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Atmospheric Chemistry and Physics Discussions

Interactive comment on "On the validity of representing hurricanes as Carnot heat engine" *by* A. M. Makarieva et al.

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The authors state that partial pressure of water vapor in the atmosphere represents potential energy from which the kinetic energy of hurricanes develops when water vapor undergoes condensation [1]. It could be interesting to mention in this discussion that there is a relatively well-studied mechanism that works on a similar physical basis – potential energy released during phase transition is converted to kinetic energy of mechanical motion.

This is the so-called drinking bird toy [2-4], an elegant and original device that is used in physics education for demonstration of several physical laws. I borrow a slightly modified bird description from ref. [2]:

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Interactive Discussion

Discussion Paper

<< The bird consists of two spherical glass bulbs connected by a glass tube. The bottom bulb (body) is almost filled with a highly volatile liquid, normally methylene chloride, whose normal boiling point is close to room temperature. There is no air inside the bird, but only this internal liquid in thermal equilibrium with its vapor ... The upper bulb (head) is covered with a porous tissue wetted with water. The evaporation of water cools the bird head outside, so that the CH_2Cl_2 vapor inside also has to cool. The vapor in the head condenses; the CH_2Cl_2 vapor pressure inside the head becomes smaller than that in the body according to the Clausius-Clapeyron equation, and **this pressure gradient forces the internal liquid to rise up in the tube**. As the liquid rises, the center of mass of the system also rises, and the momentum produced by the weight eventually forces the bird to tip forward and to dip its beak in the glass with water, keeping its head wet. When the bird is almost horizontal, the lower end of the tube emerges above the internal liquid surface and some vapor passes from the body to the head. While drinking, the bird remains horizontal for a short time. Then, part of the liquid drains back into the body and the bird returns to its upright position. >>

As long as there is water in the glass and the relative humidity is lower than 100%, the bird performs periodic "dipping" motions. For this reason it is used in education as an example of a false perpetual motion machine.

The mechanism behind the bird motion is the condensational drop of gas (CH_2Cl_2 vapor) pressure inside the bird head that follows the decrease of head temperature compared to body temperature. This temperature gradient between the head and the body is caused by evaporation of water from the head, but it can also be reached by other mechanisms, e.g. by illuminating the body [2]. In parallel, in the physical concept advanced by the present authors [1,5] condensation of (water) vapor in the atmosphere, drop of air pressure and the resulting pressure gradient cause dynamic air motions of various intensities. But as water vapor concentration decreases with height in the gravitational field of Earth, not **any** vertical gradient of temperature is sufficient to induce condensation of water vapor. As previously shown [5], the vertical temperature

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gradient must exceed the critical value of 1.2 K/km for such condensational circulation to be switched on.

I find the introduced notion of 'latent work' [6] (this work can in principle be converted to kinetic energy with a 100% efficiency) very meaningful. For complete condensation of water vapor, latent work is estimated to be $A \sim RT\gamma$ (where γ is the relative share of water vapor partial pressure in the air pressure) [6]. For the drinking bird which has no air inside but only the condensable gas, the maximum available latent work should simply become $\sim RT$.

References

[1] Makarieva A.M., Gorshkov V.G., Li B.-L.: On the validity of representing hurricanes as Carnot heat engine. ACPD 8: 17423-17437 (2008).

[2] Güémez J., Valiente R., Fiolhais C., Fiolhais M.: Experiments with the drinking bird. Am. J. Phys. 71: 1257-1263 (2003).

[3] Abraham N., Palffy-Muhoray P.: A dunking bird of the second kind. Am. J. Phys. 72: 782-785 (2004).

[4] Lorenz R.: Finite-time thermodynamics of an instrumented drinking bird toy. Am. J. Phys. 74: 677-782.

[5] Makarieva A.M., Gorshkov V.G.: Biotic pump of atmospheric moisture as driver of the hydrological cycle on land. HESS 11: 1013-1033.

[6] Makarieva A.M.: Interactive comment on "On the validity of representing hurricanes as Carnot heat engine" by Makarieva et al. ACPD 8: S7609-S7613.

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