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# Physics of the Dispersive Nature and Energy Propagation of Rossby waves

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Rossby wave dynamics is the cornerstone of all modern textbooks on atmospheric and ocean dynamics. The oscillation mechanism of Rossby waves is generally understood through the conservation of QGPV and potential vorticity gradient is identified as its restoring force, although it is not clear what is its mechanical restoring force from the perspective of the Newton's second law, as in other types of waves in fluid mechanics. Furthermore, for most types of waves in fluid, the mean pressure work is equal to the product of the mean wave energy and the group velocity of waves. Therefore, it is said that energy of wave motions propagates at the speed of the group velocity of waves. However, the relationship between pressure work and group velocity seems to break down in the case of Rossby waves, because the zonal component of the mean energy flux obtained from the mean pressure work has one term "missing" in comparison with the group velocity energy transport. The "missing" term issue has been traditionally attributed the non-uniqueness in representing the ageostrophic components in a QG system. This paper reports the key results of the recent research on these three outstanding issues on the physics and energy fluxes of Rossby waves. The goal is to unify the physics and dispersive nature of Rossby waves with all other waves in fluid mechanics, as it should be. Our study takes a new look from the mass conservation and QG momentum perspective at the old question: what is the exact form of the mechanical restoring force responsible for the oscillation that causes Rossby waves only to propagate in one direction? The identification of the exact form of the mechanical restoring force responsible for Rossby wave motions enables us to formulate a QG model uniquely. The unique formulation of a QG model ensures that the energetics of a QG model is the same as that derived from the QG potential vorticity equation. As a result, the well-known but somewhat mysterious "missing term" in the energetics of Rossby waves can be easily recovered.