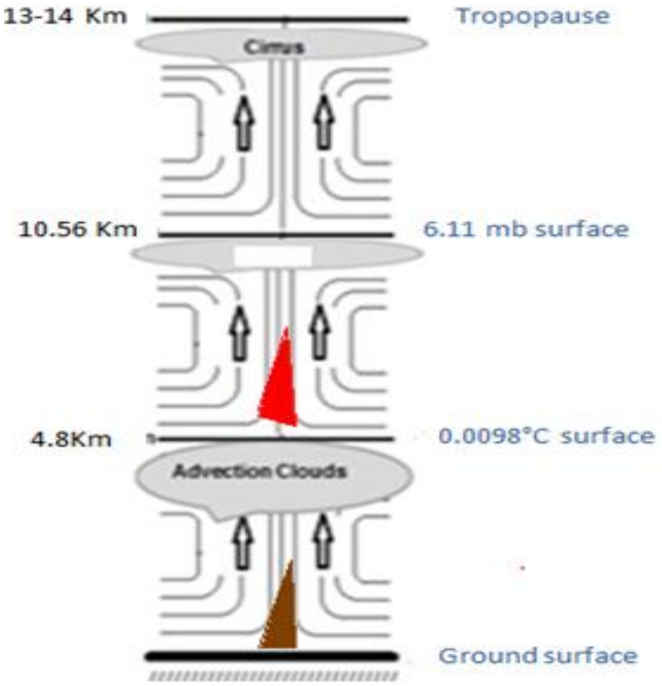


Figure 4f. Ideal gas properties suggest passive convection transfer from earth's surface to tropopause and automatically excluded the spread of cloud formation latent heat to that earth's surface.There is therefore no possibility of accumulation of heat or water vapor in lower troposphere. This is not consistent with earth's atmosphere physics.

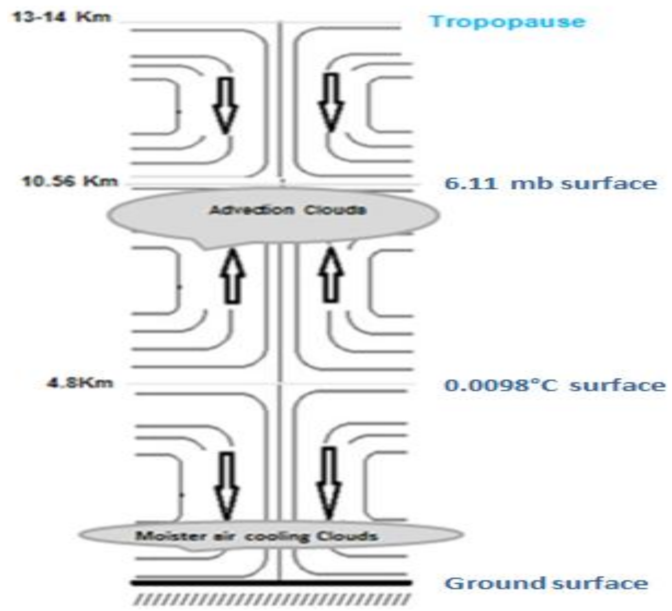


Figure 5. Cyclones are triggered by passive deep convection generated by a cold hot source located at the mid- troposphere. They appear as high towers consisting of three floors: Cold updrafts occupying floors 2 while cold downdrafts occupy floor 1 and 3

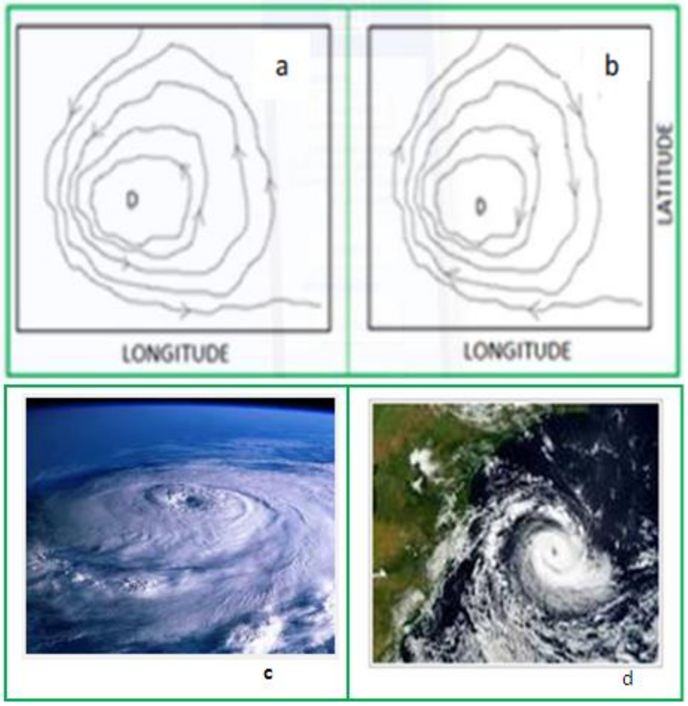
TROPOSPHERE GRAVITY WAVES AND LOCAL PRESSURE FLUCTUATIONS

In fluid medium, movement from point A to point B of local pressure fluctuations (δ P) are provided by gravity waves. For incompressible fluids (including the atmosphere because of its elasticity), these waves travel at phenomenal speeds. In the troposphere, the propagation is essentially straight and parallel to the direction of gravity acceleration ($\vec{g}$). Therefore, when a surface depression (D) occurs, it is almost spontaneously covered by altitude low pressure (L).

Reciprocally, when L occurs, it is immediately relayed by a D. This is same for Anticyclone (A) and high pressure (H). In the troposphere, D and L appear without any indication of which the two came first. Hurricanes (or tornadoes) are caused by warming ground surface areas, while cyclones are caused by mid-troposphere cooling domains. Due to gravity waves, satellites in their current configuration cannot differentiate between hurricanes and cyclones. This is a very embarrassing situation that leads to numerous confusion and makes ineffective "*Weather Alerts Systems* ".

Conclusions

The troposphere, generally known as birth place of weather phenomena, is a huge thermodynamic engine driven by the energy received from the sun. All winds,



Figures 6. Streamlines of geostrophic winds triggered by cyclones around their low pressure groove. Direct rotation is observed in the northern hemisphere (e.g. a and c) while indirect rotation is observed in the southern hemisphere (e.g. b and d): based on trigonometric considerations.

storms and clouds result from the differences in the amount and utilization of this energy. Since the radiant energy appears principally as heat, it was necessary to resort the thermodynamics properties of saturated water vapor in order to better understand how the moist air reacts to heat changes in any portion of the troposphere. New and unique kinematic profiles of hurricanes and cyclones can now be easily plotted. It should be noted that, all natural meteorological phenomena included hurricanes and cyclones can be traced to the manner in which the energy from the sun is received over different parts of the earth.

Since the troposphere is a medium in which mass motions are easily started, convection is found to be one of the chief ways in which heat is transferred there. This transfer may be accomplishing either by vertical or by horizontal motions. According to our results: warmer disturbances that occur in lower-troposphere are dissipated (that is, Atmosphere is a force-restore engine or dissipative system) by a typical mass motion usually called hurricanes (or tornadoes) while cooler disturbances that occur in mid-troposphere are dissipated by another typical mass motion called cyclones. Knowing that coriolis force act to west on updrafts, everyone can now understand why hurricane and cyclone move preferentially from East to West due to the localization in updrafts of their heat sources.

Cyclones' heat source is made of huge and cooler fogs (those observed temperatures are less than -45°C) which can travel even increase (over hot oceans) in the troposphere while hurricanes' heat source is fixed on the Ground: that's why cyclone lives and travels longer than hurricane. Moreover, contrary to a widespread idea in meteorology that warm air is less dense than cold air, this work shows that: between the two equal level surfaces of water vapor and temperature respective rating 6.11 mb and 0.0098°C, hot air is less light than cold air. This explains the presence of cold upwelling in cyclones and hot downdrafts in hurricanes. We cannot conclude this work without strongly highlighting the fact that hot air, contrary to what is taught until now, is not lighter than cold air in all parts of the troposphere. This troposphere's thermodynamic property is unfortunately unknown to public and has led to numerous errors and inconsistencies that abound in many scientific books and publications (including audiovisuals productions). In the next investigation on climate, using only certainties (e.g. ideal gas approximation imposes a partition of the troposphere into 3 regions, vertical temperature gradient in the troposphere has a negative sign, moist air condenses as it cools, pressure in the air parcel is the same everywhere and is equal to that of its immediate neighbors in all circumstances (that is, state of atmosphere quasi static equilibrium) instead of wrong presumptions (e.g. ideal gas approximation is valid throughout the atmosphere, warm air is lighter than cold air throughout the atmosphere, updrafts are necessarily associated with warming, downdrafts are necessarily associated with cooling) would allow:

a) To deeply ameliorate our view of troposphere phenomena regardless of their spatial and temporal scales (e.g. Rossby's suggested representation of general circulation),

b) To greatly exorcise our fears (sometimes ridiculous) generally triggered by a lack of explanations devoid of ambiguity,

c) To better protect ourselves from disasters caused by these devastating events, those life cycles until now unfortunately escapes the human control.

Knowing physics processes behind devastating event makes it less daunting (a good example is experienced in Mexico where building's architecture is gradually adapted to the local soil structure which paradoxically amplifies seismic waves which comes from far away, instead of reducing their intensity).

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