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Dear Reviewer # 2:

Thank you very much for your comments on the manuscript (MS) entitled "*The basic mechanism behind the hurricane-free warm tropical ocean*" (acp-2009-742).

The following are the point-by-point replies to your comments.

Comment 1:"My primary concern is with Eq. 4 of the manuscript, which forms the basis for the authors' argument. It is well known (e.g., Phillips 1966, JAS) that the implementation of the traditional approximation used to derive Eq. 1 of this manuscript fails to preserve the angular momentum principle of the exact set. If one instead lets r=a in the metric coefficients for the spherical geometry (and in the expression for the "earth velocity"), and employs this approximation in the rotational form of the momentum equations, the angular momentum principle of the exact set is preserved AND the first and fourth terms on the RHS of Eq. 1 of this manuscript DO NOT APPEAR. Thus, in this implementation of the traditional approximation (which preserves the angular momentum principle) vertical acceleration of a parcel arises from the imbalance between the perturbation buoyancy and vertical pressure gradient terms (having subtracted out the hydrostatically-balanced reference state).

One might call into question the traditional approximation itself in certain applications. In particular White and Bromley (1995, QJRMS) cite diabatically driven synoptic-scale motions in the tropics as an example of where the "cosine Coriolis" terms might make small quantitative contributions to the momentum budget. I suggest that the authors review the aforementioned articles (and others) and develop a more well-motivated, rigorous approach to the problem at hand."

Reply: The references which you have provided for us are very helpful. Thank you very much. We follow your suggestion and apply a completely-accurate equation considered by Phillips (1966) to our study. So the revised section 4 in the ms (with the revised sentences in green) will look like:

"***4 . The linkage between the LLEWW and the upward acceleration***

Focusing on the mechanisms for destroying the balance situation characterized by a completely-resting relative-wind field with zero vertical velocity ($w = 0$), zero horizontal velocities ($u = v = 0$) and zero buoyancy frequency ($N = 0$), we turn to the external processes for creating upward acceleration ($dw/dt > 0$) of vapour at the sea surface. According to the completely-accurate motion equations (derived in the Earth's spherical coordinates) considered by Phillips (1966, 1968) as well as by other scientists (e.g., White and Bromley, 1995; White, 2002, p. 14), the creation of vertical acceleration at the sea surface is attributed to five processes:

$$\frac{dw}{dt} = \underset{1}{2\Omega u \cos\varphi} - \underset{2}{\frac{1}{\rho}\frac{\partial p}{\partial r}} - \underset{3}{g} + \underset{4}{\frac{u^2+v^2}{r}} + \underset{5}{F_{rz}}\ , \qquad (1)$$

where the Earth's radius r *is not the constant* $a = 6.37\times10^6$ *m. The five processes include the combined effect of the* $\cos\varphi$ *Coriolis parameter and the relative zonal velocity (term 1). In a completely-resting atmosphere on the rotating Earth with* $\Omega > 0$ *and* $N = 0$*, so long as the zonal wind is not zero at the Equator with* $\cos\varphi = 1$*, the magnitude of this term i.e.,* $2\Omega u$ *could be at least as large as that of midlatitude* $\sin\varphi$ *Coriolis term i.e.,* $2\Omega u \sin(\pi/4) = \sqrt{2}\Omega u$ *receiving most attention due to its significant role in the horizontal momentum equation. A large number of studies (e.g., Garwood et al., 1985; Leibovich and Lele, 1985; Draghici, 1987; Mason and Thomson, 1987; Draghici, 1989; Shutts, 1989; Burger and Riphagen, 1990) have emphasized the non-neglectable effect of* $\cos\varphi$ *Coriolis terms on the synoptic-scale systems in the tropics, the turbulent kinetic-energy budget in the oceanic surface mixed layer, Ekman layer stability, boundary layer eddies and* *nonhydrostatic mesoscale atmospheric systems etc.. Besides this* $\cos\varphi$ *Coriolis term in Eq. (1), the contribution to* $dw/dt \neq 0$ *is also attributed to the vertical pressure gradient force (term 2), the gravity (term 3), the Earth's curvature effect (term 4) and the frictional force (term 5).*

The completely-resting background with $N = 0$ *emphasized in the present embryo-initiation study is at least in the hydrostatic balance:*

$$-\frac{1}{\rho}\frac{\partial p}{\partial r} - g = 0. \qquad (2)$$

As a result, the contribution to $dw/dt \neq 0$ *comes from the following three right-hand side (rhs) terms:*

$$\frac{dw}{dt} = 2\Omega u \cos\varphi + \frac{u^2 + v^2}{r} + \mathrm{F}_{rz} \qquad (3)$$

for destroying the balance situation and creating upward acceleration of vapour at the sea surface. According to Holton (2004, p. 41), the magnitudes of the last two rhs terms of Eq. (3) are much smaller than the magnitude of the first rhs term. So the last two rhs terms can be eliminated, leading to:

$$\frac{dw}{dt} = 2\Omega u \cos\varphi. \qquad (4)$$

In Eq. (4), Ω *is the angular rotation rate of the Earth while the Earth's rotation is the well-known source of external force acting on the atmosphere. Be aware that if* Ω *were zero or horizontal velocity were absent (White 2002, p. 23) together with zero horizontal convergence i.e.,* $\nabla_2 \cdot \mathbf{V} = 0$*, then hydrostatic balance would lead to the zero vertical acceleration:*

$$\frac{dw}{dt} = 0. \qquad (5)$$

Without the vertical acceleration and without the horizontal convergence, the moist air at the sea surface with $w = 0$ *could not be transported to the middle troposphere. However in reality, the angular rotation rate of the Earth* $\Omega = 7.292 \times 10^{-5}\ s^{-1}$ *is non-zero, so is the external-force-induced LLEWW (*$u > 0$*) due to processes such as the deflection of the cross-equatorial wind induced by the land-sea differential* *heating*. *Therefore Eq. (4) reveals that even beginning with a completely-resting atmosphere on the rotating Earth with zero-relative-wind field* ($u = v = w = 0$) *and* $(2\Omega)^2 > N^2 = 0$, *the external-force-induced LLEWW-burst* ($u > 0$) *can boost upward acceleration in the latitudes with* $\cos\varphi \neq 0$.

Again we draw attention to the following four facts. Firstly, $\cos\varphi$ *reaches its maximum value (i.e.,* $\cos 0^{\circ} = 1$*) at the Equator and the relative velocities* u *and* w *detected on the rotating Earth are in the same equatorial plane with* $\mathbf{\Omega}$ *perpendicular to the vertical coordinate* $\mathbf{k}_{eq} = \mathbf{w}_{eq} / \left|\mathbf{w}_{eq}\right|$ *(Fig. 3). Secondly,* $dw/dt = 2\Omega u > 0$ *at the Equator created by the external-force-induced evenly-distributed flow (double-line arrows in Fig. 3) could be at least as significant as the midlatitude Coriolis force* $\sqrt{2}\Omega u$ *which receives tremendous attention. Thirdly, the external-force-induced LLEWW does exist in the real atmosphere. We focus on such a LLEWW to avoid the "chicken-and-egg" problem in the nonlinear atmosphere, which might facilitate the extraction of the leading signal carried by the external-force-induced LLEWW according to Eq. (4). Fourthly, although the magnitude of external-force-induced* $2\Omega u$ *is smaller than that of the gravity, the gravity is always balanced more or less by the vertical pressure gradient force. So long as the horizontal wind i.e., LLEWW* ($u > 0$) *comes into play, the contribution of* $2\Omega u$ *(despite being abandoned as a residual term) to* $dw/dt > 0$ *(commonly observed in the convective systems around the equator) might be greater than the net contribution of the gravity and vertical pressure gradient forces especially for destroying the completely-resting atmosphere on the rotating Earth with* $(2\Omega)^2 > N^2 = 0$. *According to Phillips (1968),* $(2\Omega)^2 \ll N^2$ *is required for neglecting the* $\cos\varphi$ *Coriolis terms. Thus in our opinion, neglecting the external-force-induced* $2\Omega u$ *at the Equator would not facilitate the study focusing on the initiation of hurricane's embryo from a completely-resting atmosphere on the rotating Earth with* $(2\Omega)^2 > N^2 = 0$.*"*

In order to draw readers' attention straight to the point that neglecting the external-force-induced $2\Omega u$ at the Equator would not facilitate the study for initiating the embryo of hurricane from the completely-resting atmosphere on the rotating Earth with $(2\Omega)^2 > N^2 = 0$, we also revise some sentences

in **abstract**:

"… *So the basic question is how, starting with a completely-resting atmosphere on the rotating Earth characterized by zero-relative winds (* $u = v = w = 0$ *) and zero buoyancy frequency (* $N = 0$ *), external forces create the rapidly-upward acceleration of moist air at the warm sea surface. … Our investigation suggests that the external-force-induced significant-LLEWW embedded in the significant trade easterlies over the warm ocean be necessary and sufficient for making the embryo originate in a completely-resting atmosphere on the rotating Earth with* $u = v = w = 0$ *and* $N = 0$",

in **introduction**:

"*The above studies might lead to a more basic question of how, starting with a completely-resting relative-wind field (* $u = v = w = 0$ *) in hydrastatic balance with zero buoyancy frequency (* $N = 0$ *), external forces create the rapidly-upward acceleration of moist air at the warm sea surface. … One is the idealized-balance situation characterized by a completely-resting atmosphere on the rotating Earth with zero-relative winds (* $u = v = w = 0$ *) and zero buoyancy frequency (* $N = 0$ *) (e.g., without the presence of trade easterlies). … The geostrophic balance and hydrostatic balance refer to the absence of horizontal acceleration and vertical acceleration with* $N = 0$",

and in **summary and conclusions**:

"… *So a more basic question is how, beginning with a completely-resting atmosphere on the rotating Earth (with* $\Omega = 7.292 \times 10^{-5}\ s^{-1}$ *) characterized by zero-relative winds (* $u = v = w = 0$ *), zero buoyancy frequency (* $N = 0$ *) and* $(2\Omega)^2 > N^2 = 0$, *external forces create the rapidly-upward acceleration of moist air* *at the warm sea surface. ... This direct effect of external-force-induced LLEWW ($u > 0$) on $dw/dt > 0$ has been described by the vertical momentum equation $dw/dt = 2\Omega u$ at the Equator with $\cos\varphi = 1$ for destroying a completely-resting background in hydrostatic balance characterized by $(2\Omega)^2 > N^2 = 0$ which is opposite to the condition $(2\Omega)^2 \ll N^2$ for neglecting $2\Omega u \cos\varphi$ (Phillips, 1968). Despite receiving little attention, $dw/dt = 2\Omega u > 0$ could be at least as large as the midlatitude Coriolis force [i.e., $2\Omega u \sin(\pi/4) = \sqrt{2}\Omega u$] due to the significant LLEWW resulting from the deflection of the significant cross-equatorial flow driven by the significant differential heating between the largest continent with the highest plateau and the largest ocean with the warm pool located to the east and on the equatorward side of the continent on the rotating Earth. ...*

Different from the studies focusing on the hurricane generation from the given embryo, our investigation focuses on how external forces activate the embryo in a completely-resting atmosphere on the rotating Earth with zero-relative winds ($u = v = w = 0$) and $(2\Omega)^2 > N^2 = 0$. We might conclude that the high SST is necessary while the high SST working together with the external-force-induced significant LLEWW would be sufficient for making the embryo originate in the wave-free trade easterlies under the hydrostatic-balance condition with $N = 0$. ..."

Comment 2:"Of course, on large scales the perturbation field is approximately hydrostatically balanced, and vertical motion is typically deduced from the mass continuity equation."

Reply: In the original ms, we have taken the mass continuity equation into account to emphasize the additional effect of low-level equatorial convergence zone. Realizing that in the original ms we did not spell the mass continuity equation out in the discussion of the contribution attributed to the equatorial convergence zone, we will revise the ms as following:

"*In reality, the embryo initiation is a complicated nonlinear process due to the* *nonlinear term $w\partial w/\partial r$ in the definition of dw/dt. Additional nonlinear processes indicated by nonlinear terms such as $u\partial u/\partial x$ in the horizontal momentum equations will come into play due to the presence of trade easterlies in the real atmosphere. In this sense, the contribution (to the vertical vapour transport) could also be attributed to the physical processes described by the horizontal momentum equations through the linkage between the low-level equatorial convergence $\nabla_2 \cdot \mathbf{V} < 0$ and the rising motion determined by the mass-continuity equation. Although the additional nonlinear processes such as $u\partial u/\partial x$ could make the embryo-initiation process more complicated, they could enlarge the effect of LLEWW embedded in trade easterlies on $w > 0$ at the sea surface due to the additional effect of low-level equatorial convergence zone (Anthes, 1982, p. 49-51). This well-known low-level equatorial convergence zone would be able to create the upward transport of moist air from the warm sea surface to the midtroposphere under the condition that the negative effect of other internal disturbances is small as compared with the effect of the equatorial convergence zone. This low-level equatorial convergence zone together with $dw/dt = 2\Omega u > 0$ at the Equator might account for most convective clouds observed around the Equator under the effects of the largest continent with the highest plateau and the largest ocean with the warm pool located to the east and on the equatorward side of the continent on the rotating Earth (Fig. 2).*"

Sincerely,

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Professor

Reference:

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