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The equivalence of gravitational and centrifugal torques in the equatorial plane in a shallow atmosphere

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A central issue concerning the interaction between the Earth's polar motion and the atmospheric equatorial angular momentum (AEAM) is the role played by the terrestrial gravitational field. It has been shown in previous studies that the gravitational torque is cancelled by the pressure torque, suggesting that there is no direct signature of the gravitational torque in variation of the AEAM. This issue becomes prominent with the realization that the AEAM exchange between the two major gaseous layers of the troposphere and the stratosphere is nearly an order of magnitude stronger than the corresponding AEAM exchange between the solid Earth and the entire atmosphere, consistent with the strong negative correlation between tropospheric and stratospheric angular momentum found by Zhou et al. (2008). In search of physical mechanisms for the phenomenon, we find dominance of the "matter" term in both the AEAM budget and the balance of total mechanic torques (the negative of the centrifugal torque dominates the balance of the gravitational torque, the pressure torque, and the friction torques combined). We introduce here the centrifugal torque, which is practically identical to the gravitational torque in the equatorial plane for any shallow layer of atmospheric mass, including the whole atmosphere, satisfying the hydrostatic density-pressure relation. We will prove that on what we call a Simple Hydrostatic Equilibrium Spheroid (SHES) Earth the centrifugal torque and the gravitational torque are exactly equal. On a realistic Earth, the discrepancy is about 7%. Results from theoretical and data analysis will be presented, and the implication of this finding is discussed.