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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on "Comment on "Biotic pump of atmospheric moisture as driver of the hydrological cycle on land" by A. M. Makarieva and V. G. Gorshkov, Hydrol. Earth Syst. Sci., 11, 1013–1033, 2007" *by* A. G. C. A. Meesters et al.

A. G. C. A. Meesters et al.

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In the first part of this comment, the remarks of M & G made in S176-S184 will be answered briefly (the remarks on condensation will not be addressed here). The second part is again devoted to the biotic pump theory (BPT), this time from the condensation viewpoint. Whilst this was not a subject of the DP, we were asked earlier to comment on the role of condensation (S59-S68 and S257-261); in addition, the condensation aspect seems to have a greater appeal to some people than does the evaporative force (discussed in the DP) which force appears hard to understand.

1. About relaxation, et cetera

Ad S177: What we called "confusing" in the text of Feynman merely concerned the way in which two paragraphs were put after one another whilst their connection was not well explained (unlike the treatment of the topic in other textbooks). Our remark was mostly meant to advise readers with an interest in the subject to consult other works too. The remainder of the statements made in the 1^{st} half of S177 have already been answered in our previous comment (S167-175) or indeed already in the DP. As such, there is no point in repeating them again.

Ad S177 (bottom)-S178: The argument is ingenuous, but incorrect. Feynman's statement that "usually mixing of two gases occurs as a combination of convection and diffusion" just says that, in practice, mixing tends to occur as a consequence of several causes, amongst which convection plays a major role. This is a very common observation. However, it is stated nowhere that diffusion is the cause of, or cannot exist without, convection! The remainder of the argument in S178 is based on this erroneous interpretation of Feynman's statement.

In S179, first paragraph, it is stated that: "The equations of hydrodynamics do not reveal the nature of pressure gradients and say nothing about it. One imposes an external pressure field ...". This is an unrecognizable rendition of the facts to anyone with some serious expertise in atmospheric modeling. Only at the lateral and upper boundaries (if any) are pressures imposed externally. Within the boundary layer, everything depends on the appropriate internal computation of the pressure field from diagnostic or prognostic equations. The easiest method is to determine the bulk pressure gradients using the well-known hydrostatic pressure equation, whereas more refined methods are applied for work on finer scales (see the literature on dynamic meteorology, e.g. Pielke 1984).

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In S180, first full paragraph, M & G refer again to the thought experiment in the DP. We stated that relaxation will occur in a very short time. This is in accordance with common sense, to which we can safely appeal for this case. On the other hand, the "tornado-like upwelling of air masses" (S180) is entirely based on the evaporative-force-theory which we repeatedly have shown to be incorrect.

The question as to what happens to the kinetic energy that is released upon relaxation, has a subtle answer. The pressure difference generates a "wave of expansion" traveling at the speed of sound (see the Comment of Referee 2) and it is within this wave that the kinetic energy is located. Within the wave, which is narrow for the case of the thought experiment, the air is suddenly displaced to a new position where it remains after the wave has passed. Displacements of air caused directly by evaporation and condensation also have their relaxation waves traveling at the speed of sound, but these displacements are much more gentle and represent only a minor addition to the displacements caused simultaneously by thermal expansion, etc. Even these latter waves are so elusive compared to the system of large-scale motion in which they are embedded, that they have rarely received attention (see the literature list in the Comment of Referee 2, to which we would like to add Tijm and Van Delden (1999) in which some observational evidence is presented). In conclusion, the relaxation caused by evaporation (and condensation) can cause only very slow displacements — as stated already in the DP. Needless to say, this has nothing to do with the "upwelling" advanced in S181.

Section 3 merely contains a repetition of previous standpoints, which we have already answered in S167-S175. The inappropriateness of the "vacuum-cleaner-argument" follows already from the extensive discussion in S172-S173.

The same holds for Section 4. For example, in S184 it is stated that we "were unable to retrieve from this that the pressure difference along the vertical dimension is also

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affected". However, the only derivation from the Evaporative Force given by M & G relies on the manifest assumption that it is not affected. And if it is affected, how can the Evaporative Force survive the almost immediate relaxation to equilibrium discussed in the DP?

2. About condensation

The BPT was based by M & G (S59-S60 and elsewhere) on a two-fold "simple physical fact": (1) Condensation of atmospheric water vapor leads to a drop of local air pressure in the region where the condensation occurs; and (2) This pressure drop initiates a dynamic air flow directed towards the region of condensation.

The following section briefly explains why both of these seemingly obvious "facts" are incorrect. It also explains why condensation *does* influence atmospheric motion. For reasons of convenience the line of argument is presented in a simple way, neglecting e.g. the larger system in which the clouds are embedded (and in which the ascent of heated air always plays a major role).

a) Condensation enhances local air pressure

When water vapor condenses, the pressure is changed by two joint effects. The first is the disappearance of water molecules from the vapor phase, the second is the release of a surprising amount of heat, causing the air molecules to move faster (i.e. the temperature rises). Both effects exert an influence on atmospheric pressure, the first being negative and the second positive. However the second effect appears to be strongly dominating. Thus, the pressure rises (rather than drops as suggested by M & G) locally upon condensation (compared to air without condensation and under otherwise equal conditions). This follows from physical laws that have been well established for one and

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a half century on the basis of observation, and which allow the prediction of laboratory results with high accuracy. Currently used weather forecast models take both these effects into account. The BPT, on the other hand, simply neglects the strongest of the two effects (i.e. the release of latent heat). As such, the question as to “how it might happen that this has not been described before”, is not well posed: the condensation part of the BPT, unlike current atmospheric prediction models, is based on incomplete information and therefore unfit to be used in practice.

b) Condensation causes local expansion of the air

The second point (local expansion of the air upon condensation) is a direct consequence of the first point. The air responds to the locally higher pressure by an elastic relaxation to a volume that is greater than the volume which would be occupied without condensation. As a result, the mass density decreases. Furthermore, this relaxation largely compensates the pressure change induced by condensation, which constitutes another reason why M & G their computations are erroneous. It is pertinent to note that this latter point follows from the reasoning advanced in the DP, but now applied to condensation instead of evaporation.

c) The consequences for atmospheric motion

The relaxation of the air described under (b) largely restores equilibrium in the air column. However, some disequilibrium will remain, for the following reason: each air column has its own equilibrium distribution of weight and pressure, and so there should remain horizontal pressure gradients between columns with and without condensation (which are however much smaller than the gradients predicted by the BPT-calculations). As a consequence, horizontal and vertical motions are induced. In the first place, since the wet air has a lower density than its surroundings at the same

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height, upward forcing will occur according to Archimedes' Law. Further, the expansion of the cloud occurs in the first place at its top, where the counter-pressure is weakest, but also sideward (horizontal divergence). The lateral displacement of mass causes the air column in which the cloud is located to become lighter (per unit surface area). Hence the pressure on the surface is lowered. This causes (or enhances) convergent motion at the surface. These surface processes are well known and typically occur in association with the formation of convective clouds. At the same time, it is known from observations made with radiosonde balloons, etc. that enhanced pressure and horizontal divergence are present simultaneously at greater heights, and that mid air is lighter (and warmer) in the region where condensation occurs. All this is explained by conventional theory, but not by the BPT. For example, if clouds are sucking in air from all sides as the BPT predicts, they should, according to mass balance considerations, not become lighter (as is observed) but rather denser and heavier than dry air at the same altitude. As a consequence, application of Archimedes' Law would predict downward motion of the cloud (weight greater than buoyancy), i.e. the opposite of what is observed.

All this conventional theory can be found in the textbooks, but it worthwhile to point out that the dynamic effect of condensation is usually not highlighted, as it is but a detail of a larger system in which thermal gradients — rather than different amounts of condensation — are dominating. In general, condensation enhances the existing upward forcing caused by existing temperature gradients. However, in the tropics (where condensation is most vigorous), the dynamics of the atmosphere is determined to a large extent by the field of heating provided by latent heat release. For this reason, especially in tropical meteorology much attention has been devoted to the influence of condensation on atmospheric dynamics (e.g. Holton (1979), section 12.2 about cumulus convection). This suffices to show that the influence of condensation on atmospheric dynamics is an old and important field of research. But from this research it follows that the neglecting of latent heat release and hydrostatic relaxation, as is

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done in the BPT, leads to a highly incorrect picture of how condensation interferes with atmospheric dynamics.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 401, 2009.

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